JMBAI

JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

VOL.56 NO.01 • JANUARY-JUNE 2014

PRINT ISSN 0025-3146 • ONLINE ISSN 2321-7898

SPECIAL ISSUE

Asia Regional Symposium on

Ecosystem Approaches to the Management and Conservation of Fisheries and Marine Biodiversity in the Asia Region

Published by

MBAI

Marine Biological Association of India

CMFRI Campus, P.B. No.1604, Ernakulam North P.O., Kochi – 682 018, Kerala, India

Tel: 0484 – 2394867. Fax: 0484 – 2394909. E-mail: mail@mbai.org.in; mbai@rediffmail.com **www.mbai.org.in**

JMBAI

JOURNAL OF THE MARINE BIOLOGICAL ASSOCIATION OF INDIA

(Bi-annual)

Citation: J. Mar. Biol. Ass. India

The Journal publishes original contributions dealing with the following fields of investigations. Phytoplankton, marine algae, zooplankton, nekton, benthos, corals and coral reefs; ecology, zoogeography and systematics; primary production and experimental work on ecosystem including energy flow at different trophic levels; population dynamics and theoretical models; recycling of matter, influence of environmental factors on metabolic activity; marine microbiology; mariculture and experimental work on propagation of cultivable species; biology of fishes, marine reptiles, sea birds and mammals; physical, chemical, geological and meteorological features of the environments related to marine biology, marine environmental damage caused by pollution and engineering works; underwater observations; conservation of living resources, modifications in methodology and techniques and development of new apparatus related to marine sciences.

Single copy of each volume (No.1 & 2) of the Journal will be supplied free to the bonafide members of the Association. For others, the rate of subscription (annual) for the Journal is as follows:

Inland : Rs.5000/- (No.1 & 2)
Overseas : Equivalent in US$

MBAI
Marine Biological Association of India

The Marine Biological Association of India

CMFRI Campus, P.B. No.1604, Ernakulam North P.O.,
Kochi – 682 018, Kerala, India
Tel: 0484 – 2394867. Fax: 0484 – 2394909.
E-mail: mail@mbai.org.in; mbai@rediffmail.com

Website:www.mbai.org.in

Ecosystem Approaches to the Management and Conservation of Fisheries and Marine Biodiversity in the Asia Region

Preface

This special issue of the Journal of Marine Biological Association of India presents selected papers of the Asia Regional Symposium on "Ecosystem approaches to the Management and Conservation of Fisheries and Marine Biodiversity in the Asia Region" organized by the Mangroves for the Future (MFF) initiative in partnership with Ministry of Environment, Forests and Climate Change (MoEF & CC), Government of India, Food Agriculture Organization (FAO), Bay of Bengal Large Marine Ecosystem Project (BoBLME), United Nations Environment Programme (UNEP), The Southeast Asian Fisheries Development Center (SEAFDEC) and Central Marine Fisheries Research Institute (CMFRI) in Cochin during 27-30 October 2013.

The objectives of the symposium were to explore ecosystem approaches for the management of fisheries and marine biodiversity, to examine scientific information and knowledge, to debate contrasting viewpoints and to seek practical and sustainable solutions to complex problems relating to the sustainable use of aquatic ecosystems. The symposium covered the following five thematic areas: (i) Coastal Ecosystems and Fisheries - Towards an Ecosystem Approach to Fisheries Management, (ii) Marine Spatial Planning, Marine Protected Areas and Fisheries Management, (iii) Artisanal Fisheries, Livelihoods and Biodiversity, (iv) Bycatch and Bycatch Management, and (v) Sharks, Marine Turtles and other endangered, threatened and protected (ETP) species. The symposium was attended by 30 international participants from over 12 countries and 30 national participants from India. Thirty-seven oral presentations and key note addresses were made during the symposium and wide ranging discussions were held probing practical science based solutions for achieving sustainable fisheries, exploring integrated management measures including spatial and temporal protection measures as well as conventional fisheries management approaches. This publication includes 17 of the scientific presentations that have been submitted as full scientific papers and peer reviewed by selected Reviewers.

We would like to thank the reviewers of the manuscripts for their assessment of the papers and to all the authors who engaged in the process of assembling the papers for this special edition. Our special thanks are due to Dr J.R. Bhatt, Advisor, Ministry of Environment, Forests and Climate Change for his support and keen commitment to organizing the symposium and bringing out this special edition. Finally we thank Dr. P. U. Zacharia, Chief Editor, Journal of the Marine Biological Association of India for his help and for his own efforts in reviewing the articles.

October 2014

E. Vivekanandan
Maeve Nightingale
Guest Editors

This publication has been made possible by funding from Sida.

Mangroves for the Future (MFF) is a partnership-based regional initiative which promotes investment in coastal ecosystem conservation for sustainable development. MFF focuses on the role that healthy, well-managed coastal ecosystems play in building the resilience of ecosystem-dependent coastal communities in Bangladesh, Cambodia, India, Indonesia, Maldives, Pakistan, Seychelles, Sri Lanka, Thailand and Viet Nam. The initiative uses mangroves as a flagship ecosystem, but MFF is inclusive of all types of coastal ecosystem, such as coral reefs, estuaries, lagoons, sandy beaches, sea grasses and wetlands. MFF is co-chaired by IUCN and UNDP, and is funded by Danida, Norad and Sida.

MFF would like to acknowledge the additional editorial contributions from; Dr. Rudolph Hermes, Dr. Simon Funge-Smith, Prof. Steven J. Kennelly, Dr. Ranjith Mahindapala, Dr. N. M. Ishwar and Dr. P. U. Zacharia.

Published by Journal of the Marine Biological Association of India (J. Mar.Biol.Ass.India)

Available from:

The Marine Biological Association of India
CMFRI Campus, P.B. No.1604, Ernakulam North P.O.,
Kochi - 682 018, Kerala, India
Tel: 0484 - 2394867. Fax: 0484 - 2394909.
E-mail: mail@mbai.org.in; mbai@rediffmail.com
Website:www.mbai.org.in

Mangroves for the Future (MFF)
IUCN Asia Regional Office
63 Sukhumvit 39 Wattana,
10110 Bangkok, Thailand
Tel: (+66) 2-662 4029 Fax: (+66) 2-662 4388
www.mangrovesforthefuture.org

Journal of The Marine Biological Association of India
Vol.56 No.01 • January-June 2014 • Print ISSN 0025-3146 • Online ISSN 2321-7898

CONTENTS

CONTENTS cont...

Available online at: www.mbai.org.in doi: 10.6024/jmbai.2014.56.1.01750s-01

Managing tropical fisheries - using trawl fisheries to look at issues and solutions

Simon Funge-Smith* and Steven J. Kennelly[1]
Asia-Pacific Fishery Commission, FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.
[1]ICIC Consulting, 15/1-7 Arthur Ave, Cronulla, 2230, Australia

*Correspondence e-mail: simon.fungesmith@fao.org

Received: 14 Oct 2013, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Using tropical trawl fisheries as an example, the paper explores options to improve fishery management in Asia and develop regional guidelines by the Asia-Pacific Fishery Commission (APFIC). The paper provides a background description of the history of tropical trawling and its evolution to the present day. The ecosystem and fishery impacts are described under the headings of socio-economics, environment and ecosystem and governance. The management options are outlined for the various issues in tropical trawl fisheries, noting that management is context specific for each fishery. The APFIC guideline process to develop a management plan for a tropical trawl fishery is described.

Keywords: *Tropical trawling, guidelines, fishery management.*

A short history of trawling in Asia

The earliest records of trawling in the Asian region relate to beam trawls towed behind sailboats in Manila Bay. Industrial trawling began in the early part of the 20th Century, with steamships and then diesel-powered vessels towing large nets. In the early 1970's the modification of otter board gear to suit small, low powered vessels allowed trawling to rapidly become a dominant form of fishing in tropical Asian waters. These fisheries underwent a rapid expansion over a period of decades and led to massive increases in the total catches of shrimp and finfish.

Types of trawling

The main gear used in Asia's tropical trawl fisheries is the Bottom otter trawl, which has two major variants (the shrimp trawl and fish trawl). There are also modifications to give high opening nets which can target a broader part of the water column. There are also pair trawls which are used in some countries (e.g. Thailand) but banned in others (e.g. Malaysia). These are operated either on the bottom or as mid-water or pelagic trawls. They are generally faster trawls and capable of catching pelagic and faster swimming species. Push nets are another form of active gear, and were widely used, but have been on the decline due to their high impact on resources and habitats.

Asian tropical trawl fisheries typically operate at depths ranging between 10 m and 150 m but are often restricted to a maximum depth of about 70 m. Trawling, therefore, remains a feature of coastal fisheries. This results in significant overlap and/or interaction with other gear type fisheries. There are now an estimated 83,000 trawl vessels currently operating in the tropical parts of the APFIC region (Funge-Smith *et al.,* 2012).

Catch from trawling

Asia catches approximately 50 % of the world's wild fish (48.7 million tonnes) and five Asian countries are in the top ten global producers of capture fish. Trawl fishing is one of the chief methods responsible for placing the Asia-Pacific region as the world's largest producer of fish (Table 1). Overall, in regions where significant tropical trawl fisheries exist, they produce 25-52% of the total marine catch, making a total production of over 6.6 million tonnes. These trawl fisheries include not only high and low value fish but also high value products such as shrimp. China and four other Asian countries produce approximately 55 % of the global shrimp catch.

Table 1: Overview of trawl fishing in Asia

Number of trawl vessels	> 83,000 vessels
Trawl fisheries provide % of country marine catch	50 % PR China, South China Sea/Beibu, Hong Kong SAR
	52% Thailand (2009)
	48% Malaysia (2012)
	>50% India (2010)
	43% Vietnam (1997)
	~25% Indonesia (2008)
Approximate total trawl catch of southern PR China, India, Thailand, Malaysia, Vietnam, Indonesia	6.58 million tonnes

Catch levels

The increases in capture fishery production that are being achieved in the Asian region in recent decades can be attributed to large increases in fishing effort and the expansion of the geographical range of fishing activities as a result of mechanization, technology and globalization. They are also driven by the retention of most animals caught (including shorter-lived, small, fast-recruiting species), with very little discarding. Tropical trawl fisheries have been a major driver of these trends in coastal areas.

What is being caught in tropical trawl fisheries?

Tropical trawl fisheries in Asia catch approximately 800 species; including sharks, fish, crustaceans, cephalopods, shellfish, echinoderms and other benthos. Approximately 300 species contribute to the fishery and the vast majority of species are all utilized in some form. Discarding is therefore relatively uncommon and at low levels, except in targeted shrimp trawl fisheries.

Problems due to the rapid expansion of trawling

The rapid expansion of geographical range and effort expended on trawl fishing since the 1970's has meant that regulatory and management systems have either not been put in place or have been unable to keep pace with development. The result is that many tropical trawl fisheries are poorly managed, giving rise to social and economic problems and increasing concerns on their effect on fish populations and coastal ecosystems.

Social & economic issues

- **Conflicts with other segments:** There are significant conflicts with other fleet segments (esp. artisanal fishers) as they often target the same species, as well as encroachment in reserved areas.

- **Overcapacity:** More than 83,000 trawlers operate in tropical Asia. There are probably too many vessels for the size/value of the catch.

- **Low profit margins:** Rising fuel prices and labour costs, coupled with too many fishing vessels and stable or declining catches means that many trawl fisheries operate at marginal profitability. This drives subsidies and a tendency for state support to the sector.

- **Linkages to dependent industries:** Onshore fish processing, surimi, fishmeal, and aquaculture operations have arisen because of the availability of trawl products. This demand means that curtailing the landings of the trawl fishery may have negative impacts on the supply of raw materials. Strong economic and social interests will tend to influence management measures and decision making.

Ecological and environmental issues

- **Overfishing:** Trawling is a highly efficient and relatively non-selective method for catching large quantities of fish. The large scale trawling in Asia's tropics contributes to overfishing of stocks to unsustainable levels. Trawling in fishing areas and at times where juveniles of commercial species occur prevents them from contributing to the next generation. When larger mature spawning animals are caught, it may lead to recruitment overfishing. Both effects lead to long-term declines in stocks

- **By-catch:** By-catch is a common feature of any trawl fishery, but becomes a particular problem when at-risk species and juveniles are caught.

- **Catch of low-value fish:** Catch and landing of low-value fish is a feature of many tropical trawl fisheries in Asia. The loss of larger fish and resulting development of production and market demand for aquaculture and agriculture feeds and fish surimi products (see social and economic issues) can drive growth overfishing and often reduces economic returns from fisheries.

- **Habitat Impacts:** Trawls are mobile gear and damage benthic habitats and disrupt ecosystem function. Longterm intensive trawling can permanently change the benthic ecosystem, however, in some tropical benthic habitats recovery after trawling can be very quick. This gives good prospects for managing tropical trawl fisheries to reduce impacts on benthic ecosystems.

- **Effects on ecosystem function:** Impacts on benthic habitats and removal of large numbers of aquatic organisms, will impact the functioning of marine ecosystems. Ghost fishing and other unidentified mortalities: considered a relatively minor issue, this is mortality of animals caught in lost gear or after escaping the trawl.

Policy & governance dimensions

- **IUU fishing:** Most trawl fisheries are subject to some management measures (e.g. closed areas, seasons or other zones, mesh sizes, gear restrictions). However, there is often poor compliance (over-capacity or weak fishery controls). Some vessels operate illegally or operate in an unregulated way. In many cases there is weak reporting of catches. This constrains management of the fishery, and the illegal or encroaching element often leads to significant conflicts.

- **Increased investment and subsidies:** In many countries, governments try to promote the fishing industry to produce more fish for food security and job creation. At the same time it attempts to stabilize the industry by acting as a buffer against fluctuating prices and changing market demands. Typical support actions are access to low cost fuel, development of port infrastructure and port services, low-cost loans, direct payments and other types of subsidies. These subsidies offset the real production costs and often make fishing appear profitable well beyond the point that it is actually economically viable. This has the tendency to encourage increased fishing effort or investment in the fishery and its downstream industries and thus contribute to further overfishing. This support may also undermine safety at sea, as vessels have to fish longer and further, but fail to invest in upkeep. A major principle should be that any subsidy provided should be used only as a temporary measure, and always be linked to mechanisms for improved fisheries management.

The varying status of different trawl fisheries means that there will be differing objectives for management

Well managed trawl fisheries are those which have addressed issues relating to impacts and sustainability of the trawl operations. They typically operate profitably and within sustainable limits.

Trawl fisheries that have not been closely managed tend to be increasingly fished to the point where the quality of resources is declining. They have often lost top-end predators and have fewer long lived demersal species. These fisheries still have a reasonable chance of being restored to provide MEY/higher trophic index with the introduction of a management plan. They could be better-managed to improve or sustain existing services & profitability.

Those trawl fisheries which are heavily overfished and have modified ecosystems have incurred significant changes to composition of the stocks. These fisheries often operate at marginal profitability, or are even subsidized. There is very little that can be achieved in these fisheries without major reforms of the fishery, its dependent industries and the supporting policies.

Moving towards more effective management of the trawl sector

The contribution of trawl fisheries to fish production, occupation and income generation must be counterbalanced by concerns about the sustainability of catches and ecosystem impacts. To support a transition of trawl fisheries to more sustainable practices, they, more than any other in the region, require careful management underpinned by sound information and backed up by solid enforcement.

A particular challenge is that with no more new fishing areas for trawlers to exploit there is a strong need to bring illegal fishing under control and develop and implement strategies that will limit the region's trawling effort to levels which will ensure long-term, sustainable demersal resources for all fleet segments.

The need for guidelines on tropical trawl fisheries

The Asia-Pacific Fishery Commission, at its 32nd Session, recognized the importance of the trawl sector and its impacts on aquatic resources and benthic habitats and requested practical advice on trawl management. In response, the Commission has developed regional guidelines which are responsive to local management measures and the capabilities of the relevant management authorities. They will be simple, pragmatic and practical, applicable to fisheries that lack high levels of science, assessment and surveillance.

As catch rates and profits have declined, ecosystems have been altered, and conflict between trawl fishers and other users of the resources, especially small scale artisanal fishers, are a common occurrence. These issues have resulted in Asian countries introducing various management reactions such as:

- complete bans on trawling (mostly at sub-national level)
- introduction of fishery zones and trawl exclusion areas (many countries in the region)
- efforts to improve post harvest utilization of low value by-catch (e.g. surimi)

Table 2: Management of trawl fisheries in Asia

Issue	Actions or management measures to resolve the issue
Conflict	● Reserve special, artisanal-only fishing zones, such as near shore closures, that exclude trawling
	● Installation of obstructions to deter illegal trawling
	● Day/Night closures to trawling to avoid other fisheries
	● Facilitate meetings between sectors experiencing conflict
	● Flow of benefits back to the community from trawl fishery e.g. employment on trawl boats, product going to communities
	● Awareness programs regarding the existing regulations.
Over-capacity	● Too many trawlers for the size of available fisheries resources
	○ Limit and freeze the number of licences
	○ Government / Industry buy-backs - Compensation for loss of income through negotiated exit of vessels
	○ Conversion of existing trawlers to other fishing gears/practices
	● Excess fishing effort
	○ Limit the number of licences
	○ Subsidies for fuel and other capacity-enhancing subsidies such as: free port facilities, ice, tax exemptions etc. only available for compliant vessels
	○ Government subsidies (incentives) that reward good practices – i.e. to not fish during certain periods and to comply with other measures and as an incentive to reduce effort
	○ Spatial zoning
	○ Seasonal closures to limit effort
	○ Total Allowable Catches and Individual Transferable Quotas
	○ Limits to days allowed to fish (Boat days)
	○ Limited entry for new participants, 2 for 1 entry schemes
	○ Fishing on rotational basis
Unprofitable trawl sector	● Operating costs are too high compared to the value of the catch
	○ Government subsidies that reward good practices – i.e., to not fish during certain periods and to comply with other measures and as an incentive to reduce effort
	○ Increase value of the catch through better marketing, eco-labelling, acceptance of the fishery and its products (e.g., for fish meal) as responsible
	○ Fishing practices and gear modifications including boat hull and engine that reduce operating costs (e.g. labour costs and fuel consumption)
	○ Increase the value of the catch by improving its quality through gear modifications (e.g., increased mesh size leading to reduced damage in cod-ends) and on-deck handling practices
	○ Long-term recovery of fishery leads to increased CPUE, improved productivity and profitability
IUU fishing	● Promote legal trawling
	○ Establish and enforce fishing zones for trawling
	○ Electronic Monitoring (including VMS)

	○	Communication between agencies responsible for issuing boat licences, skipper licences and gear registration
	○	Communication and collaboration between neighbouring countries
	●	Regular and accurate reporting of trawl activity
	○	Onboard logbooks
	○	Education program on importance of regular and accurate reporting
	○	Observer programs
	○	Improved compliance & enforcement of regulations
	○	At sea surveillance by Officers
	○	Dockside monitoring
	○	Reduction of transboundary IUU fishing
Impacts on dependent industries	●	A critical dimension of the drivers that push trawl fisheries
	●	Dependent industries may suffer if trawl catches and overall sector is reduced and may undermine management efforts - demanding fish to stay in business
	●	Management changes to trawl sector are implemented gradually, allowing support industries to adjust
Overfishing	●	Excessive trawl effort leads to depletion of stocks
	○	Capacity reduction measures
	○	Space/time closures to protect vulnerable stocks
	○	Permanent closures to trawling in critical areas for vulnerable stocks
	○	Trawling taking too many individuals (spawners and juveniles) of vulnerable small species
	○	Space/time closures to protect vulnerable small species
	○	Permanent closures to trawling in critical areas for vulnerable small species
	○	Gear modifications (mesh size, panels, grids) to exclude vulnerable small species
	○	Space and/or time closures to reduce trawling where sub-optimal sized and low-value fish occur
	○	Appropriate mesh sizes / gear changes where sub-optimal sized and low-value fish occur
By-catch of juvenile fish	●	Two types of impact:
	○	Juveniles caught before spawning
	○	Species harvested at a sub-optimal size for maximum value (growth overfishing)
	●	Measures
	○	Space/time closures to protect juveniles; to reduce trawling where/when juveniles occur
	○	Permanent closures to trawling in nearshore nursery areas
	○	Minimum Legal Lengths (MLLs) set at size of sexual maturity
	○	Minimum Legal Lengths (MLLs) set at a size close to the optimal
	○	Gear modifications (mesh size, panels, grids) to exclude undersize fish
	○	Reduce mortality of juvenile fish through introduction of Bycatch Reduction Devices (BRDs) in nets
Catch of Endangered,Threatened or Protected (ETP) species	●	Space and/or time closures to reduce trawling where/when ETPs occur
	●	Reduce mortality through introduction of Bycatch Reduction Devices in nets
	●	Reduce mortality through better on-deck discarding practices
	○	e.g. recovering techniques for turtles, sharks
Habitat impacts	●	Spatial closures to remove trawling from sensitive areas (e.g. key habitats)
	●	Obstructions to deter illegal trawling
	●	Modified trawl gear that minimizes benthic impacts
Effects on ecosystem function	●	Excessive and uncontrolled trawling disrupts normal ecosystem function and food webs
	○	Spatial closures to protect entire sensitive ecosystems containing representative habitat types and resources
	○	Obstructions to deter illegal trawling
	○	Trawl modifications to reduce impacts on ecosystem components
	○	Balanced harvesting throughout the ecosystem

- subsidies to sustain production, despite declining catches and profitability

Some of these have been effective and some have failed or even been counter-productive. Table 2 summarizes the sorts of measures that can be effective in addressing the range of issues that require management in a tropical trawl fishery.

First step to improvement

The APFIC expert workshop on management of tropical trawl fisheries developed a series of general recommendations which could be applied to all trawl fisheries in the region. They provide a general rule of thumb for management based on the minimum standards which are found throughout the trawl fisheries of the region. Of course, the measures could be more stringent and these should be viewed as a first step to getting a tropical trawl fishery under more effective and responsible management.

Initiate a process for managing trawl fisheries

- Countries with a significant trawl sector to:
  - Establish a Steering Committee to implement these guidelines
  - Initiate the development of a draft fisheries management plan for an important trawl fishery as a vehicle for capacity building
  - Establish consultative processes that engage with fishers, the fishing industry and other stakeholders for ALL steps in the above processes

Reduce the impact of trawls through spatial, habitat and temporal measures

- Minimum 3nm trawl exclusion zone (noting that some countries currently have up to 8-10nm)
- No trawling in critical habitats (e.g. on seagrass, corals), nursery grounds or in waters shallower than 10 m
- All trawl fisheries to have an annual seasonal closure of at least 1-3 months to coincide with peak spawning and nursery times

Reduce the impact of trawl gear

- Regulate trawl specifications for lighter gear (e.g. net material, footropes, bobbins) to reduce the environmental impact of trawling
- Regulations to have an effective minimum of 40 mm mesh size in the cod end, recognising that larger mesh sizes than this are preferable
- Promote gear designs that ensure correct selectivity in the cod end
- Develop and implement device designs with industry (BRDs, JTEDs, TEDs, etc) that reduce impacts on at-risk and ETP species
- Promote reduced duration of trawl tow to 2 hours to improve fish quality

Strengthen Monitoring, Control & Surveillance

- Clear, individual markings for all trawlers that are visible from a distance
- Get effective MCS working (i.e. Satellite-based VMS on all larger vessels)
- Promote a fishers' volunteer watch/reporting scheme, and integrate into existing MCS arrangements

Manage fishing effort and fishing vessel over-capacity

- Get vessel registration and licensing system working effectively
- Cap trawler numbers at existing levels
- In fisheries with overcapacity, reduce vessel numbers by 30% by 2025
- Limit effort shift into other areas and other fishery types
- Maintain horsepower and head rope length at current levels to prevent effort creep (and even reduce in cases of overcapacity)
- Stop or reform the use of subsidies (especially fuel subsidies) for trawl fisheries
- Ensure all financial incentives in trawl fisheries reward sustainable fishing practices

A final thought

This paper has focused on trawl fishing by-catch and the need to manage trawl fisheries. The need for management is not confined to the trawl sector; gears such as purse seine, gillnet and FAD associated fisheries also need management. The issues are also not entirely confined to the impacts of industrial fishing as small-scale fishing can have equivalent impacts due to the large numbers of fishers involved. There is a strong need to manage most fisheries more effectively throughout the Asian region and this look at trawl fishing gives an idea where to start. Most of what is presented here can be equally applied to other fisheries.

Reference

Funge-Smith, S., M. Briggs and W. Miao. 2012. Regional overview of fisheries and aquaculture in Asia and the Pacific 2012. *Asia-Pacific Fishery Commission, FAO Regional Office for Asia and the Pacific. RAP Publication 2012/26.* 139 pp.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-02

Managing Marine Protected Areas in Indonesia

Setyawati
Sub-Directorate of Marine, Coastal, and Small Islands, Directorate of Marine and Fisheries, National Development Planning Agency, Indonesia.

*Correspondence e-mail: setyawati@bappenas.go.id

Received: 24 Oct 2013, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract
Indonesia, an archipelagic nation that consists of 17,504 islands and a total marine area of 5.8 million square kilometers, has valuable ocean and coastal resources and services that support development and community livelihood. However, overfishing, pollution, unsustainable fishing practices, and destruction of nursery habitats have threatened the sustainability of marine and coastal ecosystems and resources. Marine protected areas (MPAs) are considered an effective tool to manage resources of marine and coastal areas, including fisheries resources sustainably. With 15.7 million hectares of marine protected areas that have been established until 2012, Indonesia is committed to manage resources of marine and coastal areas in an effective and sustainable way. The Long-Term National Development Plan, the National Medium-Term Development Plans, Law on Fisheries and Law on Management of Coastal and Small Islands areas, and several government regulations provide policies to manage MPAs that adopt the concept of sustainable use. A zoning system has been established to harmonize the multiple objectives of the MPAs. The introduction of sustainable fisheries zone in the zonation systems of MPAs management has accomodated the rights of local communities, especially fishers, to utilize fisheries resources in eco-friendly practices. This paper addresses benefits and conflicts among users of MPAs and discusses the institutional and legal framework for managing MPAs. A tool to evaluate performace of MPA management and a zoning system are also addressed. Since the government of Indonesia is also committed to increase total area of MPAs to 20 million ha by 2020, the strategies to achieve the target are also reviewed.

Keywords: *Marine Protected Areas, ecosystems, management, Indonesia.*

Introduction
Indonesia is an archipelagic nation that consists of 17,504 islands with a total land area of 1.87 million km^2 and a total marine area of 5.8 million km^2. The marine areas include archipelagic waters of 2.95 million km^2, territorial sea of 0.30 million km^2, and Exclusive Economic Zone of 2.55 million km^2. Indonesia has a wealth of biodiversity in coastal ecosystems, which consist of three ecosystems, namely mangroves, coral reefs and seagrass. These three ecosystems are dependent on each other in preserving fishery resources. Besides the ecological role, Indonesia's ocean and coasts also provide valuable resources and services to support economic development, including providing alternative livelihood for coastal communities.

However, economic growth combined with population growth has put pressure on the ocean and coastal resources. Overfishing, pollution from land-based and sea-based activities, irresponsible fishing practices, and destruction of nursery habitats have threatened the sustainability of marine and coastal ecosystems and resources. Due to pressure from destructive fishing practices, tourism, and global warming; only 5.30 percent of the total coverage of Indonesia's coral reef -around 75,000 km^2 - is in an excellent condition, and 27.18 percent is in good condition (Coremap, 2013). Mangroves are also being depleted and degraded, mainly due to logging and conversion of mangroves to other purposes. It is estimated that between 1982 and 1993, mangroves in Indonesia have been depleted at about 46,000 ha per year, at best scenario, or 160,000 ha per year, at worst scenario (Sukardjo, 2011). Fishery resources are also at the level of fully-exploited and over-exploited status in most of Indonesia's 11 Fisheries Management Areas (FMAs). Only some FMAs are in moderate level.

An increased awareness of these sustainable, protective and productive resources has promoted the need for conservation. Marine protected areas (MPAs) are considered an effective tool to manage resources of marine and coastal areas sustainably. The MPAs support sustainable fisheries management, since the MPAs rebuild the productivity of marine ecosystem in terms of fish stock. However, in managing MPAs effectively, regulations must be in place, and the institutional arrangement must be developed. A zoning system that accomodates multiple users in MPAs should be considered.

This paper is based mainly on a review of secondary literature, including books and reports published by several institutions involved in management of marine protected areas in Indonesia, that includes Ministry of Marine Affairs and Fisheries, National Development Planning Agencies, Ministry of Forestry, and other institutions. This paper also provides an overview on roles and status of existing marine protected areas in Indonesia and their distribution among provinces and within the existing 11 Fisheries Management Areas. Analysis of institutional and legal aspects, including the existing national policies concerning marine protected areas have been reviewed. Potential strategies to cover 20 million ha by 2020 have been suggested.

Marine Protected Areas

Defining Marine Protected Areas

There are many definitions of MPA. One of the internationally recognised definitions of MPA by IUCN is:

"Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher 1999).

Based on Government of Indonesia's regulations, the definition of marine protected areas is any area in marine, coastal and small islands which has been protected, managed by a zoning system, to support sustainable fisheries and environment management. The marine protected areas are established under ministerial decrees.

In other words, there are two important aspects in the definition of MPA. First, the area must be devoted for protecting environment, biodiversity, and cultural resources. Second, the area must be managed legally or through other means (Worboys *et al.*, 2005). Marine reserves, marine parks, and locally managed marine areas are included under marine protected areas.

Benefits and challenges

The MPAs provide goods and services that are ecologically, economically, and socially valuable for society. For ecological aspect, an MPA conserves marine biodiversity, especially threatened species and associated ecosystems. It also improves the health of marine ecosystem that results in improved ecosystem good and services. For example, coastal ecosystems, such as mangroves and coral reefs which are in a good condition serve as habitats for wildlife, provide coastal protection, nutrient cycling, water purification, and mitigation of climate change.

The MPAs also contribute to sustainable fisheries. Research has shown that an MPA can support fish stocks by protecting spawning grounds and nursery habitats for juvenile fish. Furthermore, when fish are mature, an MPA provides spillover effect into surrounding areas, such as fishing grounds or recreational fishing areas.That is why a marine protected area with 'no-take' zone is important in reversing the declining trend of fish populations and productivity. Pisco (2002) argues that in marine reserves, animals, including fish increase in their biomass, abundance, number of species, and body size. The average biomass is more than four times larger in reserves than in unprotected areas nearby. The density triples, and the number of species is 1.7 times higher in marine reserves than in unprotected areas. In addition, the average body size of animals is 1.8 times larger in reserves than in fished areas.

Tourism in a MPA is a major source of income for local communities in many countries. Local communities can get economic benefit through their involvement in tourism business or MPA management. Besides, tourism can provide financial support for sustaining MPAs.

MPAs are also important for enhancement of knowledge through education and training. They become locations where people can observe, do research, and also deliver knowledge to children about marine biodiversity. MPAs also have an important role in educating communities as well as visitors about the history and culture of the areas they protect.

However, since different entities such as local communities, conservationists, governments, services industries, visitors, and boat and fishing industries want to obtain benefits from the MPA, it can result in conflicts of use between tourism and conservation or between fishing and conservation. As mentioned before, tourism becomes a financial resource for managing marine parks and gives revenue for the local governments and employment for local communities. Unfortunately, growing tourist demand to access the marine protected area can reverse purposes of the area because it can reduce natural value and deteriorates the environment. The presence of man-made facilities, such as hotels, restaurants and other recreational infrastructure may give negative impacts on the marine protected areas' environment. In order to avoid this unintended consequence and to make ecotourism a tool for conservation, strengthening of cooperation between public authorities and private operators, improving capacity of marine park managers, and developing understanding of biodiversity conservation for visitors are needed.

Conflicts also happen within local communities, particularly local fishers who fish in the area. The designation of a MPA can directly impose costs on fishers by closing off access to fishing grounds. Carter (2003) argues that this conflict can be eliminated if the fishers' loss, because of relocating to another fishing grounds, has little effects or no costs, or if they are given compensation of ''spillover'' effects from the MPA to the remaining fishing grounds. Introducing sustainable fisheries zone into a zoning system in MPAs may also eliminate the conflicts.

Current status

Until 2012, Indonesia established 15.7 million hectares of marine protected area (Table 1) consisting of 42 national MPAs and 66 district MPAs. A gap analysis of critical conservation areas in 2010 identified that Indonesia's MPAs protect 747,190 ha or 22.7 percent of coral reefs, 758,472 ha or 22 percent of mangroves, and 304,866 ha or 17 percent of seagrass beds (Yulianto *et al.*, 2013).

The existing MPAs in Indonesia are distributed among 31 out of 33 provinces, with larger area of MPAs in the eastern part of Indonesia. Southeast Sulawesi, West Papua, Riau Islands, and East Kalimantan are provinces that have MPAs covering more than one million hectares. DI Yogyakarta and South Sumatra are provinces with no MPAs.

The MPAs are also distributed within the existing 11 Fisheries Management Areas (Wilayah Pengelolaan Perikanan-WPP), with the largest area of MPAs located in WPP Indian Ocean and Southern Java. This WPP covers 4.2 million ha or 24.5 percent of the total area of Indonesia's MPAs (Yulianto *et al.*, 2013).

Legal and instititional framework for Marine Protected Area

Legal framework

The policy and regulatory framework for marine and coastal resources in Indonesia is well developed. In addition, aspects of sustainable use and environmental protection are increasingly addressed in policies. Prioritiy policies are expressed in long-term and medium national development plan.

Table 1. Marine Protected Areas in Indonesia

No	Category	Total number	Area (ha)
A	**Initiated by Ministry of Forestry**	**32**	**4,694,947.55**
1	Marine National Park	7	4,043,541.30
2	Marine Tourism park	14	491,248.00
3	Wildlife Conservation	5	5,678.25
4	Marine Conservation	6	154,480.00
B	**Initiated by Ministry of Marine Affairs and Fisheries and Local Governments**	**76**	**11,089,181.97**
1	Marine National Park	1	3,521,130.01
2	Marine Conservation	3	445,630.00
3	Marine Tourism park	6	1,541,040.20
4	Local Marine Protected Area	66	5,581,381.76
	Total	108	15,784,129.52

Source : Ministry of Marine Affairs and Fisheries, 2013

The current Long-Term National Development Plan (2004-2024) and the National Medium-Term Development Plans (2010-2014) have mainstreamed the principles of sustainable development in national development policies and programs. Particularly for marine, coastal and fisheries sector, Indonesia's policies have been set up to meet the goal of improvement in fisheries production to support food security, utilization of marine and coastal resources in an optimal way, and conservation for marine and coastal ecosystems. With respect to conservation, coastal and fisheries management, Indonesia's Law No. 31 year 2004 on Fisheries and its amendment (Law No. 45 year 2009), Law No. 27 year 2007 on Management of Coastal and Small Islands areas, and Government Regulation No. 60 year 2007 on Fisheries Resource Conservation also adopt the concept of sustainable use.

Ensuring availability of regulations, improving understanding of the regulations, and law enforcement are crucial for effective management. The laws and regulations on coastal resource management and marine protected area are explained in Table 2.

Act No. 31 of 2004 on Fisheries as amended by Act No. 45 of 2009 states that fish resources conservation are needed to guarantee the existence, stock and continuity of fishery resources, including their ecosystems, species and genetics. The government can establish a site as a conservation area, in the form of aquatic nature reserve, national water park, water recreation park, and/or fishery reserve.

Act No. 27 of 2007 on the Management of Coastal Region and Small Islands regulates the planning, management, supervision, and control in coastal regions and small islands.

Government Regulation No. 60 of 2007 on Fishery Resources Conservation regulates three conservation activities: ecosystem conservation, conservation of fish species, and conservation of fish genetics. Ecosystem conservation consists of the ocean, seagrass beds, coral reefs, mangroves, estuaries, coastal swamps, rivers, lakes, reservoirs, ponds, and artificial aquatic ecosystems. Conservation of fish species is intended to protect endangered fish species, maintain fish species diversity, preserve the balance and stability of ecosystems, and utilize fishery resources sustainably. Conservation of fish genetics requires maintenance, breeding, research and preservation of gametes.This regulation is followed by Decree of the Minister of Marine Affairs and Fisheries No. 30 of 2010 that regulates plans for management and zonation of MPAs, and Decree of the Minister of Marine Affairs and Fisheries No. 17 of 2008 that regulates protected areas in coastal and small islands areas.

Act No. 32 of 2004 on Regional Government as last amended by Act No. 12/2008 regulates local governments' authority to manage marine resources in their territory. The authority consists of exploration, exploitation, conservation and management of ocean resources. Provincial governments manage territory of 12 nautical miles from shoreline towards the sea and/or towards the waters within the archipelago, while regency/municipal governments manage 1/3 (one third) of provincial authority.

Institutional framework

Responsibilities to manage marine protected areas in Indonesia are divided horizontally and vertically (Table 3). In the horizontal dimension, the responsibilities are divided among sectors or ministries, while in vertical dimension the responsibilities are shared among three levels of government (central, provincial, and district). With more than one authorized institution carrying out management,overlapping authority can cause conflict and decreased effectiveness.

At the national level, the Ministry of Marine Affairs and Fisheries that was established in 2000 is responsible to manage coastal resources in Indonesia, including marine protected areas. However, the responsibility to manage MPAs is also shared among other ministries, particularly Ministry of Forestry. Although each agency has defined duties, there is still overlap between their responsibilities. Harmonizing duties between the Ministry of Forestry and Ministry of Marine Affairs and Fisheries needs to be developed. As an initial effort, Ministry of Forestry handed over 8 marine conservation areas and marine tourism parks to Ministry of Marine Affairs and Fisheries in 2009. As of 2012, Ministry of Forestry manages 32 National MPAs while Ministry of Marine Affairs and Fisheries manages 10 National MPAs.

Since the enactment of the Regional Government Act No. 22/1999 and its amendment Act No. 32/2004, local

Table 2. Laws and regulations concerning Marine Protected Areas in Indonesia

No	Subject	Laws/Regulations	
1	Planning	Act No. 25/2004	National development planning system
		Act No. 17/2007	Long term national development plan
		Presidential Regulation No. 5/2010	Medium term national development plan
		Act No. 26/2007	Spatial Planning
2	Decentralization	Act No. 32/2004	Regional government
		Act No. 33/2004	Financial balance between central and regional government
3	Coastal Resource management and Marine protected area	Act No. 5/1990	Conservation on biological resource and their ecosystem
		Act No. 41/1999	Forestry
		Act No. 31/2004	Fisheries(amended by Act No. 45 of 2009)
		Act No. 27/2007	Coastal and small islands management
		Govt Regulation No. 60/ 2007	Fisheryresources conservation
4	International context	Act No. 17/1985	Ratification of United nations convention on the law of the sea
		Act No. 5/1994	Ratification of United nations convention on biological diversity

Table 3. Governmental organizations for marine protected areas in Indonesia

Government Organizations	Responsibilities related to MPA
Ministry of Marine Affairs and Fisheries	Marine, coastal and fisheries resource management, including aquaculture, fish capture, control and monitoring, research, conservation, and coastal community empowerment
Ministry of Forestry	Manage and control forestry, including mangroves, water ecosystems and national parks, including marine national park
Ministry of Home Affairs	Manage home affairs and regional autonomy, coordinate and supervise regional policies, develop good relationship between central and regional governments
Ministry of Tourism and Creative Economic	Develop national policy for tourism, including eco-tourism

governments have the power to manage their coastal resources. Decentralization has mandated local governments to manage the protected areas in their territories. Since then, there has been improvement in local governments' initiatives to enhance the extension of protected areas. Until 2012, as many as 66 district level-MPAs have been declared. The central government manages National MPAs, and provides policy and technical guidance to regions. Full involvement of provincial and district governments to manage local level MPAs is important for effective management of MPAs. This has to be followed by strengthening capacity of local human resources on managing MPAs.

National strategy for MPA

Effective management tool

There are several issues when managing MPAs. Lack of infrastructure and equipment, inadequate human resource capacity, inadequate management plans as well as finance are problems faced in managing MPAs. In order to manage the MPAs effectively, recently Indonesia has promoted a tool to evaluate the MPAs management. There are five levels of management, namely, red (initiation level), yellow (establishment level), green (minimum management level), blue (optimal management level) and gold (sustainable management). Red level requires a conservation area to be initiated and evaluated with provisioning, while yellow level requires an established conservation area containing a management institution, and zonation and management plans. In order to obtain green level, a conservation area has to have a low level of management containing a management institution, zonation and management plans, institutional and human resource improvement, infrastructure, and equipment. A conservation area with blue level is a conservation area with optimum management, and a conservation area with gold level has sustainable funding and good impacts on the prosperity of locals (Ruchimat *et al.*, 2012).

Most of Indonesia's MPAs are still in red and yellow level. None of them fullfils the gold level. In order to improve the level of MPAs, several efforts are needed. These include completing zonation and management plan, increasing human resource capacity and institution, supporting MPAs infrastructure and equipment, harmonizing rehabiltation, conserving and utilizing marine tourism and sustainable fisheries, and promoting cooperation and network. An MPA manager may use this tool to carry out self-evaluation on the performance of the MPA, and plan for improving the performance.

Zoning plan

In a multiple use MPA, some areas have high conservation value, and some areas permit some activities, such as recreational fishing and tourism, but prohibit exploitative uses. In order to identify which area is highly protected or not highly protected, a zoning plan should be established. Based on Government regulations, MPAs are managed and regulated by using a zoning system. There are four zones - core zone, sustainable fisheries zone, usage zone, and miscellaneous zone. Every MPA has to have a core zone with minimum 2 percent of the total area of the MPA. The core zone protects habitat for spawning and nursery, protects fish population, unique coastal ecosystems or traditional culture sites, and allows research and education. The usage zone is mainly for ecotourism, while the miscellaneous zone is for specific purposes, such as for rehabilitation.The sustainable fisheries zone allows environment-friendly fisheries and aquaculture activities, as well as marine tourism. By having sustainable fisheries, the conflict between fishers and MPAs can be reduced or even eliminated. By having this zone, the paradigm of marine protected areas in Indonesia has been shifted from prohibiting livelihood activities to mutually beneficial framework (Ruchimat *et al.*, 2012).

Fig. 1 is an example of a zoning plan for a district level MPA in Nusua Penida Bali Province, namely Marine Tourism Park of Pulo Pasi Gusung that covers an area of 20,057 ha.

It must be mentioned that effectiveness of zoning plan is influenced by the level of local communities' participation in formulating the zoning plan. Conflicts in managing MPAs often happen because of not involving local communities and related stakeholders.

Toward 20 million hectares of MPA

The government of Indonesia is commited to increase total area of MPAs to 20 million ha by 2020. In order to achieve 20 million ha or approximately 6.5 percent of Indonesia's territorial waters, the government of Indonesia has to declare additional 4 million ha in the next seven years. A number of studies have been conducted to define potential areas

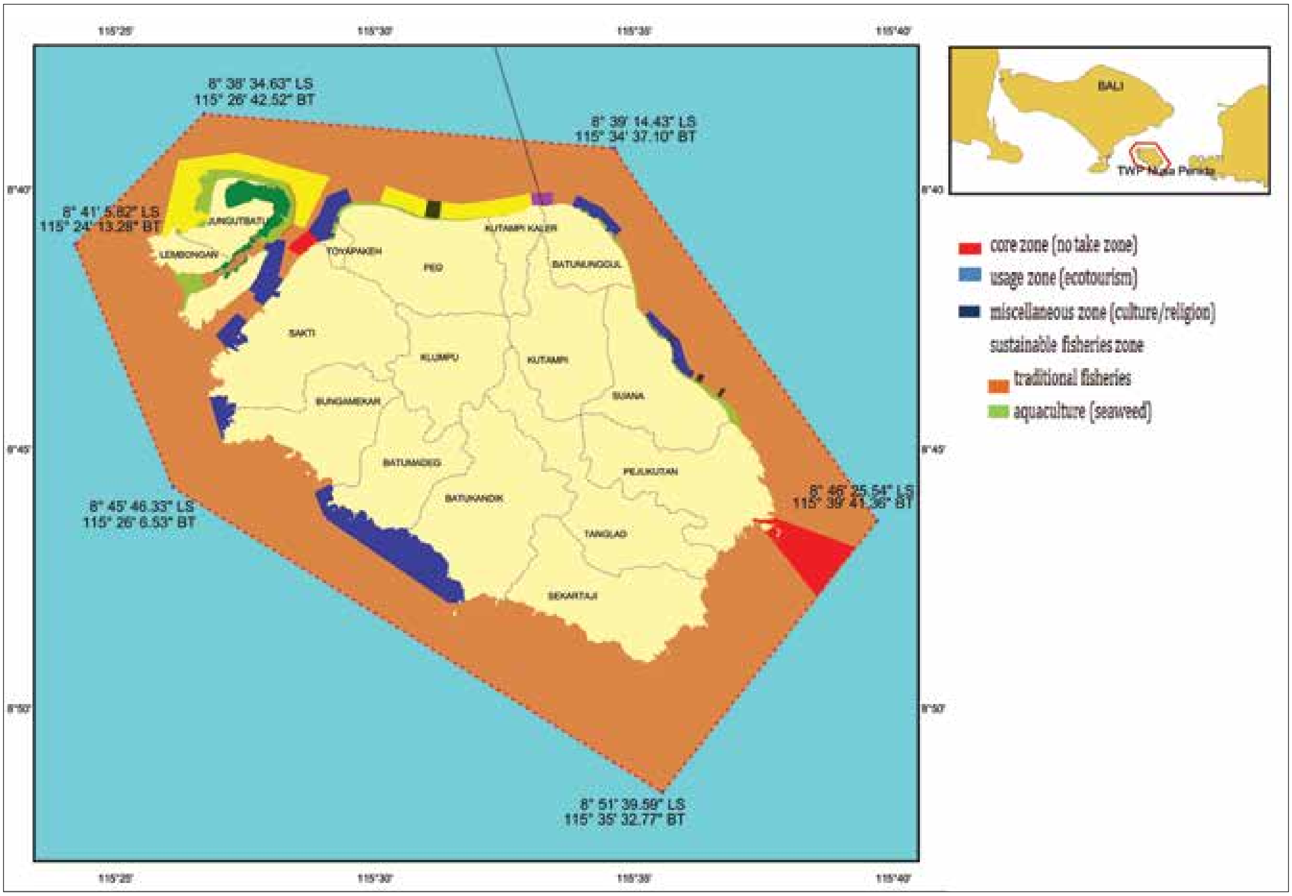


Fig 1. Zoning plan for district level MPAs in Nusa Penida, Bali (Source: Pokja KKP Nusa Penida, 2012)

to achieve the government's target. The studies include Indonesia Protected Area Plan Atlas in 1984, scientific design of resilient MA networks in Lesser Sunda Ecoregion, results from MPA's related project such as community-based marine protected areas from Coral Reef Rehabilitation and Management Project. Potential strategies towards this has been identified. The first step is to integrate community-based MPAs (village level) into national MPAs. The second step is to develop new MPAs in several priority areas. By 2013, more than 300 community-based MPAs would have been established (Yulianto *et al*., 2013). These efforts require coordination between communities, local government and central government.

Conclusion

It is clear that marine protected areas provide benefits from economic, ecological and social aspects. In a multiple use MPA, conflicts between fishers, tourism and protected areas are the concerns. A well designed-zoning plan is required to meet the needs of all participants. The long term and effective management of MPAs demands improved coordination among institutions directly involved in marine conservation management as well as full commitment of local governments.

References

Carter, D.W. 2003.Protected areas in marine resource management: Another look at the economics and research issues. *Ocean & Coast. Manag.*, 46: 439-456.

COREMAP II (Coral Reef Rehabilitation and Management Program). 2013. Coral reef condition in Indonesia. Jakarta: LIPI. Retrieved from http://www.coremap.or.id/Kondisi-TK/Government Regulation Nomor 60 Year 2007 on Fishery Resources Conservation.

Huffard, C. L., M.V. Erdmann, T. R. P. Gunawan (Eds.). 2012. Geographic priorities for marine biodiversity conservation in Indonesia. Jakarta: Ministry of Marine Affairs and Fisheries and Marine Protected Areas Governance Program.

Kelleher, G. 1999. Guidelines for marine protected areas. Gland, Switzerland and Cambridge, UK: IUCN.

Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO).2002. *The Science of marine reserves*. www.piscoweb.org.

Pokja KKP Nusa Penida. 2012 Rencana Pengelolaan kawasan (management plan for Nusa Penida conservation area), Klungkung. Presidential Regulation Nomor 5 Year 2010 on Medium Term National Development Plan 2010-2014. Jakarta.

Ruchimat, T., R. Basuki and Suraji. 2012. Recognizing the potential of Indonesia's marine, coastal, and small islands protected areas: Profiles of 76 marine, coastal, and small islands protected areas. Jakarta:Ministry of Marine Affairs and Fisheries of the Republic of Indonesia, Marine Protected Areas Governance and USAID.

Yulianto, I., Y. Herdiana, M. H. Halim, P. Ningtias, A. Hermansyah and S. Campbell. 2013. Spatial analysis to achieve 20 million hectares of marine protected areas for Indonesia by 2020. Bogor: Wildlife Conservation Society and Marine Protected Areas Governance.

Worboys, G. L, M. Lockwood and T. D. Lacy 2005. Protected area management: Principles and practice. South Melbourne: Oxford University Press.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-03

Solving by-catch problems: Successes in developed countries and challenges for protein-poor countries

Steven J Kennelly
IC Independent Consulting, 15/1-7 Arthur Ave, Cronulla, 2230, Australia.

*Correspondence e-mail: steve.kennelly@icic.net.au

Received: 21 Nov 2013, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

One of the world's most serious and controversial fishing issues is the waste associated with the incidental capture, mortality and discarding of unwanted by-catch. In response to by-catch issues, developments in fishing technology changed focus towards more selective fishing gears under an objective to catch targeted species whilst avoiding unwanted by-catch. In more recent times, this field has expanded to address problems associated with fishing gears (especially dredges and trawls) impacting on habitats and ecosystems. Through a series of case studies, this paper describes the various categories of by-catch issues and how one can go about examining and resolving them. It also summarizes recent developments in the field, including the important development of FAO's International Guidelines on By-catch Management and Reduction of Discards. A relatively simple framework for ameliorating by-catch issues is described which is comprised of five key steps and has proven to be quite consistent across many examples. Using other case studies summarizing work in Nigeria, Cameroon, Madagascar and the Gaza Strip, this paper also describes some of the complexities associated with the implementation of by-catch reduction practices in protein-poor countries - as compared to the simpler situation in developed countries. It illustrates that the critical need for food security in poor countries goes hand-in-hand with the need for sustainable fisheries management - but the implementation of the latter in these circumstances is extremely complex and always country-specific. This paper marks a very successful period of achievement in ameliorating some of the most critical problems facing the world's fisheries. It also outlines how this work has broadened to address other emerging fisheries issues including ecosystem impacts. Finally this paper describes the enormous challenges faced by developing, protein-poor countries as they wrestle with by-catch issues whilst trying to feed the hungry.

Keywords: *Fishing technology, by-catch, discards, ecosystems, over-exploitation, buyemsellum sector, developing countries.*

Introduction

There have been many papers and reviews written about fisheries by-catch and discards. In Kennelly and Broadhurst (2002), we attempted to summarize the situation at that time. In this paper, I give a brief synopsis of that paper before providing an update of more recent issues and efforts to deal with by-catch, especially in developing countries.

Humans have been harvesting fish for at least 90,000 years using technologies that have developed from simple harpoons through to huge factory trawlers (Fig. 1a,b). For most of this history, under an assumption that the oceans, lakes and rivers

Fig. 1a. Early fishing technology from 90,000 years ago found in Zaire (from Yellen *et al.*, 1995).

Fig. 1b. The largest fishing vessel ever launched - the factory trawler Atlantic Dawn (from Fishing News International, March, 2000).

could not be exhausted, developments in fishing technology have focused on methods that caught ever-greater quantities of fish of an ever-increasing diversity.

It wasn't until the 14th Century that we began to see a problem with this unchecked development of fishing methods. For example, in 1376, in a petition to Edward III of England, an early form of beam trawl called the "*wondyrchoun*" was criticised for its impacts on small fish and benthic habitats. But the development of fishing technology continued unchecked, with little concern for overfishing or the small fish that were being discarded. From the early use of flaxen lines and cast nets, larger dragnets, fish traps, and pronged tridents (Nun, 1993) humans developed quite sophisticated fishing techniques and in the 19th Century, there was a dramatic increase in the use of most of the major methods used today. Around this time, longlines, drift nets, beam trawls, beach seines and trap nets were being used and new methods for catching very large quantities of fish were developed including purse seines, Danish seines and the modern-day otter trawl. The efficiency of these methods (and in particular, the trawl) in catching large quantities of fish established these techniques as the prime tools used up to the present day.

So, for most of history, humans have considered fishing technology as a major aid in providing a seemingly inexhaustible supply of seafood. With the benefit of archaeological evidence, however, we now know that such technological advances have led to major reductions in biodiversity and the progressive depletions of many fish populations (Pitcher, 2001).

Warnings during the 14th to 19th Centuries about the negative impacts that advances in fishing technology may be having on stocks and ecosystems were realized in the 20th Century, when major declines occurred in many of the world's stocks. The unchecked construction of bigger vessels (culminating in huge factory trawlers), combined with advances in electronic equipment, netting designs and materials all led to a strong test of the millennia-old assumption that seafood resources were inexhaustible. This is an assumption that we now know to be false.

The last few decades

This direction in the development of fishing technology changed dramatically during the last few decades in light of one of the world's most serious and controversial fishing issues - the waste associated with the incidental capture, mortality and discarding of unwanted by-catch (defined here simply as those organisms that are caught but not targeted). In response to such issues, developments in fishing technology changed focus to more selective fishing techniques, so that targeted species (and targeted sizes of those species) are caught whilst unwanted by-catch are not. In more recent times, this field has expanded to address broader problems of fishing gear (especially dredges and trawls) impacting on habitats and ecosystems.

This focus on by-catch reduction and ecosystem-effects of fishing has resulted in many successful changes in fishing practices which are estimated to be conserving millions of fish and other organisms in many parts of the world. These successes have occurred in many types of fisheries and have improved many of the world's most non-selective and problematic fishing techniques. Below, I describe some examples under various categories of by-catch.

By-catch of charismatic species

Despite centuries of concern over the discarding of small fish from nets (especially trawls), one of the first attempts to resolve by-catch issues did not address trawling but the more selective method of purse-seining (Hall 1994; 1998). Concern over the incidental mortality of dolphins in tuna purse-seines had been one of the most infamous by-catch issues since the 1960's with dramatic outcries from various environmental and conservation organisations. The most common way

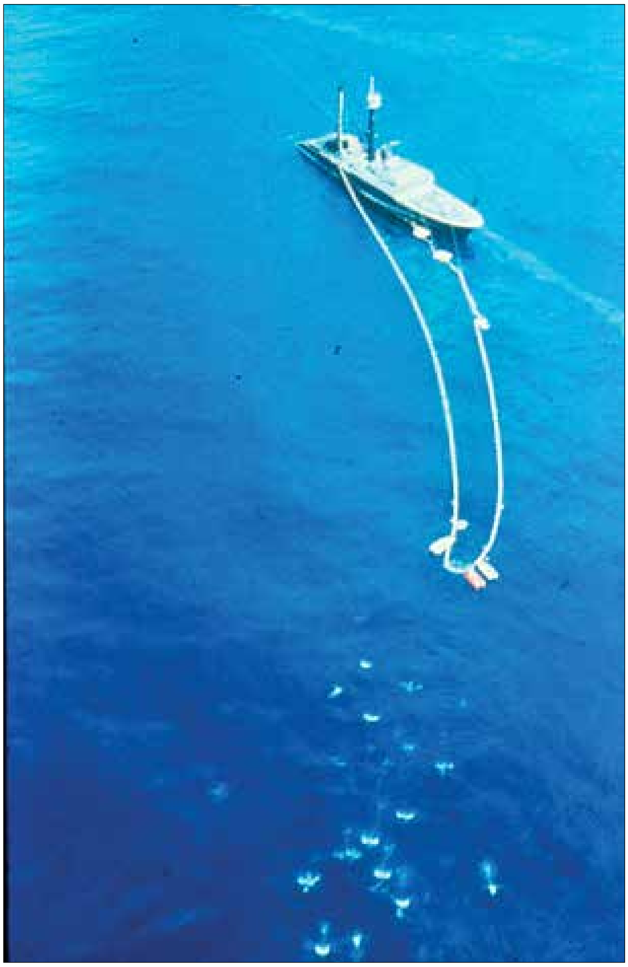


Fig. 2. The backdown manoeuvre used to release dolphins from tuna purse seines in the Eastern Pacific.

purse-seiners fish for tuna in the eastern Pacific Ocean is to encircle groups of dolphins to catch the tuna with which they associate. During the 1960's, the incidental mortality of dolphins using this method was approximately 350,000 dolphins/year which is believed to have caused significant declines in their populations. Through an extensive observer program (with 100% coverage) that provided detailed data on the interaction, coupled with the development of a series of technological innovations, dolphin mortalities were reduced in this fishery to negligible levels (Hall 1994, 1998). These modifications included changes in mesh sizes in a certain section of the net, modified methods for tying the cork line, a manoeuvre termed "backdown" after dolphins were encircled (Fig. 2; Medina, 1994), using speedboats to "herd" dolphins to the rear of the net and avoiding areas containing populations of particularly prone dolphins. Once these modifications were developed, a large-scale education programme trained skippers and crews in the new techniques. The success of the work done in this fishery showed that it was possible to save by-caught dolphins without closing a major fishery.

By-catch of other species, especially juveniles

Another, near-global example of how fishing technology contributed to minimizing by-catch is the success that various types of by-catch reduction devices (BRDs) have had in decreasing the unwanted by-catch of large numbers of juvenile fish from shrimp trawls (Broadhurst 2000). Much of this work began in the Gulf of Mexico and Europe more than 30 years ago but the example below comes from work done in New South Wales (NSW), Australia.

In NSW, high-profile by-catch problems in shrimp fisheries started in the late 19th century (Dannevig, 1904; Kennelly 1995) but reached a maximum in the late 1980's with threats to close certain fisheries to stop the by-catch of juvenile fish. Firstly, an observer programme estimated large by-catches of juvenile fish in these fisheries (Liggins and Kennelly, 1996; Kennelly *et al.*, 1998). Then, after a series of field experiments using commercial vessels (Broadhurst, 2000), two gear modifications proved successful at reducing by-catch while maintaining and sometimes even enhancing catches of shrimp. Because the targeted shrimp in the estuarine fishery were smaller than the by-catch to be excluded, a modified Nordmøre-grid (Isaksen *et al.,* 1992) was found to be most effective (Fig. 3a, b). For the oceanic fishery, a composite square-mesh panel anterior to the cod end (Fig. 4a, b) was developed that allowed small fish to swim out of the cod end, while commercially important shrimp, slipper lobsters, squid and octopus were retained. The sizes of fish excluded could be selected by adjusting the mesh size in the square-mesh panel. Both these modifications are now among the BRDs that are used in NSW's shrimp fisheries.

By-catch - conspecifics, especially juveniles

The size selectivity of all fishing gears means that most methods will catch undersized, unwanted individuals of the

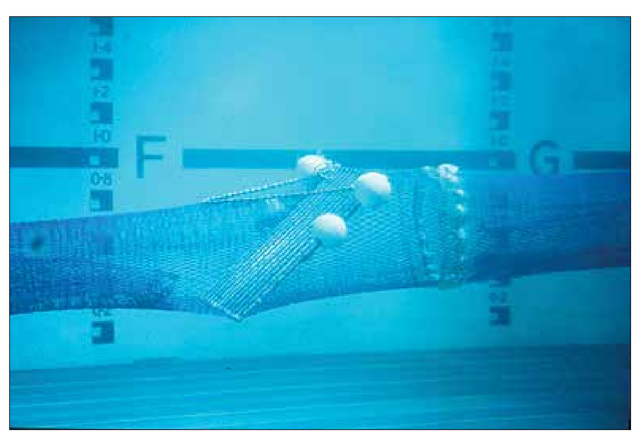


Fig. 3a. The Nordmore grid used to reduce the by-catch from NSW estuarine prawn trawls.

Fig. 3b. The difference in catches and by-catches when using the grid (right side of the tray) compared to a conventional control codend (left side of the tray).

target species, which is another form of by-catch. For trawl codends, a variety of studies have examined ways to improve selectivity. This starts with surveys to properly quantify and describe the particular selectivity issue (in terms of species and sizes), followed by experiments that test the effectiveness of alterations. Examples of this are mesh size changes in codends, changing the orientation of the meshes and/or using devices such as grids or panels. For example, codends made entirely of square-shaped meshes (which stay open better when towed) have been shown to be very efficient in increasing the selectivity for desired sizes of prawns in the Gulf St. Vincent prawn fishery (Broadhurst *et al.*, 1999).

By-catch - perceived, but not real, problems

Because of their controversial nature, by-catch issues may arise that, upon close inspection, are simply the result of inaccurate perceptions. In such cases, often an observer program will quantify and identify if any issue exists and if, in fact, any amelioration work is necessary. An example comes again from Australia when poor local publicity concerning the use of a small prawn hauling net led to significant outcry and calls for the method to be banned in the rivers where it was used. The particular concern was that it was thought that this fishing method (like trawls) caught and killed large numbers of juvenile fish. The technique involved a simple Danish seine, set in known holes in certain rivers for 4-5 minutes where school prawns were known to aggregate. The highly selective

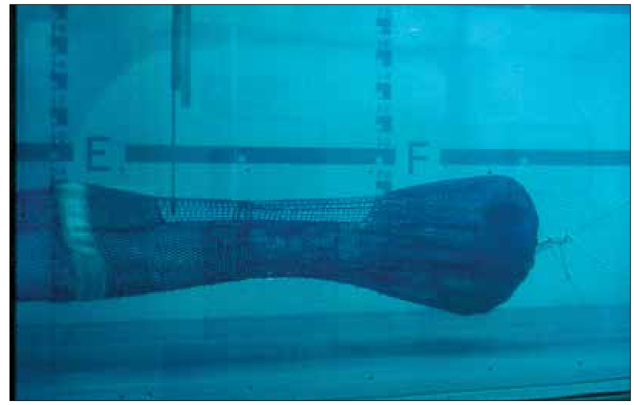


Fig. 4a. The square mesh panel used to reduce the by-catch from NSW oceanic prawn trawls.

Fig. 4b. The difference in catches and by-catches when using the panel (right side of the tray) compared to a conventional control codend (left side of the tray).

gear used and its rapid deployment and retrieval meant that actually very few fish were caught in this fishery and, those that were caught, were released in good condition within seconds. A simple observer program followed by the public display of the results led to a marked decline in controversy surrounding the method in those rivers, where the method continues to this day (for details see Gray *et al.*, 2003).

Ecosystem impacts

During recent years, public concern about the effects of fishing on the environment has broadened from relatively simple by-catch and discarding issues, to encompass a much wider context involving the impacts of fishing methods on whole ecosystems (Pitcher, 2001). One of the main issues facing the world's fisheries today concerns the impacts of fishing on all species affected - not just those that are caught, retained or discarded, but also the ecological implications of disrupting habitats and the many uncaught species affected (Kaiser *et al.,* 1998; Watling and Norse, 1998; Freese *et al.,* 1999; Lindegarth *et al.,* 2000). While the species that comprise the biodiversity of these systems (sponges, ascidians, byrozoans, polychaetes, microscopic organisms, juveniles of commercially exploited species, etc.) often have little charisma, public appeal or commercial priority, their role is seen as critical because they underpin much of the local ecosystem. Since fisheries rely on the continued normal functioning of these ecosystems, it becomes obvious that the fishing industry itself should be very concerned about these issues.

This broadening of our perceptions of fishing has led to major initiatives throughout the world to adopt an "Ecosystem Approach" to fisheries management. Issues concerning biodiversity and ecosystem-wide effects of fishing are now central to most management plans where there are policies to manage in an ecologically sustainable manner. A corollary is that there are now significant demands for more scientific information on the ecological impacts of fishing and finding solutions that will minimize them.

In recent years, there has been a substantial effort by scientists to increase our knowledge of these issues but, because of the scales and complexities involved, such studies are usually difficult, expensive and of a long duration. Nevertheless, as was the case above, substantial work has been occurring to firstly quantify and identify particular issues, species and methods of concern - through observer programs augmented with SCUBA-based and remote underwater video and photographic sampling. For example, such work identified problems associated with mobile gears like trawls disrupting natural ecosystem function via direct contact with benthic habitats. And subsequent to this characterization work has been experiments to test alternative ways of towing trawls using modified otter boards and ground gear (Fig. 5a, b).

UN FAO International guidelines on by-catch management and discarding COFi, February, 2011

In 2009, the United Nations Committee on Fisheries (COFI) decided that it was timely to take stock of what had been achieved over recent decades in resolving by-catch issues and tasked FAO to develop International guidelines on by-catch management and reduction of discards. These were approved by COFI in 2011 (FAO, 2011). The guidelines discuss by-catch management planning, data collection techniques and ways to do by-catch assessments, research and development. Critically, the guidelines summarise the various measures available to manage by-catch and reduce discards including: input and output controls; improving the design and use of fishing gear and by-catch mitigation devices; spatial and temporal measures; by-catch limits and/or quotas; economic incentives; and others. The guidelines also provide information on the consequences of by-catch and discarding issues for monitoring, control and surveillance (MCS) activities in addition to awareness, communication and capacity-building measures. Finally the guidelines provide guidance on their implementation, special considerations for Regional Fisheries Management Organizations (RFMOs) and special requirements of developing countries.

Among the emerging issues identified in the guidelines that deserve mention here are recommendations about less obvious, cryptic interactions of fishing gears with ecosystems: the unobserved mortality of species due to pre-catch losses, ghost fishing and post-release mortality (Gilman *et al*., 2013

Fig. 5a. Trawl otter boards can cause significant habitat damage and consequent effects on the ecosystem.

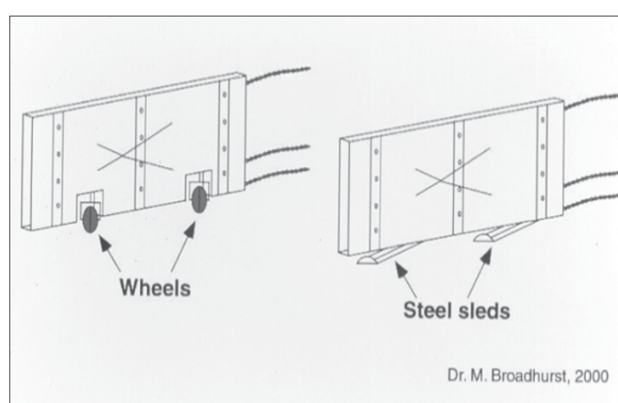


Fig. 5b. Adding wheels or sleds can greatly reduce such impacts (as well as improve fuel efficiency).

for a review). Examples include when organisms are caught (or collide with the vessel or gear) and die but are not landed onboard. This can occur when species are impacted by mobile gear but not get caught, or when the crew may intentionally release some or the entire catch prior to landing onboard (slipping). Another set of examples concerns organisms that escape from fishing gear alive but die later - such as when small fish escaping through a trawl cod end may later die due to stress or injury, or when demersal dredges damage scallop shells which leads to subsequent disease. Further, significant losses can occur through predation of the catch from the gear - such as when sharks and cetaceans feed on catches from pelagic longlines or escapees from trawl codends and BRDs, or when crabs, octopus, etc. feed on catches in traps and nets.

As was the case for work on by-catch and discard reduction, the guidelines recommended that member states identify, quantify and reduce impacts of unobserved mortality of species due to these emerging issues concerning pre-catch losses, ghost fishing and post-release mortality.

Common framework used to resolve by-catch issues

Success stories in reducing by-catch involve many different species, using a diversity of fishing methods in a variety of fisheries and locations. One might expect that this diversity of approaches, gear types, species and fisheries would make it difficult to identify any overarching summary of how one might go about solving by-catch problems in a given fishery. However, the opposite is true - there is actually a relatively simple framework that describes how by-catch problems get resolved that has proven to be quite consistent across many examples (Fig. 6).

This framework involves industry and researchers each applying their respective expertise to the particular problem. It comprises five key steps: (1) quantifying by-catch (mostly via industry-based observer programs) to identify the main species and their sizes, (2) developing alterations to existing fishing gears and practices that minimize the mortality of these species/sizes, (3) testing these alternatives in appropriately-designed field experiments onboard commercial vessels, (4) gaining acceptance of the new technology throughout the particular fishery and, most importantly, (5) communication of the solution to the interested stakeholders who first raised the issue as a concern via videos, photographs, etc.

At all stages of this framework, but most importantly at its beginning and end, it is crucial that ALL interested parties: fishers, environmental groups, government officials and

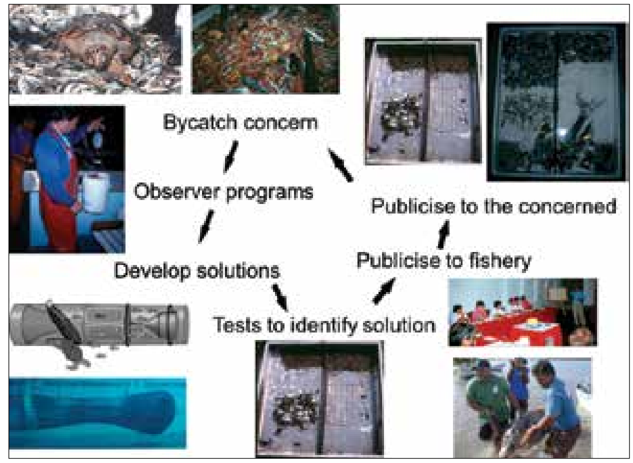


Fig. 6. The By-catch Reduction Framework.

scientists, engage positively to identify, resolve and then communicate the by-catch problem and its solution.

By-catch challenges in developing countries - Improving food security by the introduction of sustainable fishing practices

Whilst the above discussion outlines how by-catch and discarding issues have evolved and been addressed in many parts of the world, it is vital to consider how by-catch issues affect developing countries. That is, whilst developed countries followed a framework of identifying and quantifying issues, then developing what were often technological solutions, developing countries often have very different by-catch issues and generally lack the resources needed to adhere to such a model. Yet, there is a need for sustainable fishing practices to be implemented in developing countries where food security is a major, long-term problem. Using the term "vital" in this context is literal - the lack of sustainable fishing practices is impacting food security and livelihoods in many parts of the world.

Recent data from FAO indicates that approximately one-third of world fisheries production occurs in low-income, food-deficient countries - where seafood is a major source of protein. Unfortunately, however, many of the fishing methods used in such countries lack the improvements that have been implemented in developed countries which make fishing gears more selective. For example, the use of trawl nets in developing countries has, to a large extent, not incorporated the use of by-catch reduction technologies that reduce the wastage associated with the capture and discard (or, in many cases, retention) of undersize fish. This leads to the sub-optimal use of the resource, with significant consequences for the population's food security. Below, I use four case studies from Nigeria, Cameroon, Madagascar and the Gaza

Strip to describe some of the complexities associated with the implementation of sustainable fishing practices in these countries - as compared to the simpler situation in developed countries. This discussion illustrates that the critical need for food security in poor countries goes hand-in-hand with the need for sustainable fisheries management - but the implementation of the latter is extremely complex and always country-specific.

Nigeria

Currently, Nigerian shrimp trawl fisheries have extensive implementation of by-catch reduction technologies, which are mostly driven by European Union requirements for shrimp imports (a major market for the Nigerian trawl industry). Virtually all trawlers use Turtle Exclusion Devices (TEDs) and quite well-designed square mesh panel BRDs that effectively reduce the by-catch of large quantities of juvenile fish (Fig. 7a, b)

Fig. 7a. The Turtle Exclusion Devices currently used in Nigeria.

However, this finfish by-catch has a very well-established market where it is retained and on-sold at sea from trawlers to smaller-scale canoe operators who then on-sell this by-catch onto onshore buyers (mostly women) who dry and smoke the fish for on-sale at local and regional markets (Fig. 8a, b).

This multilayered sector (termed the "*buyemsellum*" sector) provides significant seafood protein to a large number of people who would otherwise simply lack it. Introducing BRDs to these fisheries thus causes a problem as it effectively reduces the by-catch available for on-selling. The current fisheries challenge in Nigeria, therefore, is to examine and resolve this *buyemsellum* issue. Work has begun via significant socio-economic surveys of the sector in an attempt to identify alternative sources of seafood for the sector, different employment options, etc.

Also noted to be important in Nigeria is the need for a general "awareness and enlightenment" campaign to educate the general population and key stakeholders about the need for sustainable fisheries management, conservation of resources

Fig. 7b. Square mesh panel BRDs currently used in Nigeria.

and how changes to fishing practices can assist in such areas. Particular groups to target in such work are the captains, crews and consumers so that they can be sufficiently informed to begin to contribute to the process.

Madagascar

Madagascar currently has a very well managed shrimp trawl fishery, with no *buyemsellum* sector and a significant uptake

Fig. 8a. The Nigerian "buyemsellum" sector at Lagos. Large canoes buy by-catch from trawlers at sea and then on-sell it to local women who dry and smoke the fish for further on-selling.

Fig. 8b. Dried and smoked fish products in the "buyemsellum" sector.

of by-catch reduction technologies, under drivers that include the shrimp import requirements of Europe and a desire by the industry to eventually achieve Marine Stewardship Council certification. Without the complexity arising from a *buyemsellum* sector, the main issues for Madagascar's trawlers are to improve the performance of the BRDs currently used so that they release more discards whilst increasing the retention of shrimp. Quite straightforward modifications (that have been developed elsewhere) to the gears currently used should be able to assist with these priorities.

Cameroon

The Cameroon trawl sector is characterised by having very little formal fisheries management, no implementation of sustainable fishing practices, and no pressing drive to improve fishing methods due to export requirements (most of the targeted shrimp is not exported to Europe). There is also a significant *buyemsellum* sector that, as in Nigeria, complicates the need to reduce by-catch with the need to provide fish for undernourished people. The current challenges for this fishery therefore concerns most aspects of fisheries management - especially a better functioning Monitoring, Control and Surveillance (MCS) system, a program to quantify and then ameliorate by-catch issues, as well as identifying ways to manage the *buyemsellum* sector. But first, Cameroon needs a general "awareness and enlightenment" campaign to educate the general population and key stakeholders about the need for sustainable fisheries management, conservation of resources and how changes to fishing practices can assist in such areas.

Gaza Strip

The Gaza Strip area of Palestine is the most densely populated part of the world with approx. 10,000 people per square kilometre. It is an occupied territory with a very small fishing ground that is policed by Israeli armed forces.

In 2005, the Palestinian Authority were quite well advanced in their knowledge and acceptance of sustainable fishing management. Further, the region attracted significant humanitarian attention and funding with several projects and initiatives underway or being developed by a variety of governments and organisations to improve fisheries management practices in the region. A key driver was the need to make Gazan wild fisheries management more sustainable as it formed a vital source of protein for the huge population.

However, in 2006, following a general election, major military actions occurred in the region, effectively sidelining the above initiatives for more urgent priorities such as basic security and emergency access to food.

Lessons learned in developing countries

In Nigeria, and Madagascar, we see that the implementation of sustainable fishing practices is well underway, with the use of BRDs and TEDs now routine. In Cameroon, however, we see a country that is just beginning its journey to modern fisheries management, compliance and research. Whilst in Gaza, we see that other, higher priority issues have thwarted attempts to introduce sustainable fishing practices. However, it is well accepted that, in each case, there is a recognised, critical need for initiatives that will reduce by-catch and discarding, improve selectivity and therefore lead to better managed fisheries.

One of the key lessons learned from these case studies is that each developing country has its own unique mix of socio-economic and/or political circumstances that either encourage or discourage the uptake of sustainable fishing practices. As a consequence, solutions to by-catch issues in the developing world will always be country- and fishery-specific and will often require quite different approaches to those taken in developed countries where resources for research, management and compliance activities are more plentiful. That is, for developing countries, it is very important to consider and wherever possible, transfer and/or adapt the knowledge gained in developed countries over the past few decades in designing and implementing sustainable fishing practices.

Conclusion

This paper has attempted to summarize a very successful period of achievement by the world's by-catch reduction specialists, gear technologists and fishers in ameliorating some of the most critical problems facing the world's fisheries. It also outlines how to continue this work and broaden the lessons learned to address other emerging fisheries issues through a relatively simple framework involving fishers and scientists applying their respective expertise. But it doesn't end there. This paper has also tried to highlight the complex and varying challenges faced by developing, protein-poor countries as they wrestle with by-catch issues and sustainable fisheries management practices - whilst trying to feed their hungry. But one can conclude from the recent history of this field that, even though solutions to such issues are currently not obvious, they do exist and will be found - as long as all stakeholders work together to find them.

Acknowledgements

I would like to thank Drs. Elayaperumal Vivekanandan, J.R. Bhatt and Rudolf Hermes for arranging my involvement in the Regional Symposium on Ecosystem Approaches to the Management and Conservation of Fisheries and Marine Biodiversity in the Asia Region, which led to this publication. I also thank the Bay of Bengal Large Marine Ecosystem Project and the UN FAO for funding my involvement. Ms. Kimberly Murray and Dr. Matt Broadhurst provided constructive comments on the draft manuscript.

References

Broadhurst, M. K. 2000. Modifications to reduce by-catch in prawn trawls: A review and framework for development. *Rev. Fish Biol. Fish.,* 10: 27-60.

Broadhurst, M. K., R. B. Larsen, S. J. Kennelly and P. E. McShane. 1999. Use and success of composite square-mesh codends in reducing by-catch and in improving size-selectivity of prawns in Gulf St Vincent, South Australia. *Fish. Bull.,* 97: 434-448.

Dannevig, H. C. 1904. Preliminary report upon the prawning industry in Port Jackson. W.A. Gullick, NSW Government Printer, 17 pp.

FAO. 2011. International Guidelines on By-catch Management and Reduction of Discards, Food and Agriculture Organisation of the United Nations, Rome 2011. ISBN 978-92-5-006952-4, 73pp.

Freese, L., P. J. Auster, J. Heifetz and B. L. Wing, 1999. Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. *Mar. Ecol. Prog. Ser.*, 182: 119-126.

Gilman, E., P. Suuronen, M. Hall and S. Kennelly. 2013. Causes and methods to estimate cryptic sources of fishing mortality. *J. Fish Biol.,* 83: 766-803.

Gray, C. A., S. J. Kennelly and K. E. Hodgson. 2003. Low levels of by-catch from estuarine prawn seining in New South Wales, Australia. *Fish. Res.*, 64: 37-54.

Hall, M. A. 1994. By-catches in purse-seine fisheries. In: T. J. Pitcher and R. Chuenpagdee (Eds.) By-catches in fisheries and their impact on the ecosystem (Fisheries Centre Research Reports, University of British Columbia, Canada, 2(1), ISSN 1198-6727, 53-58.

Hall, M. A. 1998. An ecological view of the tuna-dolphin problem: impacts and trade-offs. *Rev. Fish Biol. Fish.,* 8: 1-34.

Isaksen, B., J. W. Valdemarsen, R. B Larsen and L. Karlsen. 1992. Reduction of fish by-catch in shrimp trawl using a rigid separator grid in the aft belly. *Fish. Res.*, 13: 335-352.

Kaiser, M. J. 1998. Significance of bottom-fishing disturbance. *Conserv. Biol.,* 12: 1230-1235.

Kennelly, S. J. 1995. The issue of by-catch in Australia's demersal trawl fisheries. *Rev. Fish Biol. Fish.,* 5: 213-234.

Kennelly, S. J., G. W. Liggins and M. K. Broadhurst. 1998. Retained and discarded by-catch from oceanic prawn trawling in New South Wales, Australia. *Fish. Res.,* 36: 217-236.

Kennelly, S. J. and M. K. Broadhurst. 2002. By-catch begone: changes in the philosophy of fishing technology. *Fish & Fisheries*, 3: 340-355.

Liggins, G. W. and S. J. Kennelly. 1996. By-catch from prawn trawling in the Clarence River estuary, New South Wales, Australia. *Fish. Res.*, 25: 347-367.

Lindegarth, M., D. Valentinsson, M. Hansson and M. Ulmestrand. 2000. Disturbances by trawling changes temporal and spatial structure of benthic soft-sediment assemblages in Gullmars-fjorden, Sweden. *ICES J. Mar. Sc.,* 57: 1369-1376

Medina, H. 1994. Reducing by-catch through gear modifications: the experience of the tuna-dolphin fishery. In: T. J. Pitcher and R. Chuenpagdee (Eds.). *By-catches in fisheries and their impact on the ecosystem* (Fisheries Centre Research Reports, University of British Columbia, Canada, 2(1), ISSN 1198-6727) , pp. 60.

Nun, M. 1993. Cast Your Net Upon the Waters: Fish and Fishermen in Jesus' Time. *Biblic. Archaeol. Rev*., 19.6, 70.

Pitcher, T. J. 2001. Rebuilding ecosystems as a new goal for fisheries management: reconstructing the past to salvage the future. *Ecol. App.*, 11: 601-617.

Watling, L.and E. A. Norse. 1998. Disturbance of the sea bed by mobile fishing gear: a comparison to forest clearcutting. *Conserv. Biol.,* 12: 1180-1197.

Yellen, J. E., A. S. Brooks, E. Cornelissen, M. J. Mehlman and K. Stewart. 1995. A middle stone age worked bone industry from Katanda, Upper Semliki Valley, Zaire. *Sci.,* 268: 553-555.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-04

Application of spatial planning in establishing a system of marine protected areas for sustainable fisheries management in Vietnam*

Nguyen Chu Hoi
Vietnam National University, 334 Nguyen Trai street, Ha Noi, Vietnam.

*Correspondence e-mail: nchoi52@gmail.com

Received: 06 Dec 2013, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Marine protected area (MPA) is considered as an effective management tool to maintain the sustainability of marine waters and associated economic sectors, such as marine fisheries, tourism and related services. The national system of MPAs planning in Vietnam started in 1998 and was approved by the Government in May 2010. Key coastal and marine ecosystems like coral reefs, seagrass beds, mangroves, nursery and feeding grounds, important habitats of economically valuable species, endemic and threatened species are to be managed in the planned MPAs by 2020. In the planning process, an ecosystem-based marine spatial planning (MSP) approach has been applied. The approach has 6 key steps with associated thematic maps used as supportive documents.

By using this approach, 6 marine biodiversity zones and 9 high conservation clusters and habitats have been identified in the Vietnamese seas. The conservation potential sites for MPAs have been identified following IUCN criteria with advice from Vietnam's scientists. Based on the relative range of conservation potentials and MPA site profiles, a representative system of 16 MPAs with high conservative values has been listed and approved by the Prime Minister. It is the first national system of MPAs in Vietnam with 3 main categories: Marine Park, Species and Habitat Protected Area, and Aquatic Natural Resources Preserved Area. Some lessons learnt from the MSP approach application to establish the national system of MPAs in Vietnam are shared in the paper.

Keywords: *Marine protected area, marine spatial planning, marine biodiversity zone and cluster, ecosystem-based approach.*

Introduction

Vietnam is a maritime country with significant potential for marine fisheries development which is considered a high priority for the socio-economic development of the country (ADB, 1999; Hoi and Giao, 2005; Hoi and Quyen, 2005; Thang, 2005; Hoi *et al.*, 2007). In 2012, the fisheries sector greatly contributed to the national economy with over 6.1 billion USD of GDP value from exports (Hoi, 2012a). However, fisheries development activities and overfishing, and activities of other economic sectors and oil spills have caused pollution, loss of marine biodiversity, degradation of marine ecosystems and coastal habitat destruction (Thang, 2005; Hoi *et al.*, 2007). Therefore, beginning in 1998, the Vietnamese Government fostered the establishment and management of a national system of marine protected areas (MPAs) using an ecosystem-based marine spatial planning (MSP) approach and in 2003 prepared the strategy on protected areas management (Hoi, 2008).

**The views expressed in this paper are those of the author and do not necessarily reflect the views of any government.*

The approach has been applied through the main steps of the MPA system planning process and has proved an effective tool for the establishment and management of the national system of MPAs in Vietnam (Hoi, 2008; 2012a). The MPA system was approved by Vietnam's Prime Minister in May 2010 after over 10 years. The major reason for the delay was related to the lack of an institutional framework for MPA governance at the national level (Hoi, 2012b).

This paper synthesizes the process of the ecosystem-based MSP approach in planning the national MPAs system and some of the associated management efforts in Vietnam.

Material and methods

An ecosystem-based MSP approach has been used following key steps in the national MPA planning process:

1 Defining the marine bio-geographical position of Vietnamese seas
2 Conducting marine biodiversity zoning
3 Identifying marine-island clusters with high conservation potential
4 Screening priority sites for conservation in each cluster
5 Selecting and listing the proposed MPA sites in a national system to submit to the Government for consideration and approval.
6 Developing management plan of each MPA site in the planned MPA system

The above planning process of the national system of MPAs is presented in Fig. 1.

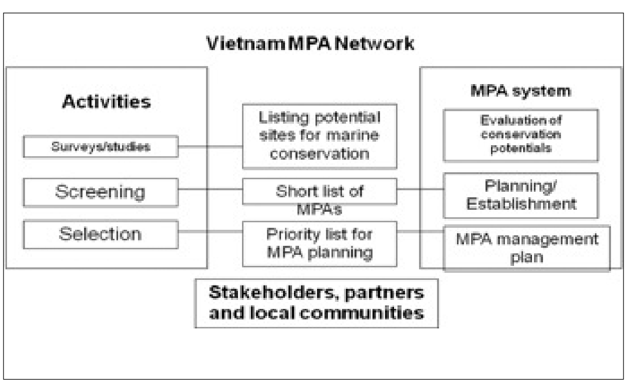


Fig. 1. Scheme of MPA screening and selection (Hoi, 2001a, b)

Following the above process, thematic maps (inputs) and maps of MPA sites (outputs) were prepared by using IUCN criteria and modified to suit Vietnam's situation (Hoi, 2008). In principle, the ecosystem-based MSP approach was used throughout the process of the MPA system planning with other supportive methods and spatial information maps.

Results

Defining the marine bio-geographical position of Vietnam's seas

To understand the bio-geographical position of Vietnam's seas, a bio-geographical classification was undertaken following Hayden *et al.,* and IUCN/CNPPA as given in Yet (2004) and Hoi (2008). Bio-geographically, the Vietnamese seas belong to the Indo-Polynesian province, marginal sea "C" in the bio-geographical classification system of Hayden *et al.*, and to zone No.13 of East Asia Sea in the classification system of IUCN/CNPPA (Yet, 2004; Fig. 2).

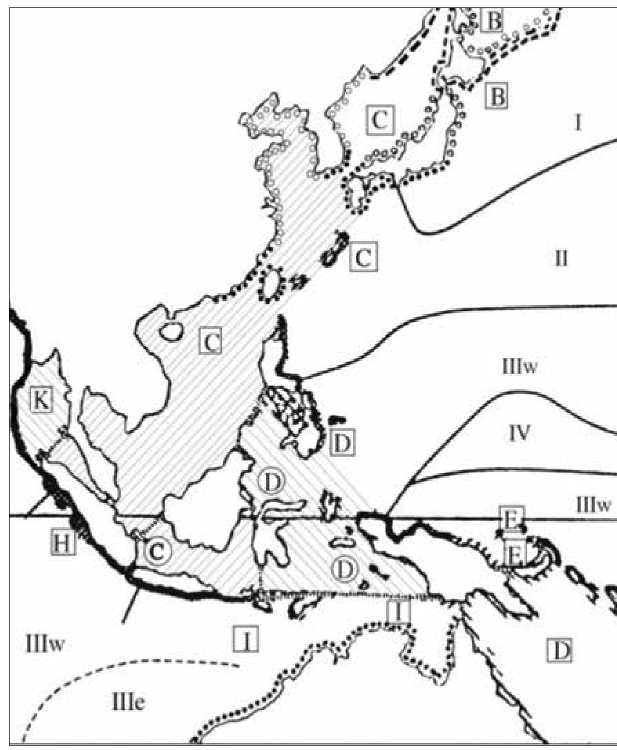


Fig. 2. Bio-geographical position of Vietnam's sea and adjacent marine waters by the classification system of Hayden *et al* (Yet, 2004) Note: A, B, C, D are coastal realms 1,2,3,4 are oceanic realms

Marine biodiversity zoning

In order to interpret conservation potentials in the MPA system planning, a scheme of marine biodiversity zoning of the Vietnam's sea has been proposed by Yet (2004). The marine biodiversity zoning was made based on the following criteria: seawater temperature, marine currents, geological conditions, sedimentation regime, species biodiversity index, and structure of fauna and flora. These criteria were collected from existing and secondary sources, augmented with additional data from SCUBA diving (ADB, 1999; Hoi *et al.*, 2000; Hoi, 2008).

Based on the above criteria, the Vietnamese sea and adjacent marine waters were initially divided into the following 6 marine biodiversity zones (Yet, 2004): Zone 1 - Western waters of Tonkin Gulf (from Mong Caito Con Co island), Zone 2 - coastal waters of Mid Central (from Con Co to Varella Cape), Zone 3 - coastal waters of Southern Central (from Varella Cape to Vung Tau), Zone 4 - coastal waters of Southern East (from Vung Tau to Ca Mau Cape), Zone 5 - coastal waters of Southern West (from Ca Mau to Ha Tien of the Thailand Gulf) and Zone 6 -offshore waters.

Identifying marine-island clusters with high conservation potentials

To facilitate the planning process, based on the islands' typology in coastal waters (An, 2008) and criteria such as marine habitat diversity, status of ecological systems, land/ sea-scapes and threats in each marine biodiversity zone, a scheme of the marine-island clusters with high conservative potential has been devised by National Assembly in 2003 (Hoi *et al*., 2000). These clusters are considered as representative spatial units for priority options in the MPA planning process.

Nine high conservation potential clusters, including marine waters with islands, have also been identified (Hoi, 2008); for example, Co To-Dao Tran cluster, Ha Long-BaiTu Long bay cluster, Cat Ba-Long Chau-Bach Long Vi cluster, Hon Me islands cluster, Hon La-Con Co cluster, SonTra-Ly Son cluster, Nha Trang-Con Dao cluster, etc.

Screening priority sites for conservation in each cluster

Based on information about marine conditions, surveyed data from SCUBA diving and socio-economic characteristics, the assessment of conservation potentials was initiated. The conservation potentials were identified following Catherine Cheung (for details, refer Hoi *et al*., 2000) considering the relative range between total biodiversity of studied ecosystems and the threats at each site (Fig. 3).

After determining the relative range, the screening of priority sites for establishing MPAs was made by Govt of Vietnam and by National Assembly in 2003 following IUCN's 10 criteria and 8 supportive criteria of local importance (Hoi, 2001a,b). These are: (1) wildness, (2) biodiversity, (3) bio-geographic importance, (4) ecological importance, (5) economic importance, (6) social importance, (7) scientific importance, (8) national and global importance, (9) feasibility, (10) area (> 10,000 hectares), (11) high conservation potential, (12) potentials for long-term development of local economies, (13) international investments, (14) local governmental support, (15) participatory readiness of local community and stakeholders, (16) capacity to obtain financial investment, (17) possibility to develop MPA good practices at national or regional level, and (18) representativeness for a marine waters/ marine biodiversity zone or a marine-island cluster.

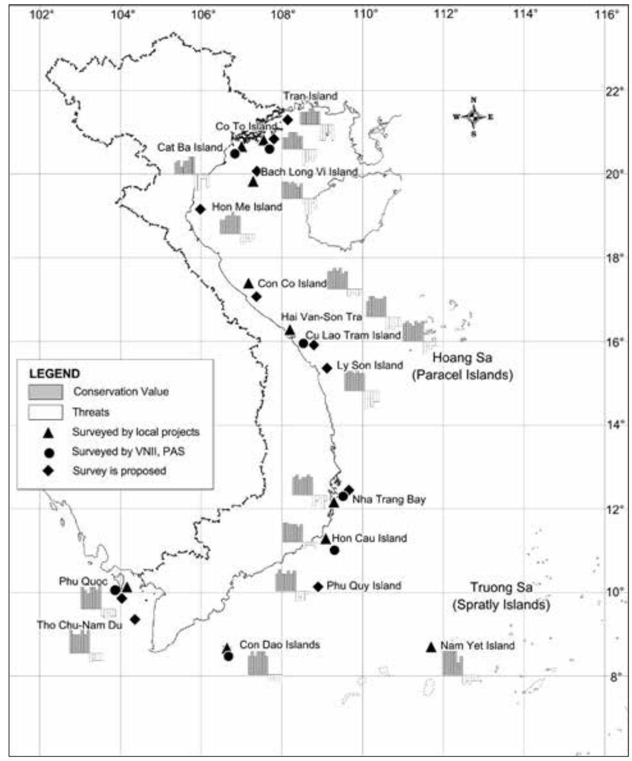


Fig. 3. Locations of biodiversity threats (Hoi *et al*., 2000; Hoi, 2008)

Selecting and listing of proposed MPA sites in national system to submit to the Government for consideration and approval

Based on the above criteria, each screened MPA site was scored for prioritizing and preparing an MPA site profile (Hoi 2001a,b; Hoi, 2008). Basically, the MPA profile is an overview of the MPA site, including key information and identification of the MPA site boundary.

The contents of such profiles include: proposed MPA name and other names, number of bio-geographical and marine biodiversity zones, geographical location, legal status, conservation status, relief and hydrological conditions, biodiversity, conservation issues, other values and cited references. After that, the selected MPA sites were categorised according to the IUCN Guidelines of 1994 and Vietnam's Law of Fisheries, 2003.

The above-mentioned steps formed the pre-planning phase and the results of each step were mapped with the support of remote sensing/GIS technique. In the next phase, which was the planning phase,a first list of a representative system of 16 MPAs with high conservative values was selected based on the relative range of conservation potentials and the MPA site profiles (Table 1 and Fig. 4). The final report of the planning results, associated with the list of MPAs and a map of proposed MPA sites was submitted to and approved by the Prime Minister in 2010. It is the first national system of MPAs in Vietnam and was grouped in 3 of 6 IUCN/WCPA categories and integrated into the Vietnam Law of Fisheries, 2003). These categories are: Marine Park, Species and Habitat Protected Area, and Aquatic Naturally Resources Preserved Area. After approval, the national system of MPAs was officially established.

Developing management plan of MPA sites in the planned MPAs system

The established MPAs in the national list were then moved into implementing the plan (post-planning phase). Once again, the MSP approach was applied to establish management zones according to function which is one of the key issues in the management plan for MPA site. The function zones were classified into different degrees of conservation and utilization: core zone, buffer zone (internal and external), ecological restoration zone and local community use zone (Fig. 5). Based on this zoning scheme and other input data, the management plan for the MPA site was prepared and approved by the authority (according to legal regulation). A MPA Management Board has been formulated to implement the management plan (Hoi, 2001a,b; Hoi, 2008).

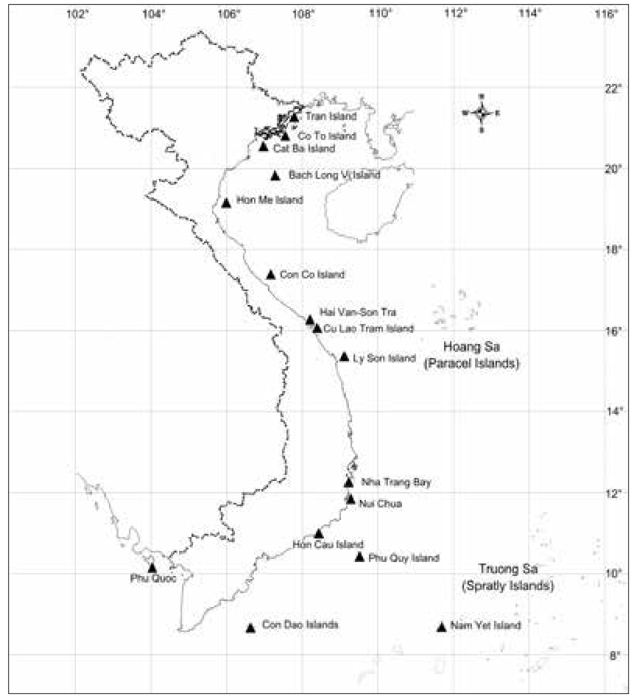


Fig 4. Planned system for MPAs in Vietnam towards 2020 (Govt. of Vietnam, 2010)

Discussion

Table 1. The list of MPAs in Vietnam planned for 2020 year (Govt of Vietnam, 2010; Hoi, 2012b) Category I: marine park; Category II: species and habitat protected area; Category III: aquatic naturally resources preserved area

No.	Name of MPAs/Province	Category (IUCN, Fisheries Law)	Total area/ sea area (ha)	Bio-geographical and marine biodiversity zone
1	Tran Island / QuangNinh	III	4200/3900	C-01
2	Co To Island / QuangNinh	II	7850/4000	C-01
3	Cat Ba/ Hai Phong	I	20,700/10,900	C-01
4	Bach Long Vi / Hai Phong	III	20,700/10,900	C-01
5	Hon Me / Thanh Hoa	III	6700/6200	C-01
6	Con Co / Quang Tri	II	2,490/2140	C-01
7	Son Cha-Hai Van/ ThuaThien-Hue	II	17,039/7626	C-02
8	Cu Lao Cham / Quang Nam	I	8265/6,716	C-02
9	Ly Son / Quang Ngai	III	7,925/7113	C-02
10	NhaTrang Gulf/ Khanh Hoa	I	15,000/12,000	C-03
11	Nam Yet Island / Khanh Hoa	II	35,000/20,000	C-06
12	Nui Chua /NinhThuan	I	29,865/7352	C-03
13	PhuQuy Island / BinhThuan	III	18,980/16,680	C-03
14	HonCau/ BinhThuan	II	12,500/12,390	C-03
15	Con Dao / Ba Ria-Vung Tau	I	29,400/23,000	C-04
16	Phu Quoc / Kien Giang	II	33,657/18,700	C-05
	Total area		270,271/169,617	

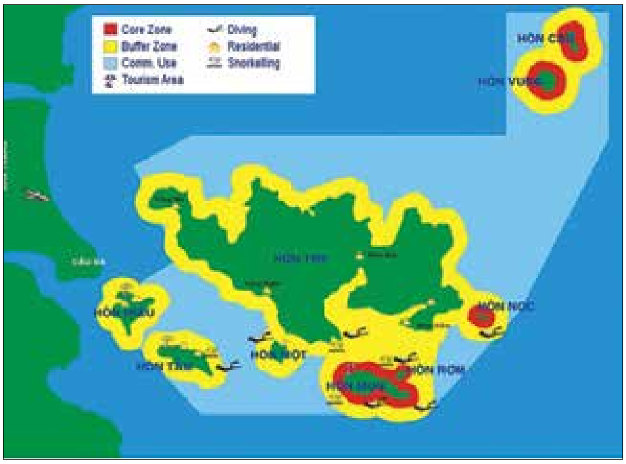


Fig 5. An example of a function zoning scheme in Nha Trang Bay MPA site Source: The report of Nha Trang bay MPA, 2009 (Hoi *et al.*, 2000)

The total area of the 16 MPAs is about 270,271 hectares, of which 169,617 ha are marine, including about 70,000 ha of coral reefs, 20,000 ha of seagrass beds, mangroves and nursery grounds of coastal and marine species. This also includes protection of 100 rare/unique species in the MPAs (Gov. of Vietnam, 2010; Hoi, 2012b).

Basically, the national system of 16 MPAs is representative of all ecological zones of Vietnam's seas. They are distributed in marine biodiversity zone 1 (6 MPA sites), zone 2 (3 MPA sites), zone 3 (4 MPA sites), zone 4 (1 MPA site), zone 5 (1 MPA site) and zone 6 (1 MPA site). However, in the clusters with high conservation potentials in Central and South Vietnam, there area fewer MPA sites than in North Vietnam (Hoi, 2012b).

Until now, only 5 of the 16 established MPAs have been effectively managed with defined function zones in which key habitats, ecosystems, ecological processes and fishery resources are conserved and restored. The remaining MPAs will be brought under management during 2014-2016. The Ministry of Agriculture and Rural Development (MARD) plays a role in the management of the MPAs, by covering main functions like development of a legal framework, technical support, promotion of international cooperation, supervision and control. MARD has appointed coastal provinces to be responsible for managing the MPA sites within their authority. The MARD is directly managing only the trans-boundary (inter-provincial) MPAs of special importance (Hoi, 2012b).

The establishment and management of the above established MPAs have contributed to sustainable fisheries development and implementation of the Millennium Development Goals (MDGs) in Vietnam (Hoi and Giao, 2005; Hoi and Quyen, 2005).The Nha Trang Bay MPA in Central Vietnam is considered to be the first site of such good practices. After 4 years, the operation of a few detrimental traditional fishing gears has been reduced, while fishery resources have been restored in the MPA site. The size and density of mussels and biomass of several other species have been increased. For people living in six fishing villages in the islands inside the Nha Trang MPA, alternative jobs have been provided (from fishing to eco-tourism), by providing glass bottom boats and diving opportunities for tourists. The livelihood of people who are living inside and around the MPA site has been improved in recent years.

These are the first lessons learnt from the application of an ecosystem-based MSP approach in MPAs system planning and management in Vietnam. The key ecosystems in the MPAs, if successfully managed, will contribute to creating restoration and spillover effects for each MPA as well as for the whole system. This process will also contribute to maintaining coastal and marine natural assets and their ecosystem service values - a natural foundation for Vietnam's blue marine economic development and therefore the livelihood of local communities (Hoi, 2012a).

The ecosystem-based MSP approach has been initially applied in all steps of the planning process of the national MPAs system in Vietnam. At present, the approach is incorporated into national policy and law, making it a strong tool for coastal and marine spatial governance and management in Vietnam. Recently, national guidelines on MSP have been developed and approved as technical assistance for MPA planning in particular and for sustainable marine fisheries and tourism development planning in general.

Most of the MPAs in Vietnam are located near-shore, which should be managed in an integrated manner for which ecosystem-based MSP is a strong supportive tool. Application of ecosystem-based MSP approach in MPA planning emphasises the need for systematic scientific data on biodiversity and a national database for each MPA site. These data should facilitate updating information in each planning cycle according to the above-mentioned criteria.

The 3 key programs have been implemented during the period 2006-2012 using about 1 billion USD, of which 40% is from government, 30% from international support, 20% from coastal provinces and 10% from local communities. The programs will be continued until 2015, including a survey of marine biodiversity and living resources in Vietnam's seas as a part of extended planning of the national system of MPAs, which is being prepared by MARD (Govt. of Vietnam, 2010; Hoi, 2012b).

Conclusion

- The ecosystem-based MSP approach has been initially applied following 6 major steps under 3 planning phases to establish a national system of national MPAs in Vietnam.
- As most of the MPAs in Vietnam are located near-shore, they are subjected to a number of impacts from outside and within the MPA. Hence, they have to be managed in an integrated manner. Ecosystem-based MSP will become a strong support tool to help integrated MPA management in Vietnam.
- Thematic maps are key products of the MPA planning process under the ecosystem-based MSP approach and provide spatial information for decision-making to establish a national MPA system.
- It is necessary to have systematic data and a database of the criteria for the MPAs planning areas.
- The ecosystem-based MSP approach is a new concept in Vietnam and for some regions in Asia. Establishing a regional MSP partnership for supporting coastal and marine sustainable fisheries management is necessary to achieve long-term development and conservation goals.
- The ecosystem-based MSP should also be considered as an approach for the implementation of the mission of the Mangroves for the Future (MFF) initiative to ensure the success of future investments into coastal ecosystems throughout the region.

References

ADB, 1999. A proposed plan for coastal and marine protected areas in Viet Nam. Final report of ADB/UNDP, Ha Noi.

An, L.D. 2008. Islands system in Vietnam's coastal waters: development potentials. Publishing House of Natural Science, Ha Noi.

Govt of Vietnam. 2010. Decision No. 742/QĐ-TTg dated 26 May 2010 on approval of Vietnam MPAs system planning towards 2020. Ha Noi.

Hoi, N. C. 2001a. Status and Mechanism of Marine Protected Areas Management in Viet Nam. *J. Mar. Sci. Tech.*, Tom 1, No.1/2001, Ha Noi.

Hoi, N. C. 2001b. Initiative Results of Screening Marine Protected Areas in Viet Nam. *J. Mar. Sci. Tech.*, Tom 1, No. 4/2001, Ha Noi.

Hoi, N. C. (Chief Editor). 2007. Fisheries policy of Viet Nam.Publishing House of Agriculture, Ha Noi.

Hoi, N. C. (Chief Editor). 2008. Planning of MPAs system in Viet Nam towards year 2020. Final Report preserving in MARD, Ha Noi.

Hoi, N. C. 2012a. Blue marine economy and MPAs system in Viet Nam. *MoP J. Sci., Technol. and Environ.*, 26, Ha Noi.

Hoi, N. C. 2012b. The status and management of the marine protected areas in Viet Nam. *J. Sci.*, Vietnam National University, Natural Science and Technology 28, No.4S (2012) Ha Noi, 77-86.

Hoi, N. C and H. N.Giao. 2005. National Marine Policy: A Vietnam Case Study. The report of the 2nd Global Conference on Oceans, Coasts and Islands. Lisbon, Portugal.

Hoi, N. C., N. D. Hoe and H. M.Tuong, 2004. Chapter III: Coasts and Seas of Viet Nam. In "*Viet Nam: the Life and Environment*". Publishing House The Gioi, Ha Noi.

Hoi, N.C. and C. L. Quyen, 2005. Fisheries sector report for identification of projects on improving coastal poor people livelihood, The draft of FAO. Ha Noi.

Hoi, N. C., D. N. Thanh and N. H.Yet, 2000. The scientific baselines of MPA system planning in Viet Nam.Published by IUCN Vietnam, Ha Noi.

Thang, N.V. 2005. Some policies and challenges for sustainable development of fisheries sector in *Viet Nam. J. Fish.,* 12 (2005), Ha Noi.

Yet, N. H. 2004. About marine biodiversity zoning in Viet Nam.The thematic report of the Project on planning of MPAs system in Viet Nam towards year 2020 which preserving in MARD, Ha Noi.

Available online at: www.mbai.org.in doi: 10.6024/jmbai.2014.56.1.01750s-05

Shark ban in its infancy: Successes, challenges and lessons learned

Khadeeja Ali* and Hussain Sinan[1]
Marine Research Centre, Ministry of Fisheries and Agriculture, H. White waves, Malé, Republic of Maldives.
[1]Fisheries Management Agency, Ministry of Fisheries and Agriculture, Malé, Republic of Maldives

*Correspondence e-mail: kali@mrc.gov.mv

Received: 09 Dec 2013, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract
The slow growing nature and low reproductive output of sharks make them extremely vulnerable to over fishing. The shark fisheries of the Maldives expanded in the early 1970s. When management measures failed to enhance the declining shark fisheries, with inadequate information on shark stocks, in the face of uncertainty, precautionary approach was adopted and a total ban on all types of shark fishing was imposed. Nevertheless, a fishing ban was not able to halt the import and trade of shark souvenirs. From a socio-economic perspective, insufficient work was done to minimize the impact of the ban on former shark fisherfolk. Lack of broad stakeholder consultations prior to the ban and without providing a phase-out period for the shark fishery and declaring a total ban were some of the major factors contributing to the issues. Inability to impose an explicit ban on the trade, import and export of shark products is another major factor hindering the conservation purpose of the shark ban.

Keywords: *Shark fisheries; over-exploitation; Maldives; implementation issues.*

Introduction

Fishing has been an important activity in the Maldives for centuries and a major source of employment and food. The country has enjoyed a productive fisheries sector for over a thousand years (Anderson and Hafiz, 1996). The principal catch was tuna, and even today, tuna fisheries dominate the fisheries sector. Fisheries used to be the main pillar of the economy, until the tourism industry, with its outstanding growth, replaced fisheries as the main contributor to the country's GDP (Adam, 2006).

In the 1970s, with major developments to the fisheries sector, shark fisheries emerged as one of the most prominent small-scale fisheries. The vast majority of the total catch, an outstanding 90%, is contributed by the tuna fisheries, and all other small-scale fisheries, including the shark fishery contribute 10% to the total catch (Sinan *et al.*, 2011). As shark fisheries had no significant influence on the country's economy, little attention was given to the fishery (Sinan *et al.*, 2011). However in recent decades, the rise in international concern over the increase in exploitation of sharks had increased the awareness on the sustainability of shark populations. Sharks are vulnerable to over-exploitation due to their biological characteristics such as slow growth, attainment of first maturity at a late stage in life, production of few offspring and long life span (Musick *et al.*, 2000). The high revenue generated by country's dive tourism industry through shark watching (Anderson and Ahmed, 1993) and the growing demands from environmentalists, gave rise to concerns over the status of shark stocks of the Maldives

(McAllister and Partners, 2002) and thus gradually brought the shark fishery into the focus of fisheries management in the Maldives. Various management measures were adopted, which culminated in a complete ban on all types of shark fishing in 2010.

This paper aims to provide a historical perspective of the shark fisheries of the Maldives as well as provide a review of the existing issues that are affecting the ability of the Ministry of Fisheries and Agriculture (MoFA) to effectively implement the shark fishing ban. The information presented in this paper was from existing literature on shark fisheries and anecdotal interviews with former shark fishermen including reef fishermen and also from consultations with the tourism sector.

History of shark fishing in the Maldives

A small-scale, but highly targeted fishery for sharks was practiced in the Maldives for hundreds of years (Anderson and Ahmed, 1993). Sharks were first exploited for their liver. In those days, shark liver oil was in huge demand, as it was used to paint the wooden boats to prevent decaying of the wood (Anderson and Ahmed, 1993). This traditional fishery primarily targeted large sharks such as tiger sharks (*Galeocerdo cuvier*) and sometimes the bluntnose six gill sharks (*Hexanchus griseus*). This ancient pattern of shark fishing died out in the 1970s with widespread motorization of boats and with introduction of new fishing methods such as long lining and gill netting. By the early 1980s three types of shark fisheries were established; the deep water benthic shark fishery, oceanic shark fishery and the reef shark fishery (Sinan *et al.*, 2011).

The deep water benthic shark fishery

The expansion of deep water benthic shark fishery took place in the early 1980s. The fishery was developed to obtain shark liver oil rich in squalene and the primary target were the gulper sharks (*Centrophorus* spp., using multihook handlines (Anderson and Ahmed, 1993).

Reef shark fishery

With the adoption of new fishing methods, the previously unexploited reef shark resources became targeted and thus began the reef shark fishery in earnest. Gillnets, longline and handlines were used to target reef sharks. Silvertips (*Carcharhinus albimarginatus*), grey reefs (*Carcharhinus amblyrhynchos*), black tip reef shark (*Carcharhinus melanopterus*) and white tip reef sharks (*Triaenodon obesus*) dominated the catch. Reef sharks were targeted for their fins and meat which were sundried and exported to the Southeast Asian markets (Anderson and Ahmed, 1993). Since species-specific catch data was never obtained, it was difficult to estimate the amount of catch contributed by the reef shark fishery (Sinan *et al.*, 2011).

Oceanic shark fishery

With the development of more efficient fishing methods, oceanic sharks were targeted using longlines and handlines. Silky sharks (*Carcharhinus falciformis*) and silvertips (*C. albimarginatus*) dominated the catch in some parts of the Maldives (Anderson and Ahmed, 1993). Likewise the reef sharks, oceanic sharks were also targeted for their meat and fins. Massive oceanic sharks' jaws were also taken and dried as they made an attractive souvenir for the tourists (Anderson and Ahmed, 1993).

Conflicts with other stakeholders

Reef shark fishery and tourism

Tourism is the chief contributor to the country's GDP. A survey in 1990 showed that the majority of tourists (70%) reported that the marine environment was their main reason for enjoyment and 38% took part in snorkeling while 18% reported their main purpose of visit was for diving (Sinan *et al.*, 2011). There are over 98 tourist resorts most of which have a dive centre and with the number of liveaboards on rise, there is increasing focus on dive tourism. For many tourists, the most significant part of diving is to experience the marine mega fauna; hence there is growing interest among divers in watching larger fish such as sharks and manta rays. Grey reef sharks (*C. amblyrhynchos*), white tip reef sharks (*T. obesus*), and scalloped hammerheads (*Sphyrna lewini*) are among some of the most watched sharks of the Maldives (Anderson and Ahmed, 1993).

Anderson and Ahmed (1993) estimated the total annual revenue from shark watch dives to be 2.3 million US dollars. A single grey reef shark (*C. amblyrhynchos*) living in its habitat generated 3300 US dollars per year as revenue while the same shark killed for its fins and meat generated only about 32 US Dollars. Hence, a reef shark alive can be assumed to be 100 times more valuable than the same shark killed in need of its fin and meat. While the total annual revenue from shark watching was estimated to be 2.3 million US dollars, the total revenue from the reef and oceanic shark fins exports combined was estimated to be 1.7 million US dollars. Anderson and Ahmed (1993) implied that if the annual revenue from the reef shark fishery was assumed to be 0.5 million US dollars, then reef shark fishing generated only a quarter of the earnings generated by reef shark watching per year.

With recognition of the importance of diving to tourism, 15 important dive sites, which included prominent shark watching sites, were declared as marine protected areas in June of 1995. In the same year, the whale shark (*Rhinocodon typus*) being quite a remarkable sight to see, was also declared a protected species. Even with increased awareness on the importance of reef sharks to the tourism industry, reef shark fishing continued in the central atolls which were important tourism zones. In 1998, to conserve the reef sharks for the tourism sector, a 10 year moratorium on all types of shark fishing was declared in seven atolls which are important tourism zones (Sinan *et al.*, 2011).

Oceanic shark and tuna fisheries

Tuna fisheries dominate the fisheries sector and are the second largest contributor to the economy. Pole and line tuna fishermen believed that sharks, particularly the association of silky sharks (*C. falciformis*) with the tuna schools, increased the tuna catch. Many tuna fishermen complained that taking sharks associated with tuna schools reduced the availability of tuna particularly from the fish aggregating devices deployed around the country. Due to the significance of tuna fisheries to the economy, several management measures on shark fisheries were taken to reduce this particular conflict. Shark fishing was banned during daytime in tuna fishing grounds, as well as around fish aggregating devices. Shark fishing around two seamounts was also banned as these are important tuna fishing grounds (Sinan *et al.*, 2011).

Status of shark fisheries

In the Maldives, as the tuna fisheries dominated the fisheries sector, little importance was given to collecting catch data on shark fisheries. As a result, no specific statistical information on shark catch was reported. As the shark fishery was a multi-species fishery and due to the lack of statistical information on sharks, assessments of shark stocks were never carried out. However, as the shark fisheries were completely export oriented, catch data was estimated from export data.

Deep water benthic shark fishery

Exploitation of deep water gulper sharks began in the early 1980s (Anderson and Ahmed, 1993; Sinan *et al.*, 2011). Gulper shark catches were highest in the early years of the fishery and reached a peak between 1982 and 1984 (Fig. 1). The sharp rise in the gulper shark catches was due to high price fetched from squalene rich liver oil of gulper sharks, which attracted many fishermen to the fishery (Anderson and Waheed, 1999). After the fishery peaked in between 1982 and1984, the gulper shark catches started showing significant declines (Sinan *et al.*, 2011).

The sudden decline could be because gulper sharks live in deep, cold waters with limited food supply, which makes them have slower growth and reproduction rates than most shallow water sharks. This increases their vulnerability to overfishing (Anderson and Ahmed, 1993). Further the usual depth ranges inhabited by the gulper sharks of the Maldives are very narrow, limited to the deep outer slopes of atolls. With this small habitat, the gulper sharks stocks would be relatively small. Thus, gulper sharks stocks were not able to withstand the increased exploitation rates (Anderson and Ahmed, 1993). From the anecdotal information from fishermen it was deduced that gulper shark catch had reduced to 50% within a few years of starting of the fishery. Fishermen usually fished for gulper sharks at 200-300 m, but with declining catch, they had to fish deeper extending to depths of 600-800 m or even more (Anderson and Ahmed, 1993). By the 1990s, the gulper shark fishery had entirely collapsed, and only after 15 years, gulper shark exports have been noticed again, though at minor levels (MRC, 2009).

Reef and oceanic shark fisheries

Catch information for the oceanic and reef shark fisheries were estimated using the export data of shark fins. As sharks were not used for local consumption, it was assumed that the whole shark catch was exported (Anderson and Ahmed, 1993; Sinan *et al.*, 2011)

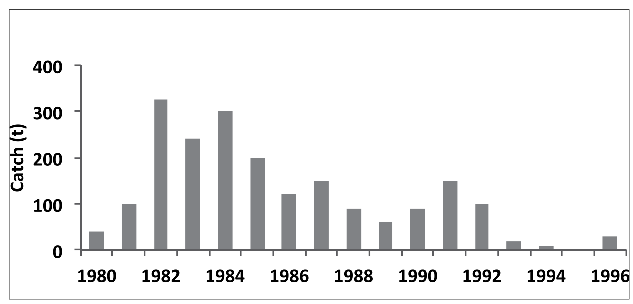


Fig. 1. Estimated annual catches of deep water gulper sharks (Anderson and Waheed, 1999)

Shark fin exports came from both oceanic and reef shark fishery. As a result, the catch estimated from export data were for the two fisheries combined. Prior to the late 1970s shark catch exports were approximately about 500 t. By the late 1970s there was steep increase in shark exploitation (Fig. 2). Widespread motorization of boats, new fishing techniques and major developments on trade were the factors that escalated the exploitation of sharks (Anderson and Ahmed, 1993; Sinan *et al.*, 2011).

From 1975, shark catches showed a significant increase, and by 1980 the shark catch reached 1900t. During 1977-2008, the average annual shark catch was about 1400t, with 1000-2000t variations in between the years (Fig. 2). The drop and rise in shark catch could be due to the demand for the shark products in the export market (MRC, 2009).

Due to the reduction in gillnet fleet for reef sharks and the increase in longline fleet for oceanic sharks, after the late

1990s, most of the shark catch was believed to be contributed by the oceanic shark fishery (Anderson and Waheed, 1999). By the early 1980s, reef shark stocks of the northern atolls of the Maldives were reported to be over-fished. Within a few years of starting of the fishery (late 1970s-early 1980s) the reef shark catch had declined significantly (Anderson *et al*., 2011). Kulhudhu'ffushi, a well-known shark fishing island in the northern Maldives, resorted to offshore shark fishing, after experiencing significant declines in their reef shark catches. And till then, Kulhudhu'ffushi fishermen were exclusively offshore shark fishermen. It was only recently and only during bad weather when offshore shark fishing was difficult, the Kulhudhu'ffushi fishermen started reef shark fishing. Reef shark catch was reported to be poor, in spite of those years of not exploiting the reef shark resources. Divers too reported very few sightings of reef sharks in northern atolls. Therefore, it can be deduced that the reef shark resources of northern atolls have not recovered (Anderson *et al*., 2011). By the early 1990s, the tourism sector was deeply concerned over the diminishing shark sightings, while a review done by MacAllister and Partners (2002) suggested that reef shark stocks of the Maldives were over-exploited.

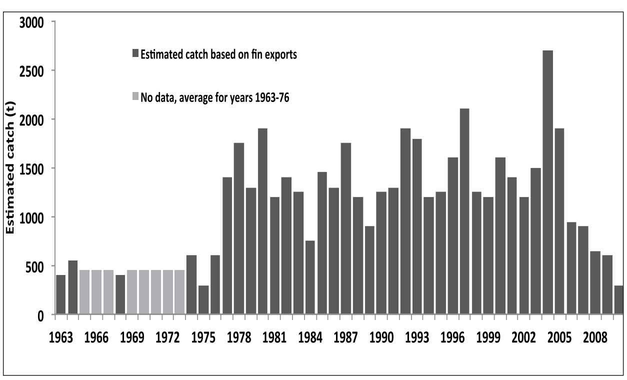


Fig 2. Estimated annual catches of reef and oceanic sharks (Sinan *et al*., 2011)

After facing declining catches of reef sharks and near shore pelagic sharks within the early years of the shark fishery, the Kulhudhu'ffushi fishermen started to target oceanic sharks. The oceanic shark catch too started showing declines after 2000. The fishermen reported low levels of large silky sharks (*C. falciformis*) in their catch which forced them to venture further out for a reasonable catch (Anderson *et al*., 2011).

A peak of 2700 t of shark catch was observed in 2004 (Fig. 2). After this, the catch declined considerably and by 2008, the annual shark catch was only about 700 t which approximately equaled to the level of shark fisheries in pre-commercial period. The significant decline after 2004 could be attributed to over-exploitation of shark stocks or could also be due to the reduction in fishing effort (Sinan *et al*., 2011). The number of fishing vessels engaged in shark fishing from 1992- 2008 is shown in Table 1. For all the islands, the number of fishing boats has decreased over the years. In addition to the declining catch levels, low economic returns and other socio-economic reasons could have driven fishermen away from the fishery (Anderson *et al*., 2011; Sinan *et al*., 2011).

Anderson *et al*. (2011) reported that the number of younger men entering the shark longline fishery in Kulhudhu'ffushi was declining, and the shark fishing group was ageing. These issues were not confined to the shark fishery alone, but were affecting the entire fishing industry of the country (Anderson *et al*., 2011).

Table 1 Shark fishing fleet during 1992-2008 from the major shark fishing islands (Sinan *et al*., 2011)

Atoll/Island	1992	1998	2003	2008
Hdh. Kulhudhuffushi	10	80	45	10
R.Madduvari	41	22	10	2
R.Meedhoo	46	12	12	7
Adh.Dhan'gethi	12	5	7	6
AA.Himendhoo	20	12	9	9
F.Feeali	24	0	0	1
Th.Vilufushi	8	6	1	3
Total	161	137	84	38

Shark fisheries management

Since the emergence of shark fisheries, the shark fishermen were always in conflict with other stakeholders. Therefore, most of the management measures taken on shark fisheries were to address these conflicts. The measures taken to minimize the conflict with the tourism sector failed greatly as they did not resolve the issue of declining reef shark resources.

After the ten years moratorium declared in 1998 ended, the reef sharks stocks did not show substantial increase in abundance, which prompted new management measures. With huge lobbying from the tourism industry for a complete ban on shark fishing, in 2009 and with research suggesting decline in status of shark fisheries, MoFA took the decision to ban all types of shark fishing within 12 nautical miles from the outer atoll rims on all atolls of the Maldives (MoFA Iu'laan: FA-D/29/2009/20). Due to lack of monitoring, and difficulty in validating whether the shark fin exports were from oceanic sharks, it was decided that the best solution would be to impose a total ban. Moreover, as shark fishing was seen to be detrimental to the pole and line tuna fishery and the tourism industry, on March 2010, a year after the reef shark ban, the MoFA announced an indefinite total ban on all types of shark fishing in the whole Maldivian waters (MoFA Iu'laan: 30-D2/29/2010 /32).

Measures to minimize the impact of the ban

The undesirable impact of the ban on the fishermen had been highly debated even at cabinet level. Few months after the complete ban was announced, the cabinet decided to determine ways to facilitate other alternative income generating options for shark fishermen. Based on the perception that shark fishing was done only at a certain times of the year and the fishermen already had other income generating ways identified for periods of low fishing, instead of identifying and facilitating alternative livelihood options, a lot of attention was given to provide fishermen with compensations in exchange of their fishing gear. Therefore, a few months after the ban, MoFA initiated gear-buy-back schemes where fishing gear was bought at depreciated values. These values were determined based on the price of the fishing gear at the market at that time. From about 200 fishermen who applied for the scheme, 70% had received compensations and for 20% of the fishermen compensations were deposited to the respective island councils. To date only a few islands have not received compensations (Sinan and Ali, 2012).

In addition to the gear-buy-back scheme, to facilitate alternative income generating ways for the shark fishermen, MoFA opened a Shark Trust Fund on 2nd of June 2010. The tourism industry, the main beneficiary of the total shark ban was asked to contribute for the fund. In spite of more than 98 resorts located in the Maldives, only 2 resorts contributed to the fund (Sinan *et al.*, 2011.)

Further, to assist the shark fishermen in establishing other income generating activities, the government decided to give priority to former shark fishermen in soft-loan schemes. At the time of the total shark ban in 2010, the Ministry of Economic Development implemented a MRF 5 million scheme, to provide compensations in exchange of shark products from the primary traders. (Sinan *et al.*, 2011).

Issues affecting the implementation of the ban

Governance issues

Lack of trade - import and export ban on shark products

After the complete fishing ban, the most controversial issue was the lack of a trade ban as well as an import and export ban on shark products. Despite declaring sharks as a protected species, sale of shark jaws was still ongoing in most souvenir shops. The Fisheries Law of the Maldives (Law no. 5/87) provides for the conservation of living marine resources for a special purpose, but does not have provisions against trading of any marine species or protected marine species. Hence, albeit having announced a total ban on exploitations of sharks, this still did not ban the import, export and trade of shark products.

Following the announcement of the total shark ban by MoFA in 2010, in 2011 the Ministry of Housing and Environment (MoHE) announced a ban on capture, keeping, trade and harming of sharks under the Environment Protection and Preservation Act (EPPA). This manifested major conflicting issues between the laws and mandates of the ministries. Although biodiversity protection is well provisioned under the Environment Law, the responsibility of regulating the trade of any commodity and hence imposing trade bans on commodities comes under the mandate of the Ministry of Economic Development (MoED) under the Maldives Export and Import Law (Law no.37/79). Conflicts between the mandates of Ministries and the respective governing laws have greatly hampered the goals of management decisions and this was very evident in the case of shark fishery ban. Hence, in spite of having bought back MRF 5 million worth shark products from primary traders, even after four years of shark fishery ban, trade of shark products was still taking place. When species are protected for conservation purposes, it is essential that their trade be banned as well. In New Zealand under their fisheries management system, the laws that provide for bans have key statutory tools that ensure the conservation of protected species. The Wildlife Act of New Zealand provides ban of taking, trading and possessing all or parts of the marine protected species (NPOA NZ, 2007). Further, the Maldives is now a member of Convention on International Trade in Endangered Species of wild fauna and flora (CITES) and four species of sharks found in the Maldives, namely, the oceanic white tip (*Carcharhinus longimanus*), scalloped hammerhead (*Sphyrna lewini*), smooth hammerhead (*S. zygaena*) and great hammerhead (*S. mokarran*) are in Appendix 2 of CITES. For specimens in Appendix 2, an export permit is required by the relevant management authority and the permit is issued on the basis that the specimen was obtained legally (CITES, 2008). As the Maldives now has a fishing ban on sharks and is a member of CITES, there is an obligation to ban the export of shark products as well.

Lack of monitoring

Illegal shark fishing activities have been brought to MoFA's concern, but reported events are few. Complaints from the tourism industry on illegal shark fishing activities have been brought to the attention of MoFA, but so far most incidents have not been officially reported. Divers claim that illegal fishing for sharks was happening on a large scale, but such claims are difficult to validate, as a large number of gear owners have sold their gear to the government under the gear buy-back scheme. Sharks caught and taken on board as dead are to be reported to a fisheries observer under the tuna longline fishery regulation. As the country does not have a fisheries observer programme, the fate of sharks caught dead as by-catch cannot be validated.

Socio-economic and ecological issues

No alternative livelihood options identified for former shark fishermen

When the 10 year moratorium on shark fishing in various tourism zones ended in 2008, divers were still unsatisfied with the number of reef sharks. Even with the moratorium in place, the divers complained about the declining number of reef sharks. There was huge pressure from the tourism sector to completely ban reef shark fishing. This called for an immediate management decision, where reef shark fishing got banned very abruptly. Hence, when the reef shark ban came into effect, neither were formal stakeholder consultations held, nor were alternative livelihood options identified for shark fishermen. And with the lack of monitoring of the ban and lack of awareness on conservation of sharks, many fishermen continued shark fishing even after the declaration of reef shark ban in 2009 (Sattar, 2010).

After the total shark ban, except for the gear buy-back scheme, little work was done to secure the livelihoods of fishermen. Most of the fishermen pursued other types of fishing. Most shark fishermen reported that shark fishing was easy and generated more income, while other types of fisheries such as reef fisheries, required more effort for the same level of income. In some islands, shark fishing was done seasonally, during calm weather periods, while in other islands, the fishermen were full-time shark fishermen, carrying out shark fishing throughout the year. From the interviews with former shark fishermen, it was found that in a few islands, shark fishing was their main livelihood. In the islands, there are very little employment opportunities, and as most islanders are engaged in some type of fishing activity, it was not easy for the shark fishermen to give up their livelihoods. Many shark fishermen after the ban went to reef fishing right away. For many, reef fishing generated lower economic returns compared to shark fishing. Being exclusively involved in fishing for years, most are reluctant to take up any other activity than fishing. Many oceanic shark fishermen's concerns were that the oceanic sharks such as the silky shark (*C. falciformis*), which should not have had any conflict with the tourism sector, still got banned, forcing them to give up their livelihood. Some former fishermen claimed that at the time of the ban, the government promised some sort of commission for the fishing islands from the tourism sector but no such thing manifested after the ban. A lot of fishermen felt they were neglected after the ban, and the compensation provided by the government for the gears they owned, were insufficient to start a meaningful alternative income generating activity. The majority of the fishermen interviewed reported they were not aware of soft-loan scheme by government where the shark fishermen were given priority.

Complaints of increasing shark nuisance by reef fishermen

During interviews with former shark fishermen who have now taken up reef fishing, complaints were received on increasing interactions with sharks. Fishermen complained on depredations caused by sharks. Many complained that sharks were becoming a nuisance to them, as along with their catch, hooks and weights were lost. Similar complaints were received during interviews with reef fishermen. Contrary to fishermen's sayings, divers still report that sharks have not shown a significant increase in abundance. Further, as sharks in general are slow growing with low reproductive output, it is hard to perceive that sharks could show such an increase in abundance within four years into the ban. Fishermen's complaints are based on the increasing nuisance of sharks, hence this may not necessarily imply an increase in abundance of sharks. Nevertheless, such complaints cannot be neglected and needs validation, hence further studies need to be carried out to determine the cause of increasing interactions with sharks in the reef fishery

Conclusion

The shark fisheries were a minor fishery and had only a minor impact on the economy of the country. The country's economy is heavily dependent on the tourism sector, and reef sharks were seen to be an invaluable asset to the dive tourism industry. Although stock assessments on sharks were lacking, the declining status of shark fisheries and concerns over the decreased shark sightings, prompted the government to take the precautionary approach to conserve the shark stocks and announce a total ban on shark fisheries.

One of the greatest issues undermining the effective implementation of the shark ban, was due to the fact that all necessary institutional arrangements were not in place when the fishing ban was declared. A fishing ban proved to be insufficient in preventing the trade of shark products. Lack of ban on import and trade of shark products could also be taken as incentives for illegal shark fishing, hence, when a species is given full protection for an indefinite period, it is essential that its trade, export and import be banned as well. Another major issue was the lack of formal stakeholder consultations prior to the ban. When such a complete ban is imposed, it is imperative that stakeholders are well consulted, to provide negotiations on conflicting matters and identify and agree upon strategies prior to implementation, in order to to protect the rights of all parties involved. If this had been carried out, the Shark Trust Fund would have seen more ownership from all stakeholders. Prior to declaring the complete ban, to secure the livelihoods of fishermen, a formal analysis of alternative livelihood options should have been done or a longer phase out period should have been given for the fishery which would have provided ample time for the fishermen to move to another livelihood.

For such total indefinite ban to be successful, commitments are needed from all stakeholders including the government. Without regular monitoring of the ban, the shark ban cannot be a success. Monitoring work like the observer programme is very essential, in terms of verifying the shark by-catch. Furthermore, this would also meet international obligations.

Acknowledgements

A lot of anecdotal information presented in this paper was gathered during interviews with former shark fishermen from prominent shark fishing islands during a socio-economic survey funded by the Bay of Bengal Large Marine Ecosystem Project (BoBLME). Another source of anecdotal information was gathered from interviews with reef fishermen during a perspective survey on reef fishery conducted by the Darwin Reef Fish Project (DRFP). Thanks to both BoBLME Project and DRFP for funding these surveys which provided all the anecdotal information presented in this paper. We would also like to express our sincere gratitude to Dr. M.Shiham Adam for valuable feedback on this paper.

References

Adam, M. 2006. Country review: Maldives. In: C. De Young, (Eds). Review of the state of world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper. Rome: Food and Agriculture Organization of United Nations, 383-391.

Anderson, R. C. and H. Ahmed. 1993. The Shark Fisheries of the Maldives, Male': Ministry of Fisheries and Agriculture and FAO Rome. pp.73

Anderson, R. C. and A. Hafiz. 1996. Status of tuna research and data collection in the Maldives. In: A. A. Anganuzzi, K. A. Stobberup and N. J. Webbs (Eds.) *Proc. 6th Session of Expert Consultation on Indian Ocean Tunas, Sri Lanka,* 25-29 September 1995, *IPTP*. Colombo: s.n., 373.

Anderson, R. C. and Z. Waheed. 1999. Management of shark fisheries in the Maldives. In: R. Shotton, (Eds). Case Studies in the Management of Elasmobranch Fisheries. FAO Fisheries Technical Paper 378 (parts 1 & 2). Male': FAO Rome , pp. 367-401.

Anderson, R.C., M. S. Adam and M. R. Saleem. 2011. Shark longline fishery in the nothern Maldives, Maldives: Paper presented at the Seventh Session of IOTC Working Party on Ecosystem and Bycatch, p.24

CITES. 2008. How CITES works. [Online] Available at: http://www.cites.org/eng/disc/how.php [Accessed 01 August 2013].

McAllister, E. and Partners. 2002. Kulhudhuffishi Shark Fisheries Review, Male': Regioanal Developmenet Project Northern Development Region, Ministry of Planning and National Development and Asian Development Bank, pp.32

MRC. 2009. Status of Shark Fishery 2, Male': Marine Research Centre, Ministry of Fisheries and Agriculture, pp.31

Musick , J. A., G. Burgess, G. Camhi and S. Fordham. 2000. Management of Sharks and Their Relatives (Elasmobranchii). *Fisheries*, 25(3): 9-13.

NPOA NZ. 2007. New Zealand National Plan of Action for Conservation and Management of Sharks, New Zealand: New Zealand Government, pp.92

Sattar, S. A. 2010. Willingness to pay survery on shark watching, management and conservation in Maldives, Male': Marine Research Centre, pp.24

Sinan., H. and K. Ali. 2012. Measures taken after the shark fishing ban, GA.Villin'gili: Paper presented at National Forum on Fisheries on the Thirty Second Fishermen's Day of Maldives,12-14 December, pp.9

Sinan, H., M. Adam and R. C. Anderson. 2011. Status of Shark Fisheries in the Maldives, Male': Paper presented at Seventh Working Party on Ecosystems and Bycatch, Maldives 24-27 October 2011, pp.9

Available online at: www.mbai.org.in doi: 10.6024/jmbai.2014.56.1.01750s-06

Establishment and management of fisheries *refugia* in Phu Quoc Marine Protected Area, Vietnam

Nguyen Van Long* and Vo Si Tuan
Institute of Oceanography, VAST, 01-Cau Da, Nha Trang, Vietnam.

*Correspondence e-mail: longhdh@gmail.com

Received: 16 Dec 2013, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Establishment and management of fisheries *refugia* have recently been recognized as important tools in sustainable use/ management of fish stocks and their associated habitats. To initiate the fisheries *refugia* management approach in Phu Quoc, several activities were conducted to collect baseline information for establishment of fisheries *refugia* in Phu Quoc Archipelago since 2007, including local consultations and field surveys involving local communities and concerned stakeholders. Site selection for the establishment of model/ fisheries *refugia* was based on scientific data and consultations with local communities and based on criteria of habitat representativeness, target species diversity and abundance and site management potential. Results from the baseline surveys recorded 11 spawning and nursery grounds of several target species including; octopus (*Octopus dollfusi*), cuttlefish (*Sepioteuthis lessoniana*), the Strombus shell (*Strombus canarium*), swimming crab (*Portunus pelagicus*), seahorses (*Hippocampus* spp.), rabbitfishes (*Siganus* spp.) associated with seagrass habitat and squids (*Loligo* spp.) associated with sandy bottom habitat. In the coral reef habitats, there were 10 locations where nursery grounds of barred-cheek coral trout (*Plectropomus maculatus*) were found in the waters surrounding most of the group of islands (An Thoi) in the southern part of Phu Quoc big island. Two pilot sites were selected for fisheries *refugia* management, one to protect the nursery grounds of grouper associated with coral reef habitats at Hon Roi fishing village and the other to protect the spawning/nursery grounds of the Strombus shell, octopus, swimming crab and seahorses associated with the sea grass habitats of Bai Thom fishing village. Management has been implemented on an annual basis since 2013 during spawning/nursery seasons from July to December. The key lessons learned from the implementation of fisheries *refugia* at the two pilot sites include; using local fisher knowledge for baseline inventory and assessments to determine site selection and management measures for fisheries *refugia*; the value of involving local communities and government officers in the development and management of fisheries *refugia*; and the importance of identifying specific fisheries management issues and appropriate management measures. This approach is expected to ensure success of sustainable management of fisheries and their habitats in the future.

Keywords: *Fisheries refugia, target resources, seagrass beds, coral reefs, Vietnam.*

Introduction

Overfishing and degradation of coastal and marine habitats are considered major issues to marine environment in the South China Sea and Gulf of Thailand (UNEP, 2007a). Fish stocks in this region continue to be subject to high levels of fishing effort due to increasing global demand for fisheries products and strong coastal community dependence on fisheries, making it difficult to reduce inshore fishing capacity and unsustainable fishing practices (UNEP, 2007a). Recent synthesis of fisheries trends suggests that production from capture fisheries will decline over the coming years unless the fishing effort and capacity are reduced (Lundgren *et al.,* 2006). Therefore there is an urgent need to find solutions to improve management of fisheries in the region.

Phu Quoc Marine Protected Area (MPA) supporting more than 12,000 ha of seagrass beds (Nguyen, 2004) and 473 ha of coral reefs (Nguyen *et al.,* 2006) is considered as an important fishing ground in the western part of Vietnam and in the Gulf of Thailand. Since the establishment of the MPA in 2007, a series of management activities have been implemented aimed at conserving biodiversity and resources. The results of monitoring seagrass beds and coral reefs from 2006 to 2010 showed that the condition of the habitats gradually deteriorated and that habitat associated resources (especially those of the target species) were unable to recover significantly due to overfishing, destructive fishing, coral bleaching and sedimentation (Nguyen *et al.,* 2011).

Consultations with local fishers indicated that some areas of seagrass and coral reef habitat are important spawning and nursery grounds for commercial fish species. However, these important grounds have not been considered for MPA management due to lack of sufficient information. Consequently, the linkage between habitats and life cycle of habitat associated species has not received sufficient attention in the development of an MPA management plan. Current zoning plans are mainly based on distribution and status of habitats, species richness, occurrence of endangered species, resource use patterns, and human impact on environmental resources. This approach has led to slow recovery of marine resources in general and target species in particular.

Recently, the establishment of fisheries *refugia* for sustainable use of fish stocks and their habitats has been increasingly considered as an important tool for fisheries management (UNEP 2007b). The first fisheries refugium was developed in Phu Quoc at a pilot site with seagrass habitats at Ham Ninh Commune in 2007. This initiative was part of the framework of the UNEP/GEF Project "Reversing environmental degradation trends in the South China Sea and Gulf of Thailand". The activities under the initial project were continued in the subsequent project "Studies and establishment of some pilot sites of fisheries *refugia* in Vietnam" (2012-2014) under support from the Ministry of Agriculture and Rural Development (MARD) of Vietnam. This paper presents the preliminary results of the establishment and management of fisheries *refugia* in Phu Quoc MPA.

Material and methods

Inventory and assessments of critical spawning and/or nursery grounds in Phu Quoc MPA were conducted through consultations and field surveys with involvement of local communities, managers and scientists to enable use of local knowledge. A total of 7 consultations were made, in which 4 meetings were organized at Cua Can, Ganh Dau, Bai Thom and Ham Ninh communes which have seagrass associated fisheries; and 3 meetings at An Thoi, Hon Thom and Hon Roi communes which have coral reef associated fisheries. At each consultation, there were 15 - 20 experienced local fishers fishing with different gears including trawling, hookah fishing, drift nets and purse seine. Fish traders from each commune were also invited to attend the meetings. From local consultations, the locations and seasons of different target species for scientific field assessment/validation were provisionally identified.

Field validation of the presence/existence of critical spawning and/or nursery grounds and identification of the areas of each of the critical spawning and/or nursery grounds was conducted with the involvement of experienced fishers and scientists. At each ground, 5 - 10 sites were checked by using scuba and hookah diving depending on the nature of the ground. Information on the presence of target species and characteristics of habitats were ascertained at each checked site. The boundaries of each spawning and/or nursery ground were marked using GPS.

Selection of sites for establishment and management of fisheries *refugia* was based on scientific data and consultations with local communities and used habitat representatives, diversity and abundance of target species, and management potential as selection criteria.

Results and discussion

Distribution of spawning and/or nursery grounds of target species

Seagrass beds

The data gathered from the surveys indicated that there were several target commercial fish species in Phu Quoc waters including octopus (*Octopus dollfusi*), cuttlefish (S*epioteuthis lessoniana*), strombus (*Strombus canarium*), swimming crab (*Portunus pelagicus*), seahorses (*Hippocampus kuda* and *H. trimaculatus*), rabbitfishes (*Siganus canaliculatus*, *S. guttatus* and *S. javus*), squids (*Loligo* spp.), shrimp (*Penaeus latisulcatus*) and Indian whiting (*Sillago sihama*).

A total of 11 spawning and/or nursery grounds for the above-mentioned target species were recorded in seagrass habitats and on sand-gravel and sandy bottom habitats (Fig. 1). The strombus snail was the most common species found in 7 of the 11 spawning/ nursery grounds; seahorses and cuttlefish were found in 4, swimming crab, octopus and rabbitfishes in 2 - 3 and squids in one spawning/ nursery ground. In general, each spawning and/or nursery ground was supported by more than one species with the exception of the spawning grounds of squid in the south and of seahorses in the north-east of Phu Quoc big island. Shrimp and Indian whiting are also considered as important fisheries resources but their spawning/nursery grounds were very difficult to find.

The eggs of srombus were mainly recorded on the sand-gravel bottoms or nearby seagrass beds (Plate 1) while the eggs of cuttlefish were usually attached on seagrasses or seaweeds (Plate 2). The spawning octopus and their eggs were mostly found inside the dead shells of gastropods or bivalves (Plate 3). Juvenile and mature gravid swimming crabs, juvenile rabbitfishes and seahorses were mainly found in localities

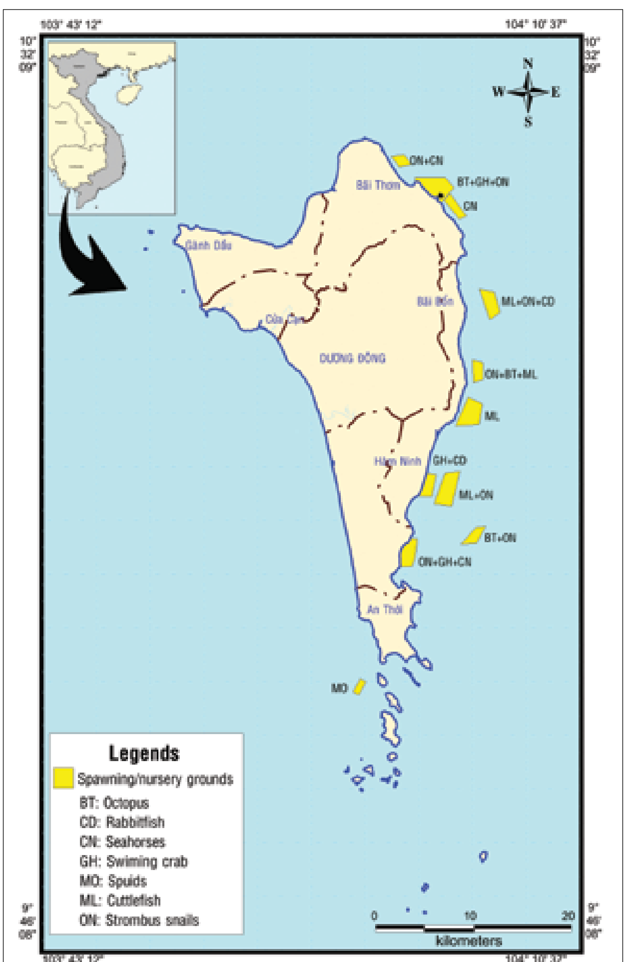


Fig. 1. Distribution of spawning/nursery grounds of target species in seagrass beds and sandy bottoms in Phu Quoc Archipelago.

Plate 1. Strombus shell (*Strombus canarium*) spawned on sandy-gravel substratum of seagrass beds

Plate 2. Eggs of cuttlefish attached on seaweeds of seagrass beds.

Plate 3. Octopus (*Octopus dollfusi*) hiding in dead shells of bivalve for laying eggs in seagrass beds

Plate 4. Eggs of squids attached on sandy bottoms.

with high seagrass cover and density. Squids generally laid/attached their eggs to seaweeds on sandy or gravel bottoms (Plate 4).

Coral reefs

In the coral reef sites, there were 10 locations of nursery grounds of the barred-cheek coral trout (*Plectropomus maculatus*) in the waters surrounding most of the group of islands (An Thoi) in the southern part of Phu Quoc big island (Fig. 2). In general, the nursery grounds were mainly distributed in the north to southwestern parts of most of these islands. Among them, Hon Kim Quy (Kim Quy island) supported a higher number of juvenile groupers than other islands. The four islands (Hon Xuong, Hon Gam Ghi, Hon Mong Tay and Hon Vong) are currently located in the restricted zone of the MPA. However it was observed that these islands supported less numbers of groupers than other islands located outside the restricted zone.

Juvenile grouper were commonly recorded on the outer reef slope with high cover of coral rubble and sand-gravel compared to that on the reef flat with high cover of live corals (Plate 5).

Establishment and management of fisheries refugia

Achievements of fisheries *refugia* management in Phu Quoc include the development of two pilot sites to protect the spawning and/or nursery grounds of some important target species associated with coral reefs and seagrass beds. These pilot sites have been managed by local communities with technical support from relevant agencies. The area for management at Bai Thom pilot site covers 312 ha with 159 ha of seagrass beds to protect spawning/nursery grounds of the strombus (*Strombus canarium*), octopus (*Octopus*

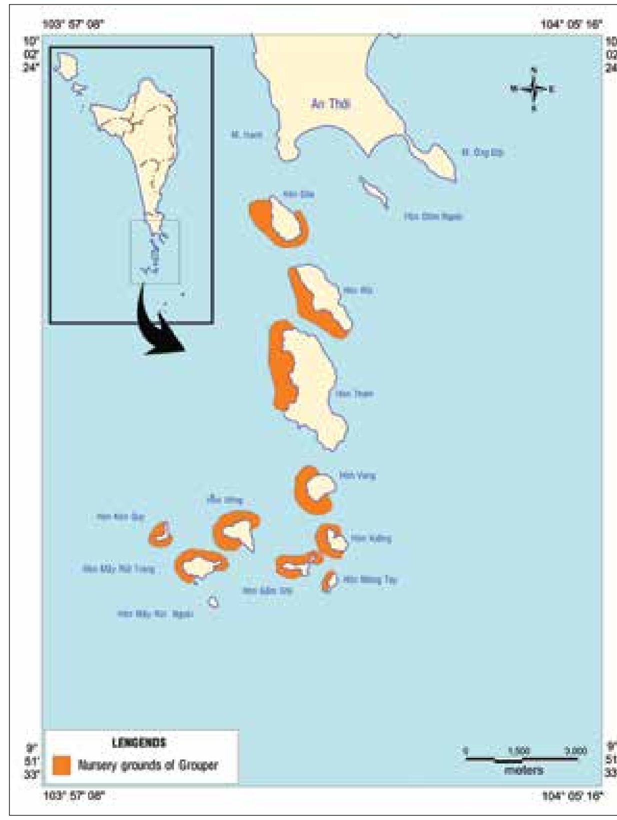


Fig. 2. Distribution of nursery grounds of barred-cheek coral trout in coral reefs.

Plate 5. Juvenile of grouper found in rubble dead coral substratum of coral reefs

dollfusi), swimming crab (*Portunus pelagicus*), seahorses (*Hippocampus kuda* and *H. trimaculatus*) and their associated habitats (Fig.1). The Hon Roi pilot site located in the southern part of Phu Quoc big island covers an area of 18.8 ha with 8.7 ha of coral reefs to protect the nursery grounds of grouper in coral reefs (Fig. 2). Through two consultations with local community at each of fishing village, regulations and community-based management team have been established for daily management at each site, especially during spawning/nursery seasons from July to December.

This is the first time the fisheries *refugia* tool has been applied in Vietnam for sustainable use of fish stocks and their habitats. Data and information from surveys show that there are several important spawning and/or nursery grounds of target species in different habitats, from seagrass to sandy-gravel bottoms and coral reefs. Among them, many grounds supporting high abundance of several target species were located outside the MPA restricted zone for management of seagrass beds and coral reefs. However most of these important grounds have not been considered during development of zoning plan of the MPA due to lack of data and information. Establishment and management of two pilot sites for seagrass beds in Bai Thom and for coral reefs in Hon Roi have indicated initial success in reducing fishing activities of target species during spawning and nursery periods in the project sites and in their associated habitats in general as well. Success from management of these pilot sites will be extended to other grounds, especially to the grounds located outside the restricted zone with less management in order to establish a network of fisheries *refugia*. Development of effective management of a network of fisheries *refugia* in the MPA will contribute to sustainable use of fish stocks and their habitats in the future.

Lessons learnt from the achievements so far are: 1) Using local fisher knowledge in compiling scientific data is an important step for compiling resource inventories and assessing fisheries *refugia*; 2) Involvement of local communities and local government officers (MPA and fisheries managers, police and border Army) plays an important role at all steps of development of fisheries *refugia*, in identifying specific fisheries issues and appropriate management measures.

More work will be conducted to develop fisheries profiles at each site as a basis for monitoring the results of the management measures (resources, fishing sector, post-harvest sector), for developing guidelines for sustainable use and training for monitoring of target species, for evaluating management effectiveness, and for developing a mechanism and measures for long-term *refugia* management at demonstration sites and other potential sites in Phu Quoc.

Acknowledgements

This study is a part of the project "Studies and establishment of some pilot sites of fisheries *refugia* in Vietnam" supported by Ministry of Agriculture and Rural Development of Vietnam (MARD) in the period of 2012-2014. We would like to thank the support from UNEP, Kien Giang Department of Natural Resources and Environment, Phu Quoc Marine Protected Area Management Board and our colleagues (Thai Minh Quang, Phan Kim Hoang, Hua Thai Tuyen) from the Institute of Oceanography, VAST. Thanks also go to SEAFDEC for supporting us attend at the Regional Symposium on Ecosystem Approaches to the Management and Conservation of Fisheries and Marine Biodiversity in the Asia Region in Cochin, India.

References

Lundgren, R., D. J. Staples, S. J. Funge-Smith, and J. Clausen. 2006. Status and potential of fisheries and aquaculture in Asia and the Pacific 2006. FAO Regional Office for Asia and the Pacific. *RAP Publication* 2006/22.

Nguyen Van Long, Hoang Xuan Ben, Phan Kim Hoang, Nguyen An Khang, Nguyen Xuan Hoa and Hua Thai Tuyen. 2006. Marine biodiversity and resources of coral reefs in Phu Quoc. *Tech. Rep UNEP/GEF Demonstration Site Project in Phu Quoc. Instt Ocean.*, 68p.

Nguyen Van Long, Vo Si Tuan, Hoang Xuan Ben, Phan Kim Hoang and Hua Thai Tuyen. 2011. Biodiversity dynamics trend of coral reefs in Phu Quoc marine protected area. *Proc. 4th Natl. Symp. Mar. Sci. Tech. Mini-Symp. Mar. Biol. Res.*: 40-45.

Nguyen Xuan Hoa. 2004. Present status of seagrass beds in Kien Giang Province waters. *Technical Report, Institute of Oceanography*, 19p.

UNEP. 2007a. Procedure for establishing a regional system of Fisheries *Refugia* in the South China Sea and Gulf of Thailand in the context of the UNEP/GEF Project entitled: "Reversing environmental degradation trends in the South China Sea and Gulf of Thailand". South China Sea Knowledge Document UNEP/GEF/SCS/Inf.4.

UNEP. 2007b. Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand. *Rep. Ninth Meeting of the Reg. Working Group Fish.*., UNEP/GEF/SCS/RWG-F.9/3.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-07

Marine spatial planning for fisheries management and biodiversity conservation: More to be done

Guo Zhenren
Institut Teknologi Brunei, Tungku Highway, Gadong BE1410, Negara Brunei Darussalam and South China Institute of Environmental Sciences, 7 West Street, Guangzhou, China.

*Correspondence e-mail: guo.zhenren@itb.edu.bn

Received: 03 Jan 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Depletion of fishery resources and degradation of marine biodiversity are attributed to two main reasons, *i.e.*, overfishing and threats from intensified land-based human activities. Marine spatial planning (MSP) can be an important tool to mitigate the above-referred threats thereby conserving the fishery resources and biodiversity. Marine spatial planning is a typical ecosystem approach that can properly demarcate marine resources spatially and temporally to a variety of human activities, and meet multiple economic, social and ecological objectives. Marine Protected Areas (MPAs) are basic components in MSP for biodiversity conservation and fishery sustainability. Two case studies show how MSP can harmonize multiple uses of marine areas concerned and avoid conflicts; however for protection of some migratory species small or isolated natural reserves are not enough. In order to form a complete ecological system for marine biodiversity conservation and fisheries management, MSP needs to be combined with other planning instruments such as spatial planning of coastal zones and pollution control planning of river basins. Furthermore, spatial and temporal landscape ecology should be addressed in MSP to accommodate the "fisheries *refugia*" requirements. To this end regional and international cooperation are indispensable, and more researches should be conducted to better understand background status of ecosystem and fishery resources, and relevant management capability in the region concerned.

Keywords: *marine spatial planning; marine protected area; fisheries management; spatial planning of coastal zone; biodiversity conservation.*

Introduction

Depletion of marine fishery resources has drawn much attention from relevant sectors in the world. Research projects conducted in the east Asian seas show that marine fishery resources have degraded in this area in the last few decades (COBSEA, 2009). For example, fish catches from four traditional fishing grounds of China, *i.e.*, Bohai Sea, Zhoushan, South China Sea Coast and Beibu Gulf have significantly decreased since the 1990s; in the Pearl River Estuary, one of the most productive areas of South China Sea Coast fishing ground, current fish catch is only one tenth of that in the 1990s. In Thailand, fish catches from the Gulf of Thailand are well above the estimated maximum sustainable yields (MSYs). Catch rates (catch per unit effort, or CPUE, kg/hr) in the 2000s from Thai waters were only 7% of the corresponding levels in the early 1960s (UNEP/GEF, 2007).

Overfishing and intensified land-based activities are two main contributory factors that have led to the depletion of marine fishery resources. Overfishing has been ascribed to three factors. Firstly and most importantly, access to the resources is uncontrolled. The second important factor is the use of new or improved fishing technologies. Besides greatly increasing fish catch, these new technologies result in the capture of large quantities of juvenile or trash fish that are not targets, thus reducing the fishery resources. The third factor is the increased capacity for fishing, using vessels with higher tonnage or horsepower. For instance, the total fishing capacity of vessels in East China Sea in the 1990s was 7.6% more than in the 1960s; in China, the size of the fishing fleet was greatly increased, the number of steel vessels with more than 600 horsepower engines shown a 77% increase since 1997 through 2005 (UNDP/GEF, 2005).

Impacts of land-based activities are also three-fold. The first one is coastal development, particularly land reclamation that in many cases has directly caused fish habitat loss. Related to this is the industrialization and urbanization of coastal areas, which has led to the generation of large amounts of pollutants and waste which are mostly discharged into the sea. The third source is the intense anthropogenic inland activities which exert pressure on the sea through rivers that carry increasing pollutant loads, often greater than direct discharges. The pollutants mix with seawater and move everywhere in the sea, causing deterioration of the marine environment. One of the key problems nowadays is eutrophication of coastal waters caused by increased nutrient discharge from land-based sources. Even Brunei, with a coastline less than 200 kilometers, had to warn people twice within 6 months not to take poisoned fish due to the sustained red tide in 2013.

In this paper, by case study and discussion, the author tries to demonstrate that marine spatial planning (MSP), combined with other planning and management instruments, can be an important tool to mitigate the above-referred threats thereby conserving the fishery resources and biodiversity, and what are to be done for better application of MSP.

MSP: An ecosystem approach and its important roles

Marine spatial planning is a management tool that can be employed to spatially and temporally demarcate marine resource areas to different activities and provide a basis for sustainable use of marine resources (UNESCO, 2009; UNEP, 2011). Effective management is needed to address overfishing and causes of land-based anthropogenic activities resulting in damage to the marine ecosystem. However, effective management should start from planning.

As an ecosystem approach, the key component of marine special planning requires identification of the major objectives of marine resource utilization/conservation and conflicts among these objectives. These include identification of biologically and ecologically important areas, as this is the basic information required for demarcation of marine space so as to incorporate biodiversity objectives into planning and decision-making; identification of conflicts between human activities and nature, and the potential ways to reduce these conflicts so as to establish the context for planning networks of marine protected areas (MPAs); and identification of cumulative effects of human activities on marine ecosystem so as to seek solutions both spatially and temporally through this planning. In this way, marine spatial planning can help to balance ecological, economic and social objectives when utilizing marine areas.

Identification of marine areas with special ecological significance is essential for biodiversity conservation and fishery resource management. These areas with special ecological importance are usually ecologically valuable and/or vulnerable areas, such as, areas of high biodiversity, areas of high endemism, areas of high productivity, spawning areas, nursery areas, migration corridors and stop-over points, and important fishing grounds.

The areas identified with special ecological significance can be then translated into MPAs for fisheries management and biodiversity conservation in marine spatial planning. These MPAs may be designated for various functional areas such as fishery closure areas including seasonal closures, no trawl areas, critical habitat designations, offshore aquaculture areas, marine reserves/no-take areas.

The role of MSP is shown in Fig. 1. By allocating certain areas as natural MPAs for fishery resources and biodiversity conservation based on the ecosystem method, marine spatial planning can create a protective barrier between human activities and critical areas that contribute to fishery sustainability and biodiversity conservation. This barrier must be protective against all fishing efforts – it is a solid red line to all fishing efforts; however access to some other environment-friendly human activities, such as scientific research and education, inspection of MPAs, and limited tourism and regulated use by local communities may be permitted. In the latter cases, MSP creates a fence with limited entrances like a dotted-line in the figure, and meanwhile, negative impact on the MPAs such as pollution due to above-mentioned activities must be strictly controlled by regulations.

The ecosystem principles demand that selected marine protected areas for fishery resources management and biodiversity conservation should be interrelated to each other as much as possible. In other words, each MPA should not be isolated but related to each other to some extent biologically, as shown in Fig. 1. Protected areas for spawning grounds, juvenile fish nurseries and valued and endangered species protection directly benefit fishery resources conservation. These should be supported by other protected areas for critical habitats, such as mangrove forests, sea grass beds, coral reefs, and islands with special value of biodiversity. The elements for fishery resources and biodiversity conservation in the whole marine spatial planning should contribute to an interrelated and complete ecosystem.

Integrated management: other necessary planning instruments

Successful biodiversity conservation and fisheries management still need support of other planning instruments. As seen in Fig.1, marine spatial planning can create a barrier between MPAs and human activities in the sea, but MSP alone is not able

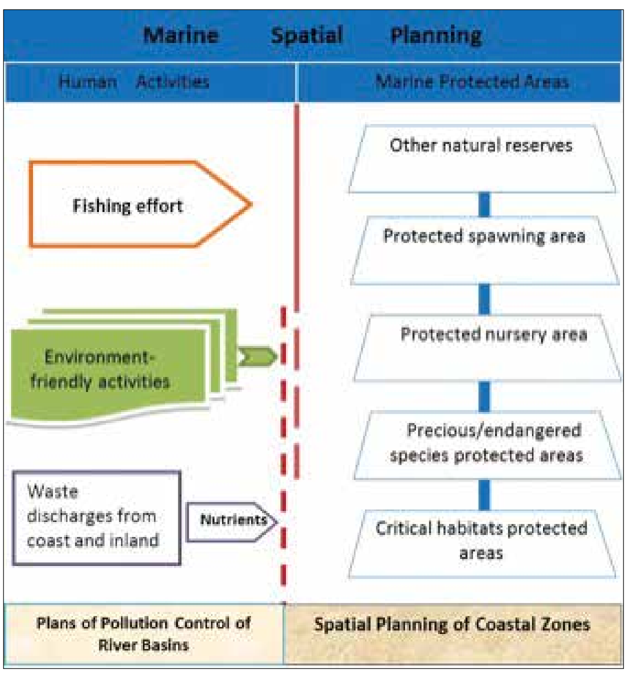


Fig. 1. Marine protected areas ensured by combined planning instruments.

to form a complete barrier. The barrier formed by MSP still has openings because it cannot stop human activities on land that may affect marine environment, such as pollution. Therefore spatial planning of coastal zones (SPCZ) and plans of river pollution control are needed to form another part of the barrier from the other end to create an integrated fence system. First of all, human activities in the coastal zone must be harmonized by SPCZ (UNEP/Sida/COBSEA, 2011). As with other ecosystem - based planning and management tools, firstly, spatial planning of coastal zones will demarcate the coastline into protected coastlines and development coastlines. To match the results given by MSP, SPCZ should include the coastlines with critical habitats, such as mangrove forests, coastal wetlands and sea grass beds on the shore or in the near shore waters, in protected coastlines, and ensure they are not occupied by ports, land reclamations etc. Secondly, spatial planning of coastal zones should help maintain water quality standards set for marine protected areas in both near shore and offshore environments. This can be achieved by integrating land use for industries and urban development in line with ecosystem requirements and by reducing the pollutant load into the sea (Guo, 2013). In addition, as seen in Fig. 1, pollution from inland activities through rivers must be controlled by implementing plans for pollution control in river basins; otherwise, water quality requirements for many marine protected areas cannot be met. Up to this end, MPAs can be ensured by the barrier jointly created by MSP, SPCZ and plans for pollution control in river basins. Similarly, the barrier created by the latter can be a fence with some entrances that may provide access for environment-friendly activities and allow necessary nutrient flow into the sea. From the above points of view, marine spatial planning is the end part of an integrated planning and management "from mountains to the sea". In China, this "unitized plan with waters and land" is legislatively supported by Marine Spatial Function Zoning, Environment Function Zoning of Coastal Waters, spatial planning of coastal zones, Pollution Control Planning of Coastal Waters, Water Quality Planning of River Basins, etc. These planning instruments operated by government administrations in charge of marine and environment management at different levels provide an integrated management framework for marine biodiversity conservation and sustainable fisheries.

Cases: Experience and lessons

Case 1: Daya Bay natural reserve of fishery resources

Daya Bay, established as a natural reserve in 1983, is located in the north of South China Sea near Hong Kong. It is an important natural reserve of fish resources with spawning grounds, sub-tropical coral reefs, sea turtles and very high biodiversity. However, for various reasons, its coastal zone was selected as the site for a large oil refinery in 1994. Consequently, downstream chemical industries and urbanization increased drastically in the area. Increasing demand for land has led to large-scale land reclamation along the coast and caused significant loss of habitats. Faced with the confliction between development and ecological resource protection, the government tried hard to reduce interference caused by development on the natural reserve by firmly maintaining the legislative status of the natural reserve. A variety of measures were taken to balance objectives of ecosystem conservation and development. For instance, the government requires that all development projects which have a bearing on the natural reserve be subjected to marine environmental impact assessment. It is forbidden for waterways to pass through core areas of the natural reserve, and wastewater from land-based sources must be discharged outside the natural reserve through long sea outfalls. In the meantime, engineering measures, like introducing fish fingerlings, have been taken to offset biological loss due to land reclamation and waterway construction. In recent years, four large artificial reefs have been constructed covering 35 km^2; 28,000 corals were replanted with a survival rate of 95.2%. Fish catch in the 1980s was between $11.1\text{-}18.1\times10^3$ tonnes in this bay with an area of 600 km^2, this declined later due to development in the coastal area in the 1990s, but have being recovering since 2004 due to continuous remedial efforts (Song *et al.*, 2012). This example is a good case of applying ecosystem principles of MSP discussed above. Balance between ecosystem conservation and other utilizations of marine resources is achieved not only by demarcating spatial resource in the marine area but also integrated management including habitat reconstruction. Marine Spatial Function Zoning and Environment Function Zoning of Coastal Waters have provided strong support to the integrated management.

Case 2: Guangxi Hepu national dugong natural reserve

Prior to the 1970s dugongs were fished, and they almost disappeared from the Guangxi coastal waters. In order to protect this endangered species, Guangxi Hepu Dugong Natural Reserve was established in 1986. This natural reserve is one of the demonstration sites for sea grass beds established in 2003 under the UNEP/GEF project "Reversing Environmental Degradation Trend in the South China Sea and Gulf of Thailand". Great efforts have been made to maintain this natural reserve which includes regulation, organizations, manpower and facilities. However, no dugong has been sighted since 1997.

The absence of a continuous and extensive sea grass habitat, which is a shortcoming of Hepu natural reserve, could be a factor contributing to the absence of dugongs, in spite of creating the natural reserve. Lessons should be learned from this case. Firstly, the requirements of landscape ecology must be taken into account in the establishment of marine protected areas and natural reserves. "*Ecological corridors*" have to be designated in some areas. Secondly, marine protected areas are usually small, while quantitative requirements for space may change with seasons and climate due to migration of some species like dugongs. This means that the general ecosystem principles of marine spatial planning must be applied to creation of MPA framework.

Discussion

For successful fisheries management and biodiversity conservation in a sea, the ecosystem and fishery resources in the sea must be fully understood so as to facilitate marine spatial planning for this sea. Taking the east Asian seas as an example, though some studies have been conducted to investigate ecological and fishery status in the east Asian seas, relevant data are scattered in the literature. It is impossible to draw a complete picture showing the current distribution of fishery resources and their relationship with the ecosystem, based on existing data. Obviously, in order to conserve biodiversity and fishery resources in the sea, background information on ecosystem and fisheries is the first need in marine spatial planning, particularly as an ecosystem approach. Therefore, more research should be initiated to collect the required background data. Based on these data, contour maps may be drawn, showing the current distribution of real fish stock, relative fish stock, *i.e.*, the ratio of existing fish stock to original natural fish stock, or the ratio of fish catch to maximum sustainable yields, etc. These contour maps would show where and to what extent over-fishing happened and is happening. Furthermore, based on the data gathered, it could be possible to identify the areas with special ecological significance for marine biodiversity conservation and sustainable fishery in this sea. This would form the basic framework of regional marine spatial planning.

It is also clear that the larger the area to which marine spatial planning is applied to, the more accurate would be the results as this would entail connections between larger marine ecosystems. Thus marine spatial planning for biodiversity conservation and fisheries management appears to be a trans-boundary issue needing regional and international cooperation. That is also why more research should be initiated to investigate the background status of fishery resources and ecosystems in the whole concerned sea as recommended previously.

Regional or international cooperation on marine spatial planning for biodiversity conservation and fishery management requires similar level of governance capability among partners. This aspect requires investigations on fishery legislations, and an examination of the capability for monitoring, control and surveillance in countries in the concerned region. This investigation will identify gaps in fishery legislation and management capability amongst the countries. Objectives can then be set for different countries for fisheries management capacity building since, for instance, weak surveillance may not be able to guarantee compliance of MSP.

Conclusion

Demarcating marine protected areas through marine spatial planning can play a key role in fishery resources and biodiversity conservation. From the planning point of view, more can be done jointly with marine spatial planning, such as the complementary Spatial Planning of Coastal Zones and river basin environmental planning to ensure requirements of marine protected areas. In addition, requirements of spatial and temporal landscape ecology should be better addressed through the ecosystem approach for marine spatial planning so as to accommodate the "fisheries *refugia*" requirements (Paterson *et al*., 2012). This will, in many cases, call for regional and international cooperation. To this point it is recommended that more research be conducted to investigate background information on ecosystem and fishery status, as well as management capability in the region that MSP is to be applied.

References

COBSEA. 2009. State of the Marine Environment Report for the East Asian Seas: 48-55, 79-85, 96-101.

Guo Zhenren. 2013. Coastal Zones Spatial Planning and Integrated Management – Innovative Approaches against Emerging Issues (*in Chinese*), Science Press, Beijing: 1-282.

Paterson, J. C, John C. Pernetta, Somboon Siraraksophon, Yasuhisa Kato, Noel C. Barut, Pirochana Saikliang, Ouk Vibol, Phaik Ean Chee, Thi Trang Nhung Nguyen, Nilanto Perbowo, Trian Yunanda, Nygiel B. Armada. 2012. Fisheries refugia: A novel approach to integrating fisheries and habitat management in the context of small-scale fishing pressure, *Ocean Coast. Manage*., 33(3): 1-16.

Song Xing-yu, Wang Sheng-fu, Li Kai-zhi, Huang Liang-min, Tan Ye-hui, Huang Xiao-ping, Liu Hua-xue. 2012. Basic biological production and potential fishery production in Daya Bay, *Ecol. Sc.* (*in Chinese*), 31(1):13-17.

UNDP/GEF. 2005. Global International Waters Assessment - Regional assessment 36: East China Sea: 40-49.

UNEP. 2011. Taking Steps toward Marine and Coastal Ecosystem-Based Management-An Introductory Guide: 8-64.

UNEP/GEF. 2007. National Reports on the Fish Stocks and Habitats of Regional, Global and Transboundary Significance in the South China Sea, UNEP/GEF Project Entitled "Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand", National Report of Thailand: 51-58.

UNEP/Sida/COBSEA. 2011. Spatial Planning in the Coastal Zone of the East Asian Seas Region: Integrating Emerging Issues and Modern Management Approaches: 6-141.

UNESCO. 2009. Marine Spatial Planning: A Step-by-Step Approach toward Ecosystem-based Management: 26-95.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-08

Importance of considering reproductive characteristics for management of marine fisheries

T. J. PANDIAN
CAS in Marine Biology, Annamalai University, Parangipettai 608 502, Tamil Nadu, India.

*Correspondence e-mail: tjpandian16@gmail.com

Received: 04 Jan 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Status of fish stocks in relation to fishing may differ from one area to another, but there is a general consensus that several fish stocks need effective management measures by taking into consideration different indicators of stock status. Through a review of literature, this paper shows the importance of integrating the reproductive characteristics into the plan for management and conservation of marine fisheries as well as ecosystems. Overexploited fishes display symptoms of (i) advancements in age and/or size at sexual maturity and (ii) reduction in fecundity in gonochoristic (bisexual) fishes. Protogynic hermaphroditic fishes show symptoms of advancement in sex/age at sex change and decrease in Reproductive Life Span (RLS). Consequent to these changes in reproductive characteristics, the Spawning Stock Biomass (SSB) will decrease leading to depletion and collapse of a stock or species of fishes. In response to advancement in Age at Sexual Maturity (ASM) and/or Size at Sexual Maturity (SSM), the depleted stock/species may display one of the following symptoms: (a) decrease in fecundity, as in European hake *Meruluccius meruluccius*, or (b) decrease in egg size, as in *Gadus morhua* or (c) both decrease in fecundity and egg size, as in roughy *Hoplostethus atlanticus*. The protogynics economize male and sperm availability by behavioral acts like spawning aggregation; however, the longer residency of such spawning aggregation in a particular site increases the vulnerability of reproductively active parents. Analyses of limited publications show that (i) overexploitation reduces not only male biomass but also female biomass and (ii) reduction in RLS to 50% in female e.g. *Epinephelus niveatus* and 33% in male e.g. *Pagrus pagrus* through precocious sexual maturity and sex change.

Keywords: *Overexploitation, sexual maturity, fecundity, sex change, egg size.*

Introduction

Fisheries constitute one of the most important natural resources for humanity and any reduction in their well-being and ability to propagate as a result of overexploitation may have significant socio-economic consequences. FAO (2012) has reported that out of 90 metric tonnes (mt) captured world over, about 78 and 12 mt arise from marine and freshwater fisheries, respectively. Fisheries provide not only food but also gainful employment. For example, fisheries provide employment for over a million people in India (CMFRI, 2012). However, annual fishing capacity ranges from just 2-3 tonnes (t) for an Asian fisher to 7 to 8 t for a fisher in Europe and North America. Understandably, overexploitation of marine fishery resources, especially by the developed countries has led to almost total collapse (99.9%) of the Atlantic cod (Hutchins and Reynolds, 2004). FAO (2012) lists nine depleted fish species that are beyond recovery; these fishes are mostly known from developed countries (Table 1). The status of fish stocks in world oceans are at different levels of exploitation. For example, FAO (2010) has reported that pelagic and demersal fishes remain underexploited along the northeast coast of India but overexploited along southeast coast. However, it has been more recently recognized that the fishery resources in the Asian countries are also on the verge of being overexploited. For example, Vivekanandan (2013a, b, 2014) has brought to light that the threadfin bream *Nemipterus japonicus* is beginning to suffer overexploitation in the southwest Bay of Bengal. Hence the need for management of marine fisheries has become obvious.

Table 1. Overexploited species (source: FAO, 2012)

Species	Main fishing countries
Gadus morhua	Canada, USA, Greenland
Melanogrammus aeglefinus	Canada, USA
Petrus rupestris	South Africa
Atracloscion aequidens	South Africa
Clupeonella cultriventris	Russia, Ukraine
Alosa pontica	Bulgaria
Thunnus thunnus	France, Italy, Turkey
T. maccoyii	Japan, Taiwan, South Africa
Chaenocephalus gunnari	United Kingdom, S. Korea
Nototheniidae	United Kingdom

Signals of overexploitation

Depletion of a commercial fish stock or species is recognized by fisheries managers by (i) drop in commercial landings, (ii) reduction in catch-per-unit effort (CPUE), and (iii) mean size (Table 2). The CPUE of the overexploited red porgy *Pagrus pagrus*, an important segment of the commercial fisheries of South Atlantic Bight, drastically declined from 11 porgy/trap/hr in 1980 to < 2 porgy/trap/hr in 2004 (Fig. 1). Table 2 lists changes in features of commercial landings of selected overexploited fishes. Fisheries management takes into consideration one or more of these features of stock/species as indicator(s) to assess the level of overexploitation. In addition to those features listed in Table 2, the overexploited fishes also display features like advancements in age and/or size at sexual maturity; reductions in fecundity of gonochoristic (bisexual) fishes and decrease in Reproductive Life Span (RLS) by female to male sex change in protogynic hermaphroditic fishes. Estimation of some of these reproductive characteristics may trace the pathway through which the Spawning Stock Biomass (SSB) is altered leading to depletion and collapse of a fish stock or species. An understanding on the combination of the features on commercial landings and reproductive characteristics may facilitate better management of marine fisheries.

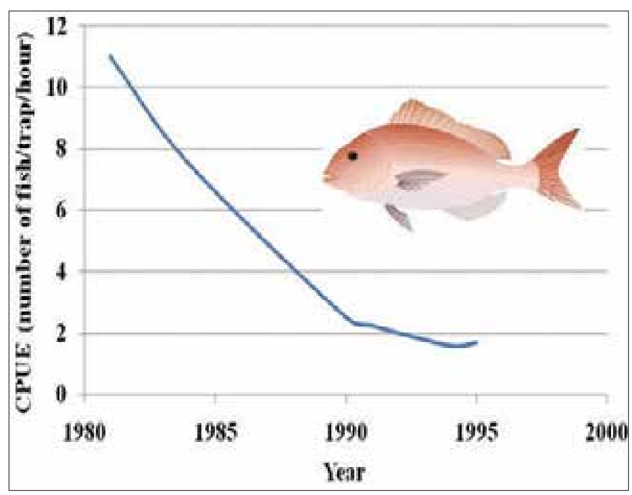


Fig. 1. Commercial landings of red porgy *Pagrus pagrus* as a function of catch per unit effort (source: Harris and McGovern, 1997, modified).

Table 2 Changes in reproductive parameters in the commercial landings of overexploited protogynics during the period from 1972 to 2002 in southeastern United States

Features	Reported changes
Pagrus pagrus (Harris and McGovern, 1997, Vaughan and Prager, 2002)	
Fishing mortality (F)	Increased from 0.25 in 1972 to 0.8 in 1998
Commercial landings (t)	Reduced from 1.5 mt in 1971 to 0.2 mt in 1995; number decreased from 200,000 during 1970s to 100,000 after 1988
Mean size landed (kg/fish)	Decreased from 1.1 kg in 1972 to 0.7 kg in 1998
Largest size captured (cm)	57.5 in 1980s
Catch effort	
(i) (no/trap/hr)	Decreased from 10 in 1980 to 1.5 in 1995
(ii) (no/trap)	Decreased from 0.8 in 1992 to 0.1 in 1998
SSB (t)	Decreased from 2500 in 1972 to 500 in 1998
Epinephelus niveatus (Wyanski et al., 2002)	
Landings in South Carolina (t)	Reduced from 130 in 1982 to 40 in 1996
Mean size landed (cm)	65-80 during 1970; 50-60 in the mid 1990s
Captured by snapper reeds	
(i) largest size landed (cm)	105 in 1979-1985; 98 in 1993-1994
(ii) oldest landed (age)	22 y in 1979-1985; 18 y in 1993-1994

Advancement of age at sexual maturity (ASM) reduces the scope for storing adequate nutrients to meet the cost of vitellogenesis, whereas size at sexual maturity (SSM) may reduce the space in the body cavity to accommodate the ripening ovaries. The response of fish reproduction to overfishing have been studied both from temperate and tropical fishes. The ASM of the Northeast Arctic cod advanced from 10 year (y) in 1940 to 7 y in 2000 and SSM from 100 cm to 75 cm. Advancement of sexual maturity (ASM), say, from nine months during 1978-1981 to eight months during 2002-2005 was noticed in the threadfin bream *Nemipterus japonicus* off Chennai (southeast coast of India) reduced 9 % of the time window for storage of adequate nutrients to meet the cost of vitellogenesis. SSM of *N. japonicus* also decreased from 38 g to 28 g, i.e. at the rate of 0.4 g/y and thereby reduced the space in the body cavity.

Alternative responses

With advancement of ASM and/or SSM, a fish may opt either to or reduce both the number and size of eggs, or reduce the egg number alone or even reduce the egg size alone. Unfortunately, relevant information on the options of the depleted fishes listed in Table 1 is not available. However, available information indicates that in response to ASM/ SSM, the overexploited stock/species may either opt to (i) reduce fecundity, (ii) egg size or (iii) both fecundity and egg size (Table 3). As a consequence of advancing SSM in *Hoplostethus atlanticus*, a pelagic spawner with determinate fecundity, there was 25% reduction in relative fecundity (RF) and 22% reduction in egg size (Minto and Nolan, 2006). With reduction in 12% body weight in SSM of *Meruluccius merluccius*, an asynchronous income (food supply dependent breeder, see also Pandian, 2013) breeding pelagic spawner with indeterminate fecundity (Pandian, 2013), the RF decreased from 187 eggs/g ovary-free fish in 1995 to 133 eggs/g in 2004. The values for specific fecundity (DEP), which ranged between 8.1 and 14.1 eggs/g (ovary-free) body weight during 1995-1998 decreased to 4.0-5.0 eggs/g during 2001-2004 (Murua *et al.*, 2010). On consultation, H. Murua (*pers. commu.*) has kindly informed that the egg size may not have undergone any change. Due to overfishing between 1971 and 2004, the sexual maturity advanced and consequently gonado-somatic index reduced in the Peruvian hake *M. gayi* (Ballon *et al.*, 2008). Considering all the four size groups (15, 19, 23 and 26 cm TL) of the threadfin bream *N. japonicus* subjected to fishing pressure in southwest Bay of Bengal, Vivekanandan (2013a) found that RF remained almost equal (303-319 eggs/g fish) during the year 1979-2004 whereas, the egg size decreased from 0.12 mg in 1979 to 0.10 mg in 2004. However, the absolute fecundity decreased, as the SSM decreased from 38 g to 28 g. Vivekanandan (2013a) also showed that the condition factor, an index of nutrient reserves in the body to meet the cost of vitellogenesis, also decreased in depleted fishes; for instance, it decreased in *N. japonicus* from 0.175 in 1978 to 0.165 in 2005. In the Chinese anchovy *Coilia mystus*, the egg size decreased from 1.4 mg in 1979 to 1.1 mg in 2007 but its RF increased from 712 eggs to 871 eggs in 2007 (He *et al.*, 2011). In the northern cooler waters, the oocytes size of the cod, a low capital pelagic spawner with determinate fecundity, decreased by 6.7%, i.e. from 646 μm in 1986 to 603 μm in 2006 for the Barents Sea stock and by 13.6%, i.e. from 618 μm in 1995 to 534 μm in 2000 for the colder Islandic stock. Apparently, the northern stock is more fragile and suffers larger decrease in oocyte size more rapidly

Table 3 Different types of response in egg number and/or size of overexploited fishes

Reduction in fecundity only (Murua *et al.*, 2010)	
Meruluccius meruluccius Cold temperate, Large, Indeterminate income breeder, Hydrated pelagic eggs.	In the Bay of Biscay, RF of the European Lake decreased 187 eggs/g ovary free fish in 1995 to 133 eggs/g in 2004, in response to 12% decrease in size at sexual maturity
Reduction in egg size (Thorsen *et al.*, 2010)	
Gadus morhua Cold temperate, > 8 ys life span, Determinate low capital breeder, Hydrated pelagic eggs	Egg size of the European cod decreased from 618 μm in diameter during 1995 to 534 μm in 2000.
Reductions in relative fecundity and egg size (Minto and Nolan *et al.*, (2006)	
Hoplostethus atlanticus Cold temperate, Long life span of > 180 y, Determinate fecundity,Hydrated pelagic eggs	Egg size of Atlantic orange roughly decreased from 33 μg at less overexploited Porcupine Bank stock to 27 μg at relatively more overexploited Cook Canyan stock. RF also decreased from 33 eggs/g to 27 eggs/g in these stocks

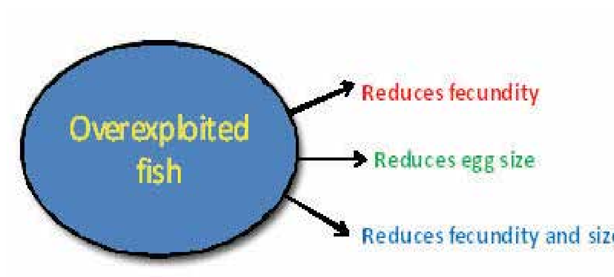


Fig. 2. The three options chosen by overexploited stock/species in response to ASM and SSM.

than that of Barents Sea. However, the annual fecundity of the Barents Sea cod stock remained at around 2 million eggs from 1986 to 2006 (Thorsen *et al.*, 2010). In fact, Kraus *et al.* (2000) reported an increase in RF of Baltic cod from 640/g fish in 1987 to 850/g fish in 1996. Clearly, in response to the decrease in age and size at sexual maturity, the egg size decreased but not the egg number in *Gadus morhua*. To an increase in fishing pressure, *H. atlanticus* responded by reducing both the number and size of eggs, *M. merluccius* by reducing fecundity and *N. japonicus*, *C. mystus* and *G. morhua* by reducing the egg size and in the last two species by increasing RF also. However, there is a need for more detailed studies to make any generalization, as the stocks of these depleted fishes are not subjected to the same level of overexploitation. Nevertheless, overexploitation decreases the reproductive potential of a stock or species (i) by reducing the SSB, (ii) reducing age diversity, (iii) advancing ASM and/or SSM and thereby (iv) fecundity (Pandian, 2014). To cite an example, the SSB of the overexploited Baltic cod decreased from 50,000 females in 1970 to 18,000 in 2008, and in turn, the recruitment from 200,000 in 1971 to 75,000 in 2009. Some of these negative effects of overexploitation on reproductive parameters of gonochoristic fishes are summarized in Table 2.

In female to male sex changing protogynics, the male ratio ranges from 0.06 in *Mycteroperca bonaci* to 0.37 in *Epinephelus akaara*. Within a species like the black grouper *M. bonaci*, there are 15 females for every male in Florida, 30 in Cuba and 77 in Mexico. These location and species specific differences in male ratios of protogynics strongly emphasize the need for accumulation of data on reproductive characteristics and consider them while devising management plans for fisheries and ecosystem management.

In protogynic stocks, selective fishing of large male members was earlier considered to impose sperm limitation, as a required number (> 6,000/egg) of sperm to fertilize an egg may not be available. However, spawning aggregation, an adaptive behaviuor common among protogynics, neutralizes the sperm limitation but ensures sperm economization by reducing sperm requirement to 863/egg (Pandian, 2014). Yet, the protogynics suffer from Reproductive Life Span (RLS) due to advanced sexual maturity and precocious sex change. For example, the RLS of a female snowy grouper *Epinephelus niveatus* is reduced from 8.4 yr^{-1} in 1980s to 4.4 yr^{-1} in 1990s, i.e. 50 % reduction in RLS (Wyanski *et al.*, 1998, Pandian, 2014). The RLS of a male red porgy *Pagrus pagrus* is reduced by 33% (Harris and McGovern, 1997, Pandian, 2014). The response of gonochoric and protogynous fishes to overexploitation shows the importance of considering the reproductive characteristics for management of marine fisheries and ecosystems.

References

Ballon, M., C.Wosnitza-Mendo, R.Guevara-Carrasco and A.Bertrand. 2008. The impact of overfishing and El-Nino on the condition factor and reproductive success of Peruvian hake *Meruluccius gayi, Prog. Oceanogr.*, 79 : 307

CMFRI, 2012. Marine Fisheries Census 2010. Part I. India. Central Marine Fisheries Research Institute, Kochi, 179 pp.

FAO, 2010. General Situation of World Fish Stocks. United Nation Food and Agriculture Organization, Rome p. 113

FAO, 2012. The State of World Fisheries and Aquaculture in Asia Pacific. FAO, Rome 230pp.

Harris, P. J. and J. C. McGovern. 1997. Changes in the life history of red porgy *Pagrus pagrus* from the south eastern United States 1972-1994. *Fish. Bull.*, 95: 732-747

He, W-P, Y-X. Li and M. Liu. 2011. Reproductive biology of *Coilia mystus* (Linnaeus) from the Yangtze Estuary, China responses to overexploitation. *J. Appl. Ichthyol.*, 27 : 1197-1202

Hutchins, J. A. and J. D Reynolds. 2004. Marine fish population collapses: Consequences for recovery and extinction risk. *Bioscience*, 54: 297-309

Kraus, G., K. Muller, K. Trella and F. W. Koster. 2000. Fecundity of Baltic cod: temporal and spatial variation. *J. Fish Biol.*, 56: 1327-1341

Minto, C. and C.P. Nolan. 2006. Fecundity and maturity of orange roughy (*Hoplostethus atlanticus* Collet 1889) on Porcupine Bank, Northeast Atlantic. *Env. Biol. Fish*, 77: 39-50

Murua, H. L. Ibaibarriage, P. Alvarez Santos, M. Korta, M. Santurtun, and L. Motos, 2010. The daily egg production method: A valid tool for application of European hake in the Bay of Biscay. *Fish. Res.*, 104: 100-110

Pandian, T.J. 2013. Endocrine Sex Differentiation in Fish. CRC Press, Boca Raton, USA, 302pp

Pandian, T. J. 2014. Environmental Sex Differentiation in Fish. CRC Press, Boca Raton, USA, (in press)

Thorsen, A., P. R. Witthames, G. Marteinsdotir *et al.* 2010. Fecundity and growth of Atlantic cod (*Gadus morhua*) along a latitudinal gradient. *Fish. Res.*, 104 : 45-55

Vaughan, D. S. and M. H. Prager. 2002. Severe decline in abundance of the red porgy (*Pagrus pagrus*) population off the southeastern United States. *Fish. Bull.*, 100: 351-375

Vivekanandan, E. 2013a. Climate change: Challenging the sustainability of marine fisheries and ecosystems. *J. Aquat. Biol. Fish.*, 1:58-71

Vivekanandan, E. 2013b. Sea water warming coincides with shift in the spawning season of a tropical bream in the southwest Bay of Bengal. *Rev. Fish Biol. Fish.*, (in press)

Vivekanandan, E. 2014. Precocious maturity and variations in reproduction of threadfin bream *Nemipterus japonicus* southwest Bay of Bengal. Sexuality, *Early Dev. Aq. Org.* (Communicated)

Wyanski, D. M., D. B. White, and C. A. Barans. 2000. Growth, population age structure and aspects of the reproductive biology of snowy grouper *Epinephelus niveatus*, off North Carolina and South Carolina. *Fish. Bull.*, 98 : 199-218

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-09

Fisheries *refugia* : A regional initiative to improve the integration of fisheries and habitat management

Somboon Siriraksophon
Policy and Program Coordinator, Suraswadi Building, Kasetsart University Campus, Bangkok 10903, Thailand.

*Correspondence e-mail: ssiriraksophon63@gmail.com

Received: 04 Jan 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

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

Keywords: *fisheries refugia, fisheries management, sustainable use, habitat management.*

Introduction

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

An obvious impediment to the reduction of inshore fishing effort is that small-scale operators are often entirely dependent on fish for income, food and well-being (Paterson *et al.*, 2006). As a result of ‘fishing down marine food webs’ (Christensen, 1998), small pelagic species now dominate landings as most demersal fisheries are overfished (Lundgren *et al.*, 2006). Consequently, the investment of time and household expenditure on fuel for fishing has increased in coastal communities attempting to secure adequate dietary nutrition and income from fishing (UNEP, 2007a).

This situation of intense small-scale fishing pressure and declining fisheries resources has contributed to the adoption of unsustainable fishing methods to maintain catch and increase incomes in the short-term. These include the use of destructive fishing gear and practices, such as operation of demersal trawls and push nets in seagrass areas, the use of explosives and release of fish poisons in coral reef areas. Small-scale inshore fishing pressure has therefore been identified as a significant cause of the degradation and loss of coastal habitats in the South China Sea (UNEP, 2008a).

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

With fish production being intrinsically linked to the quality and area of habitats and the heightened dependence of coastal communities on fish, a need exists to improve the integration of fish habitat considerations and fisheries management in the region. The dilemma for the fisheries and environment sectors is that conservation of habitat does not necessarily result in increased fish stocks while lowering fishing effort does not necessarily result in the improvement of habitat. Therefore, given the complexity of the key threats to fish stocks, fish habitats and associated biodiversity in Southeast Asia, it is imperative that mechanisms for effective cross-sectoral consultation and coordination be established, particularly in terms of the identification and designation of priority ‘places’ (Pauly, 1997) for management.

The fisheries *refugia* concept defined as “spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use” (UNEP, 2005) was developed as a novel approach to the identification and designation of priority areas to integrate fisheries and habitat management. This paper reviews barriers to the effective integration of the work of fisheries and environment departments and ministries in the context of high and increasing levels of small-scale fishing pressure in the South China Sea and Gulf of Thailand. The effectiveness of the fisheries *refugia* concept in harnessing stakeholder support for the use of area-based planning to strengthen the integrated management of critical fishery and habitat linkages is highlighted. Country experience in applying the *refugia* approach via an initiative to establish a regional system of fisheries *refugia* is presented in terms of improved communication between the fisheries and environment sectors and enhancing community acceptance of area-based management tools.

The question arises as to how the concept of fisheries *refugia* differs from other forms of area-based management used in fisheries. Marine reserves, for example, have been called by many names, including ‘no-take zones’, ‘fishery reserves’, ‘fully protected marine reserves’, ‘highly protected marine reserves’ and, recently, ‘fish stock recovery areas’ (Roberts and Hawkins, 2012). Regardless of the name applied, the underlying principles are the same, i.e., restriction or banning of fishing activity in fishing grounds. In contrast, the fisheries *refugia* concept focuses on the nature of the particular habitat and its critical significance to the life-history of the fished species. Management of *refugia* therefore focuses on the habitat rather than simply restricting access, either temporally or spatially, to fishing grounds. This paper presents the outcomes of a regional initiative to improve the integration of fisheries and habitat management from the project entitled “Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand”, which was funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) in partnership with seven riparian states bordering the South China Sea. Planning commenced in 1996; the project became fully operational in February 2002; and was formally closed at the end of January 2009. The outcomes were recently published as part of a Special Issue of the journal ‘Ocean and Coastal Management’ on the UNEP/GEF South China Sea Project (Paterson *et al.*, 2012).

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

Development of the fisheries *refugia* concept

Fisheries component of the UNEP/GEF South China Sea project

As mentioned earlier, the fisheries component of the UNEP/GEF SCS project entitled “Over Exploitation of Fisheries in the Gulf of Thailand” focused on the links between fish stocks and coastal habitats and was designed to secure agreement on the establishment of a regional system of fisheries *refugia* to maintain important transboundary fish stocks. This was aimed at the achievement of one of the overall objectives of the project, specifically "Improved integration of fisheries and biodiversity management in the Gulf of Thailand". This component was nested with other project components focusing on habitat degradation and loss, land-based pollution, and regional coordination within the broader management framework of the project.

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

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

During its preliminary planning stages, the RWG-F realised that initiatives to integrate fisheries and habitat management in Southeast Asia would be constrained by the following factors: (1) limited experience in national fisheries and environment departments and ministries with respect to the implementation of integrated fisheries and habitat management approaches; (2) limited information regarding fish life-cycles and critical habitat linkages and the role that coastal habitats play in sustaining fisheries; and (3) low level of community acceptance of 'protected' area approaches to marine management in Southeast Asia.

Barriers to effective integration of fisheries and habitat management

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

1. Limited practical experience in integrating fisheries and environmental considerations:

The need to integrate fisheries and habitat management has received high-level international recognition, particularly within the framework of the approved Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem (FAO, 2002). The Reykjavik Declaration states that in an effort to reinforce responsible and sustainable fisheries in the marine ecosystems, States "will individually and collectively work on incorporating ecosystem considerations into that management to that aim". In a note regarding the preparation of the Technical Guidelines for Responsible Fisheries dealing specifically with the ecosystem approach to fisheries (EAF) as part of the FAO Code of Conduct for Responsible Fisheries (CCRF) in 2003 (FAO, 2003, the FAO highlights that "at the time of writing (the guidelines), there was little practical experience in implementing EAF anywhere in the world". Similarly, the ASEAN-SEAFDEC Regional Guidelines on Responsible Fisheries in Southeast Asia provide guidance with regard to minimising the negative impacts of fishing on the environment and critical fisheries habitats (SEAFDEC, 2006). In this connection, the RWG-F also identified, in the early stages of its work, that a central problem faced by fisheries ministries and departments in building environmental considerations into fisheries management is a lack of examples relevant to the region on how to implement such policies at the local level (UNEP, 2006a).

2. Limited knowledge of fish life-cycle and critical habitat linkages:

Regarding the lack of knowledge concerning fish life-cycles and critical habitat linkages in the South China Sea basin, the RWG-F noted that, while the life-cycles of most fished species in the region were thought to follow the generalised three-phase ontogeny of marine fishes very little information existed at the regional level regarding specific habitats and locations used by most fish species during critical phases of their life-cycles (UNEP, 2005; 2006a). Spawning sites and the influence of ocean processes on transport of fish larvae are also poorly known (UNEP, 2006b). This situation results from past fisheries research programmes having focused on determining sustainable yields of fish stocks with little emphasis being placed on fish life-cycle research. Most fish life-cycle and habitat data and information in the region are qualitative in nature, providing general information regarding the presence or absence of fish and the life-cycle phase of fish species observed in a given habitat area.

While this work is useful in developing an inventory of habitats and locations utilized by fished species at different phases of their life-cycle, the RWG-F therefore identified the need for regional level research on the role of specific habitat areas in terms of fisheries production and sustaining fish stocks under scenarios of increased fishing effort (UNEP, 2006b).

3. Low level community acceptance of 'protected' area-based approaches:

During the meetings of the RWG-F it was noted that Marine Protected Areas (MPAs) were increasingly being promoted, or conceived, as essential fisheries management instruments (Roberts and Polunin, 1993; Gell and Roberts, 2003) and that the FAO had initiated an evaluation of the effectiveness of Marine Protected Areas as management and conservation tools for fisheries. It was agreed that, while fisheries ministries and departments in the region would need to improve their working relationships with organisations promoting MPAs, the key barrier would be in achieving acceptance among communities at the local level of the value of MPAs. The consensus view within the working group was that MPAs in Southeast Asia were widely understood by fisheries stakeholders to be areas that were closed to fishing.

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

Approach of the Regional Working Group on Fisheries

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

The RWG-F for the UNEP/GEF South China Sea Project agreed that any approach aimed at fostering integrated management should:

a) Build the capacity of fisheries and environment departments and ministries to engage in meaningful dialogue regarding how broader multiple use planning can best contribute to improving the state of fisheries habitat management in areas of the South China Sea and the Gulf of Thailand;

b) Improve understanding among stakeholders, including fisherfolk, scientists, policy makers and fisheries managers, of habitat and fishery linkages as a basis for integrated fisheries and habitat management; and

c) Enhance and sustain the participation of local fishing communities and the private sector in management interventions for improved fisheries habitat management and biodiversity conservation through a focus on sustainable use rather than the prohibition of fishing.

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

Supporting evidence

In developing the framework for a regional system of fisheries *refugia* in the South China Sea, the RWG-F recognised the need for two separate but related sets of goals and objectives as shown in Table 1. The first is related to the resource itself and the second to the institutional framework under which management is brought about. Overall, the resource related goal is to enhance the resilience of regional fish stocks to the effects of fishing. The institutional goal is to integrate fisheries and habitat management at the national level, a task which is formidable given the past history of interactions between

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

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

fisheries and environmental managers in most countries in the region. Consideration of these goals and objectives enable evaluation of whether or not areas subject to seasonal closures and fisheries management zones within multiple-use MPAs can be classified as fisheries *refugia* and form part of a regional *refugia* system.

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

Defining and disseminating information on the fisheries refugia concept

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

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

Identification of fisheries refugia: critical spawning and nursery areas

The Sixth Meeting of the RWG-F noted that most fish populations are vulnerable to the impacts of over-fishing in areas and at times where there are high abundances of (a) stock in spawning condition, (b) juveniles and pre-recruits, or (c) pre-recruits migrating to fishing grounds. The impact of over-fishing is intensified in instances where small-scale fishers and commercial fishers share the same stock, often leading to disputes regarding the relative impact of each group (UNEP, 2006a).

The RWG-F agreed that this situation is characteristic of the over-fishing problem in many marine fisheries in the South China Sea. Juveniles and pre-recruits are often caught in inshore areas by small-scale fishers while commercial fisherfolk catch adults of the same species offshore. In circumstances such as this, high levels of fishing effort in inshore waters may drive growth over-fishing, while the same circumstances in offshore areas may cause recruitment over-fishing of the same stock. FAO (2007), for example, reports that 18-32 percent of low value 'trash' fish caught primarily by demersal trawling in the Gulf of Thailand are juveniles of commercially important species often targeted by other fisheries.

The RWG-F agreed that management of 'nursery *refugia*' to safeguard fish during the juvenile and pre-recruit phases of their lifecycle and the habitats utilised as nurseries can assist in the prevention of growth over-fishing. Similarly, management of 'spawning *refugia*' may assist in the prevention of recruitment overfishing (Annex 5 of UNEP, 2006a). In considering the work of the RWG-F, the Regional Scientific and Technical Committee (RSTC) of the UNEP/GEF South China Sea project discussed *refugia* approaches that have often been used as a fisheries management tool when more conventional techniques, such as effort or gear restrictions, have failed to achieve the desired management objectives, particularly in regions where fisheries are subject to intense and unmanageable fishing pressure, such as in the Gulf of Thailand. In other instances, fisheries *refugia* have been used to separate potentially conflicting uses of coastal waters and their limited resources. The RSTC noted that the effectiveness of fisheries *refugia* will likely depend on an appropriate consideration of known critical spawning and nursery areas in the selection of sites. In this connection, the RSTC directed the RWG-F to: review known spawning areas for fish stocks of transboundary significance with the aim of evaluating these sites as candidate spawning *refugia*; and evaluate South China Sea habitat sites as potential juvenile/pre-recruit *refugia* for significant demersal species (UNEP, 2006c).

This information was compiled and reviewed during the seventh meeting of the RWG-F and was subsequently considered during the eighth meeting of the RWG-F and used to list and characterise known fish spawning and nursery areas in the Gulf of Thailand and the South China Sea (UNEP, 2007b). The RWG-F reviewed the list of sites in relation to: information on the distribution and abundance of fish eggs and larvae in the South China Sea during the post northeast monsoon periods from 1996 to 1999; and the outcomes of country consultations on the identification of fisheries *refugia*. The group subsequently agreed on 14 priority sites for inclusion in an initial system of fisheries *refugia* and an additional 9 sites for which additional information was required prior to their inclusion in the system. National maps of the agreed locations for *refugia* sites are included in Annex 6 of the eighth RWG-F meeting report (UNEP, 2007b). The locations of these sites are depicted in Fig. 1.

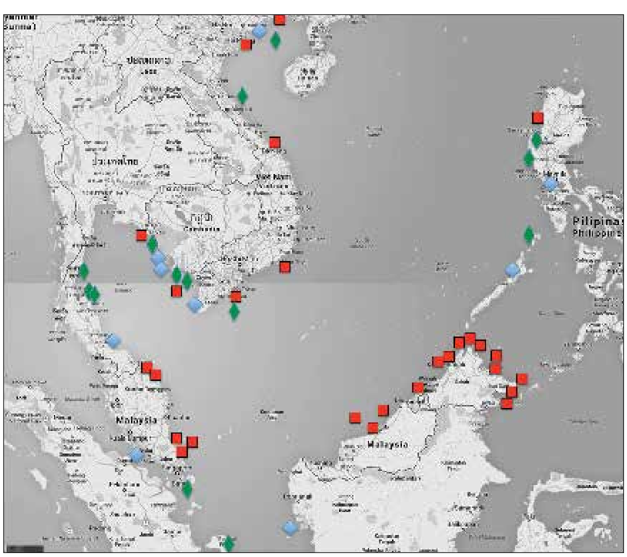


Fig.1. Location of initial sites selected for inclusion in the regional system of refugia [♦]; sites of high priority for inclusion in the regional system once the initial set have been established [◆]; and other known spawning and nursery areas of fish species of transboundary significance [■]

Improving the scientific basis for the identification of fisheries refugia

As noted above, a constraining factor in the further development of a regional system of fisheries *refugia* is the scarcity of information relating to the early-life history of the majority of significant transboundary species in the South China Sea and Gulf of Thailand. This led, during 2006-2008, to the development of a collaborative programme of technical consultations, working group meetings and training workshops with SEADFEC aimed at improving the scientific basis for the identification of fisheries *refugia*. This involved a comprehensive review of past and ongoing fish early-life history research and the compilation of information on known spawning and nursery areas for important fish species in the Gulf of Thailand and South China Sea. It was noted that past research activities conducted in the 1970s and 1980s largely focused on the identification of spawning areas and migratory routes for short mackerel (*Rastrelliger* spp.), round scads (*Decapterus* spp.), anchovy, and neritic tuna. The RWG-F agreed that there may be some limitations in the use of this research for the identification of spawning *refugia* due to possible effects, during recent decades, of oil and gas industry development in the Gulf of Thailand on fish migratory routes (UNEP, 2007b).

The RWG-F concluded that information and data collected through collaborative research activities initiated by SEAFDEC in the mid-1990s would provide a temporally relevant information base for use in identifying current spawning and nursery areas. These research activities involved cruises conducted using the SEAFDEC Research Vessel *M.V. SEAFDEC* in the following areas: the Gulf of Thailand and the East Coast of Peninsular Malaysia; the West Coast of Sabah, Sarawak, and Brunei Darussalam; the West Coast of Luzon, Philippines; and in Vietnamese waters. Larval fish sampling was undertaken at 249 stations using bongo nets in the period of the post-northeast monsoon (April-May) from 1996 to 1999. The results of these larval fish surveys were used to assist in developing a better understanding of spawning (sources) and nursery (sinks) locations for important species. Drawing on these data, the group worked with SEAFDEC scientists to map the distribution and abundance of the larvae of important demersal and pelagic fish species in the South China Sea.

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

A key constraint in the future development of the regional system of fisheries *refugia* is a shortage of information regarding fish life-cycles and critical habitat linkages in

Southeast Asia. SEAFDEC has been working to fill this information gap by including larval and juvenile fish surveys as part of its regular fisheries research cruises; however, the region has faced difficulties in the processing of samples due to limited expertise in national fisheries departments. In this connection, a joint UNEP/GEF SCS Project-SEAFDEC "Regional Training Workshop on Larval Fish Identification and Fish Early Life History Science" was convened at the SEAFDEC Training Department from 16th to 31st May 2007. This course was aimed at building regional capacity in the processing and identification of larval fish samples collected during regular SEAFDEC research cruises. This was followed by an "Advanced Regional Training Workshop on Larval Fish Identification" (25th May to 14th June 2008) and enabled the formal establishment of a 'Network of Southeast Asian Larval Fish Scientists' within the framework of SEAFDEC.

In addition to the larval fish identification training initiative, the RWG-F also identified the need to build capacity among middle to senior level fisheries managers for the establishment and management of fisheries *refugia* in the region. A joint UNEP/GEF SCS Project-SEAFDEC 'Regional Training Workshop on the Establishment and Management of Fisheries *refugia*' was therefore convened at the SEAFDEC Training Department from 28th October to 10th November 2007 with 25 young fisheries and environment professionals attending from SCS project countries. The participants in these training events subsequently conducted national 'echo-seminars' on the fisheries *refugia* concept involving staff of national and provincial fisheries and environmental agencies.

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

Strengthened enabling environment

Regional guidelines on the use of fisheries *refugia* in capture fisheries management were developed and endorsed inter-governmentally for inclusion in the ASEAN SEAFDEC Regional Guidelines for Responsible Fisheries in Southeast Asia. The *refugia* concept was then included in the following national fisheries policies and plans as a priority tool for improved fisheries habitat management: Fisheries Law of Cambodia; South China Sea Fisheries Management Zone Plan in Indonesia; the Comprehensive National Fisheries Industry Development Plan in the Philippines; Thailand's Marine Fisheries Policy; and the National Plan for the Management of Aquatic Species and Habitats in Vietnam. On the basis of this, a programme of targeted actions for operating a regional system of fisheries *refugia* was developed and included in the intergovernmental Strategic Action Programme for the South China Sea.

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

In this connection, the 44th meeting (June 2013) of GEF council endorsed the development of a full-sized GEF International Waters project entitled "Establishment and Operation of a Regional System of Fisheries *refugia* in the South China Sea and Gulf of Thailand" to test the *refugia* approach. This project will be executed regionally by SEAFDEC in partnership with six participating countries.

Experiences in the uptake of the fisheries refugia concept: Use of a concept relevant to stakeholders

The fisheries *refugia* concept has been well received at all levels and has been utilised within the participating countries to build partnerships and to enhance communication between the fisheries and environment sectors. A relevant example is the experience of Vietnam in the use of fisheries *refugia* as a tool for integrated fisheries and habitat management in the PhuQuoc Archipelago. The extensive seagrass meadows adjacent to the Ham Ninh commune of PhuQuoc represent eight percent of the total known area of seagrass in the South China Sea (UNEP, 2008b). They support a variety of economically important species, including swimming crab, cuttlefish, shrimp, rabbitfish, octopus, strombus snail, and seahorse. The species are harvested using a wide range of fishing gear and practices, including gill nets, demersal seines, pelagic purse seines, demersal trawl, push nets, traps, intertidal gleaning and raking, and hookah diving (UNEP, 2007c).

The intensity of fishing operations in the near shore waters of the site are such that serious community concern was expressed regarding the degradation and loss of seagrass habitat as a result of fishing and consequent effects on the longer-term availability of local fish resources critical for local income and food. The widespread use of active fishing gears, such as demersal trawls and push nets, in seagrass areas of the site was noted as a key source of conflict among fisherfolk. As a strategy to improve communication between fisheries and environment managers in addressing this issue, the fisheries *refugia* concept was introduced to the PhuQuoc Management Board responsible for coral reef and seagrass management as a means of improving the management of fish stocks and habitat links at Ham Ninh (UNEP, 2007c). The fisheries *refugia* concept was well received by the KienGiang Provincial Department of Science and Technology (DoST) and

Department of Fisheries (DoF), as well as representatives of the Ham Ninh commune, as it aligned closely with local knowledge on fish migrations and patterns of availability, seasons of reproduction and areas in which fish are caught. It was noted in several commune consultations at that site that the *refugia* concept and its focus on life cycle and habitat linkages was more relevant to local stakeholders than scientific concepts such as representativeness, comprehensiveness, and uniqueness that community members had previously been introduced to in discussions on MPA planning.

Emphasis on sustainable use rather than prohibition of fishing

Subsequent consultations undertaken with commune fisherfolk, fish traders, and women involved in inshore gleaning and processing at Ham Ninh revealed that, by emphasising the sustainable use aspects of *refugia* rather than the no-take approach adopted as part of conventional MPA systems, adverse reactions at the community level were avoided. This was viewed as being a necessary prerequisite to any dialogue regarding improved fishing practices within the site. The acceptance of the approach enabled the development of a collaborative pilot activity by DoST, DoF, and the PhuQuoc MPA Authority, border army, fisherfolk and fish traders of the Ham Ninh Commune to establish and manage a pilot fisheries *refugia* site at the Ham Ninh seagrass area. The objective of this pilot initiative is to improve the integration of fisheries and seagrass habitat management at Ham Ninh through the establishment and management of fisheries *refugia* to improve the long-term security of fisheries yields and to reduce the rate of seagrass degradation and loss. Specific activities included: development of an inventory of fisheries *refugia* sites for important fish species, including seasonality of spawning and age/size of recruitment from nursery areas for key species; preparation of a fisheries profile for Ham Ninh commune; identification of specific fisheries and habitat management issues at the site; and ongoing cooperative management of the Ham Ninh *refugia* site by KienGiang's Department of Fisheries and local MPA Authority.

The fisheries *refugia* concept was also used successfully by the National Fisheries Research and Development Institute of the Philippines' Bureau of Fisheries and Aquatic Resources to facilitate the resolution a long-running conflict between the fisheries and environment sectors in the Visayan Sea. As a result of intensive inshore fishing pressure, environmental NGOs had lobbied for the prohibition of fishing that was not feasible, at least, in the short term, due to high levels of local community dependence on fishing. Parties to the dispute subsequently reached agreement on the use of the fisheries *refugia* approach to identify critical areas of habitat to be regulated and managed rather than adopting total closure (UNEP, 2007b).

Focus on fish life-cycle and critical habitat linkages

While many Southeast Asian communities have traditions of local fisheries management the rapid development of fisheries over the past 50 years has contributed to the erosion of these structures. Prior to the rapid uptake of demersal trawl fishing in the 1960s, fisheries were characterised by the use of mainly passive fishing gear to target small pelagic species supplying local markets (Pauly and Chuenpagdee, 2003). Community level management at that time included rules controlling the times and locations of fishing based on community knowledge of fish movements and reproduction (Ruddle, 1994). In contrast, the imposition of closed areas and seasons by central governments over past decades has largely focused on restricting the levels of overall trawl fishing effort. While this has recently been refined to restrict the use of destructive push nets and trawl fishing in some areas, existing closed areas have rarely been designated from the perspective of the nature of the habitats contained in such areas and the essential contribution of those habitats to fisheries (UNEP, 2007a). This emphasis on fish life-cycle and critical habitat linkages will likely assist with regional efforts to develop co-management in small-scale fisheries as it will allow for the design of community level rules that align more narrowly and explicitly to the needs of communities.

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

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

Comparisons of MPAs and fisheries *refugia*

Empirical evidence of an overall increase in fishery benefits following the establishment of an MPA is still controversial as increased catches frequently do not compensate for the decreased area of fishing grounds. In addition, MPA models have shown that, the effects on fisheries yield are highly dependent on a number of factors, e.g., dispersal in the larval, juvenile and adult stages, configuration of the reserve, and the status of the fishery. It is argued here that traditional MPAs are unlikely to enhance fish stocks and catch in the South China Sea as they are directed towards achieving the wider objectives of biodiversity conservation that often precludes adequate consideration of the life history and population dynamics of fishery species. The fisheries *refugia* concept has been developed to redress this imbalance. Experience in its application suggests that the *refugia* approach may potentially bring greater long-run benefits to the fisheries and environmental sectors in achieving mutually acceptable outcomes.

In the case of MPAs, the objectives are often broadly focussed at the ecosystem level rather than on fisheries, while the sites are selected on the basis of biodiversity criteria rather than on their significance to the life cycle of the species concerned. Similarly, the focus on protection rather than sustainable use has made MPAs generally less acceptable than *refugia* at the level of the primary stakeholders (fisherfolk and local government officers). In the Southeast Asian region, where the focus of fisheries *refugia* is on the benefits to fisheries in terms of food security objectives rather than a primary focus on biological diversity, this has resulted in its wider acceptance.

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

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

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

Significance of the fisheries refugia approach

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

Conclusions

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

References

Christensen, V., 1998. Fishery-induced changes in a marine ecosystem: insight from models of the Gulf of Thailand. *J. Fish. Biol.* 53 (Suppl. A):128-142.

FAO, 2002. Report of the Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem. Reykjavik, Iceland, 1-4 October 2001. *FAO Fisheries Report No. 658. Rome, FAO.* p. 128.

FAO, 2003. The Ecosystem Approach to Fisheries. No. 4, Suppl.2. *FAO Technical Guidelines for Responsible Fisheries*, Rome, p. 112.

FAO, 2007. *The State of World Fisheries and Aquaculture 2006*. Food and Agriculture Organization of the United Nations, Rome, p. 180.

Gell, F. R., C. M. Roberts, 2003. Benefits beyond boundaries: the fishery effects of marine reserves. *Trends Ecol. Evol.* 18 (9): 448-456.

Hilborn, R., K. Stokes, J. J. Maguire, T. Smith, L. W. Botsford, M. Mangel, J. Orensanz, A. Parma, J. Rice, J. Bell, K. L. Cochranek, S. Garcia, S. J. Hall, G. P. Kirkwood, K. Sainsbury, G. Stefansson and C. Walters. 2004. When can marine reserves improve fisheries management? *Ocean Coast. Manage*. 47: 197-205.

Lundgren, R., D. J.Staples, S. J. Funge-Smith, J. Clausen, 2006. Status and Potential of Fisheries and Aquaculture in Asia and the Pacific 2006. *FAO Regional Office for Asia and the Pacific, RAP Publication 2006/22.* p. 62.

Paterson, C., I. Try, P. Tambunan, N. Barut, P. Saikliang, M. S. Dao, S. Chullasorn, 2006. Establishing a regional system of fisheries *refugia*. *Fish for the People* 4 (1): 22-27.

Paterson, C. J., J. C. Pernetta, S. Siraraksophon, N. B. Armada, 2012. Fisheries *refugia*: A novel approach to integrating fisheries and habitat management in the context of small-scale fishing pressure, *Ocean Coast. Manage*. (2012), http://dx.doi.org/10.1016/j.ocecoaman.2012.12.001

Pauly, D., 1997. Points of view: putting fisheries management back in places. *Rev. Fish. Biol. Fishes* 7: 125-127.

Pauly, D., R. Chuenpagdee, 2003. Development of fisheries in the Gulf of Thailand large marine ecosystem. In: Hempel, G., Sherman, K. (Eds.), *Large Marine Ecosystems of the World. Elsevier, B.V*, pp. 337-354.

Roberts, C. M., J. P. Hawkins, 2012. Establishment of Fish Stocks Recovery Areas. Directorate General for Internal Policies. Policy Department B. Structural and Cohesion Policies. Fisheries European Parliament, Note IP/B/PECH/2012- 53: p. 64.

Roberts, C. M., N. V. C. Polunin, 1993. Marine Reserves e simple solutions to managing fisheries. *Ambio* 22: 363-368.

Ruddle, K. A., 1994.A Guide to the Literature on Traditional Community-based Fishery Management in the Asia-pacific Island Tropics. *Fisheries Circular, FAO, Rome, Italy*. No. 869. FIPP/C869.

SEAFDEC, 2006.Supplementary Guidelines on Co-management Using Group User Rights, *Fisheries Statistics, Indicators, and Fisheries refugia. Southeast Asian Fisheries Development Center, Bangkok, Thailand*, p. 84.

UNEP, 2005. Reversing environmental degradation trends in the South China Sea and Gulf of Thailand. *Report of the Fifth Meeting of the Regional Working Group on Fisheries. UNEP/GEF/SCS/RWG-F.5/3*.

UNEP, 2006a. Reversing environmental degradation trends in the South China Sea and Gulf of Thailand. *Report of the Sixth Meeting of the Regional Working Group on Fisheries. UNEP/GEF/SCS/RWG-F.6/3*.

UNEP, 2006b. Reversing environmental degradation trends in the South China Sea and Gulf of Thailand. *Report of the Seventh Meeting of the Regional Working Group on Fisheries. UNEP/GEF/SCS/RWG-F.7/3*.

UNEP, 2006c. Reversing environmental degradation trends in the South China Sea and Gulf of Thailand. *Report of the Sixth Meeting of the Regional Scientific and Technical Committee. UNEP/GEF/SCS/RSTC.6/3*.

UNEP, 2007a. National Reports on the Fish Stocks and Habitats of Regional, Global and Transboundary Significance in the South China Sea. *UNEP/GEF/SCS Technical Publication No. 15*.

UNEP, 2007b. Reversing environmental degradation trends in the South China Sea and Gulf of Thailand. *Report of the Eighth Meeting of the Regional Working Group on Fisheries. UNEP/GEF/SCS/RWG-F.8/*3.

UNEP, 2007c. Coral Reefs Demonstration Sites in the South China Sea. *UNEP/GEF/ SCS Technical Publication No. 5*.

UNEP, 2008a. Strategic Action Programme for the South China Sea. *UNEP/GEF/SCS Technical Publication No. 16*.

UNEP, 2008b.National Reports on Seagrass in the South China Sea. UNEP/GEF/SCS Technical Publication No. 12.

UNEP, 2008c.Fisheries *refugia* as a Tool for Integrated Fisheries and Habitat Management at PhuQuoc Archipelago. South China Sea Lesson Learned Note No. 3, Viet Nam.

Available online at: www.mbai.org.in doi: 10.6024/jmbai.2014.56.1.01750s-10

Exploratory drilling for hydrocarbon resources in the Cauvery basin: Potential impacts on artisanal fishery and fishing grounds of Sri Lanka

J. M. P. K. Jayasinghe
Department of Fisheries and Aquaculture, Faculty of Livestock Fisheries and Nutrition, Wayamba University of Sri Lanka, Makadura, Gonawila, Sri Lanka.

*Correspondence e-mail: jmpkjaya@gmail.com

Received: 26 Feb 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Fisheries sector contribute around 1.7 to the GDP and provide 65% of the animal protein requirement of the communities in Sri Lanka. Present per capita fish availability of Sri Lanka is 16.1 kg, and is expected to increase to 21 kg. The sector provides employment to around 6,50,000 people. Marine fish production contributes around 85% to the total fish production and is the most important sub sector in the fisheries industry of the country. The government of Sri Lanka has identified five blocks in the Cauvery basin off the west coast of Sri Lanka for exploratory drilling for hydrocarbon resources and production upon successful discovery. These blocks are in artisanal fishing grounds where fishers from 200 bordering villages are engaged in fishing and fishery related activities. Main activities associated with hydrocarbon exploration include seismic exploration, structural emplacement, well drilling, decommissioning or well abandonment. Hydrocarbon exploration activities will restrict the areas available for fishing and obstruct the navigational paths of the fishing vessels. Leakages from drilling equipments, ballast water discharges from dredging vessels, mud and dredging material discharges, accidental oil spills and oil leakages from ships are other concerns. There will be movement restrictions to fish and disturbances to fish due to sound waves. Socio-economic impacts on fishermen due to exploratory activities include loss of opportunities for fishing, restrictions on fishing grounds, reduced fishing time, reduced fish catches and health hazards. Chemical pollution due to discharge of drill mud, drill cutting, bilge water and sewage and accidental spills and blowouts can affect the general health of fishers. Mitigation of impacts due to seismic exploration, structural emplacement, well drilling, decommissioning or well abandonment and compensation for artisanal fishermen in the event of reduced fishery activities are suggested to minimize social and environmental impacts of the exploration activities.

Keywords: *Marine fisheries, hydrocarbon exploration, artisanal fishing, environmental impacts.*

Introduction

Government of Sri Lanka has identified commercially exploitable oil and gas reserves in the Cauvery basin area within the territory of Sri Lanka which is an extension of sedimentary rocks offshore from South India. The Petroleum Resources Act, No. 26 of 2003 of Sri Lanka makes provision for the establishment of a Petroleum Resources Development Committee (PRDC) and a Petroleum Resources Development Secretariat (PRDS). The PRDS is the government agency entrusted to administer all petroleum operations in Sri Lanka. The Act makes provisions to PRDS for the regulation of petroleum operations and grant of licenses for exploration, development and production of petroleum in Sri Lanka. There are no existing exploration licenses issued for the Cauvery basin area. Past exploration activities in this area was more than 25 years ago and consisted of three exploratory wells and a number of 2D seismic programs.

The Sri Lanka government has identified five blocks (C1 to C5) varying from 4710 sq.km to 2146 sq.km in size in the Cauvery Basin (northwest coast of Sri Lanka; Fig. 1) for exploratory drilling for hydrocarbon resources and production upon successful discovery. These blocks are located in shallow areas (Table 1) in the continental shelf and in artisanal fishing grounds. The coastal area that may be affected from the dredging activities includes four fishing districts with rich demersal fishing grounds in Sri Lanka. The fisheries sector contributes around 1.7% to the GDP and significantly to the animal protein requirement of the communities. Sixty five percent of animal protein consumed in Sri Lanka is from fish and fishery products. The present per capita fish availability is 16.1 kg, and is expected to increase to 21kg.

Table 1. Blocks identified for hydrocarbon exploration in Cauvery basin and their extent.

Block	Area (sq km)	Remarks
C-1	2,539.12	Shallow water
C-2	2,146.96	Shallow water
C-3	2,424.02	Shallow water
C-4	4,700.15	Shallow water
C-5	3,915.68	Shallow water

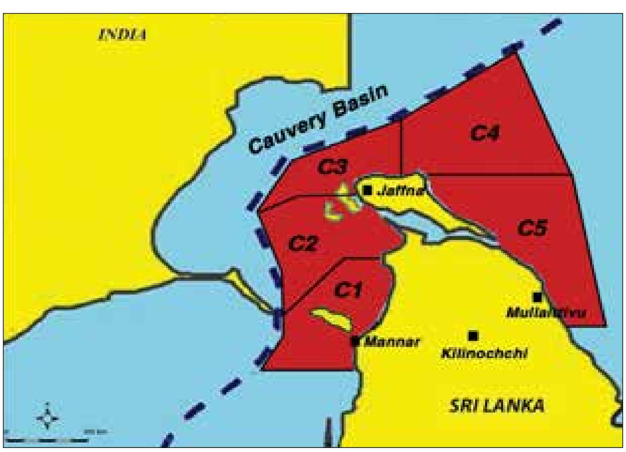


Fig. 1. Areas earmarked for the hydrocarbon exploration in the Cauvery Basin.

Exploratory activities for hydrocarbons include activities that can affect the fishing environment, fishery resources, fish breeding grounds, fish migration and recruitment. There is a possibility of reduction in fish production affecting the livelihood and income of the fishing community living in the bordering fishing villages. There is a need to assess the present status of fisheries and potential impacts of the exploratory activities with a view of identifying possible interventions to minimize adverse impacts.

Material and methods

The present paper is a consolidation of the available information, literature surveys of the coastal fisheries of Sri Lanka and personal interviews. Due to civil conflict in Sri Lanka, recent publications on different aspects of fisheries are limited. Information available are mainly with the Department of Fisheries and Ocean Resources. Only a few studies have been initiated by Universities in these areas (e.g., Piratheepa and Edirisinghe, 2011). For the present study, data on catch, seasonal variations and species composition were collected from the Ministry of Fisheries and Aquatic Resources (MOFAR), from published statistics, and from interviews with officers in head office and regional offices of assistant directors in the Mannar and Jaffna districts in the northwest coast of Sri Lanka. Published information and reports available at NARA (National Aquatic Resources Research and Development Agency), BOBP-IGO and Bay of Bengal Large Marine Ecosystem (BOBLME) program were also used as a source. Fisheries inspectors/office bearers/members of fisheries societies, and community leaders were consulted. A few selected landing sites were also visited.

Results and discussion

The coastal districts that would be affected to a greater extent by the dredging activities include Mannar, Jaffna, Kilinochchi, and Mullaithivu to a lesser extent. The total length of the coastline bordering the five blocks is approximately 480 km and there are around 200 fishing villages located in these coastal districts. Mannar and Jaffna are the major contributors to fish catches in the Northern Province and to the coastal fish production in Sri Lanka.

In 1983, prior to the internal conflict, the fisheries sub-sector in the Northern Province played an important role in the regional economy and also contributed substantially by means of providing employment, income and nutrition to the communities. Contribution from three districts (Mullaithivu, Jaffna and Mannar) of the Northern Province to the total marine fish production of the country was 40%, of which, 26% was from Jaffna District alone (MOFAR, 2012).

Fishing has been identified as the primary livelihood of the coastal communities in Mannar, Jaffna, Kilinochchi and Mullaithivu. Communities are engaged in preparation of dry fish, seaweed and holothuroid collection, and ornamental fish farming. Palk Bay and Gulf of Mannar are very rich in fishery resources due to wide continental shelf (Berg, 1971;

BOBP, 1989). Majority of the fishermen are engaged in artisanal fishery and there is a trend to increase fishing with mechanized crafts.

According to MOFAR (2009) the highest number of active fishermen (15,195) is recorded in Jaffna, followed by Mannar district (7,900). There are 750 fishermen in Kilinochchi and 1200 in Mullaithivu, where majority are engaged in lagoon fishery. There is a significant reduction in the number of fishermen in 2009 when compared to the year 1982 except in Mannar (Table 2). However, in Kilinochchi, the total number of active fishermen increased to 912 by the year 2012 (Raveenthira, personal communication) and a similar trend is expected in other districts as well in the near future.

Table 2. Number of active fishermen before and after the civil conflict

Year	Killinochchi	Mullaitivu	Jaffna	Mannar
1982	1,103	3,183	24,839	5,684
2009	750	1,200	15,195	7,900

Source: Fisheries Statistics MOFAR (2010)

With the targeted development activities of the Sri Lankan government, it is expected that the number of fishermen will increase, indicating greater dependence on the fishery resources from the area which is now earmarked for dredging.

When compared to the year 2009, contribution by the districts of Mannar (32.7%) and Jaffna (59.7%) were high in 2012 (Table 3). These two districts are responsible for increase in the overall coastal fish production of the country. Relaxation of fishing limitations after the conflict, and supply of fishing boats and gear to fishers are the main contributory factors identified for this increase (MOFAR, 2011). Ninety percent of fishermen are engaged in artisanal fishery and the majority (72%) of them use non-mechanized traditional boats. Cast nets, drift nets, gill nets, set nets (for crabs), bottom nets, long line, hooks (for cuttlefish) and beach seine are the common fishing gears used. Details of crafts and gears used during the two periods are compared in Table 4.

Day boats (1 day), outboard motor boats (OFRP), motorized traditional boats (MTRB) and non-mechanized traditional boats (NTRB) are the main types of fishing crafts engaged in harvesting the fishery resources. In addition, beach seines are also operational. There is a significant increase in OFRP and MTRB in recent years when compared to the number of fishing boats operating before the conflict in 1982 and hence, it is expected that the number of different types of boats will increase in the coming years.

Accurate information on species composition and seasonal variation of different species in the catch are not available. No attempt has been made to assess the fishery resource in a scientific manner in the recent past due to the conflict. Information on fishing effort are not available.

Reasonable amount of information on finfish and shellfish resources in Gulf of Mannar and Palk Bay of Indian side are available (George , 1973a,b; Hussain *et al.*,1985; Sivalingam, 2005). The Gulf of Mannar and Palk Bay support a large number of fisher population along the coasts of India and Sri Lanka. Fisheries of this region are typical of tropical

Table 3. Fish production in fisheries districts bordering the areas earmarked for hydrocarbon exploration in 2012 (Source: MOFAR 2012)

Fish landings (t)	1983	1990	1995	2000	2005	2007	2008	2009	2012
Northern province	75,740	24,150	4,500	8,100	24,410	15,250	13,840	21,210	59,340
Coastal fish landingsof Sri Lanka	184,740	145,790	217,500	263,680	130,400	252,670	274,630	293,170	477,220
% contribution to national fish production	40	16	2	3	18	6	5	7	14.2

Table 4. Number of fishing boats before (1982) and after (2009) the conflict

Boat types	Killinochchi		Mullaitivu		Jaffna		Mannar	
	1982	2009	1982	2009	1982	2009	1982	2009
Multi-dayboats (IMUL)	-	-	-	-	-	-	-	-
Dayboats (I DAY)	-	-	-	-	60	20	24	60
Outboard motor boats(OFRP)(OFRP)	82	100	196	200	298	1,000	86	1,200
Motorized traditional boats (MTRB)(MTRB)	24	100	138	100	192	270	81	130
Non mechanized traditional boats (NTRB)	221	100	221	120	3,562	1,000	607	500
Total	327	300	555	420	4112	2290	798	1890
Beach seines (NBSB)	5	3	70	15	110	83	115	95

Source: Fisheries Statistics (MOFAR 2011) fisheries. Main fish stocks tend to be concentrated along the continental shelf (BOBP, 1986) with high biodiversity leading to multi species fisheries. Around 450 species of fish belonging to 107 families have been recorded (BOBP, 1986). Of these, 122 species inhabit the reef areas and about 32 species in the seagrass beds and about 40 species in the near-shore as well as mangrove areas.

According to the information available, the daily average fish production in Mannar district during 1940s was around 29.3 tonnes. Vankalai, Mannar, Talaimannar and Pesalai were the main fish landing centres then. Stock assessment carried out by the vessel *Dr. Fridtjof Nansen* during 1978 to 1980 (Blindheim *et al.*, 1979) showed that fish biomass of the northwestern coastal waters was around 71,600 t, contributing about 16% to the total biomass estimated for the entire country. The results of deep sea trawl fishing trials carried out by the above vessel revealed the presence of lobsters, shrimps and finfish in considerable quantities in Gulf of Mannar.

The exploratory fishing surveys conducted under the BOBP program of Palk Bay, Palk Strait and Point Pedro showed maximum sustainable yield (MSY) as 30,000 t (BOBP/REP/23).

Activities associated with petroleum exploration may include conduct of seismic and other geophysical surveys and exploratory drilling of wells. If exploratory drilling indicates petroleum accumulations with commercial potential, production activities may follow. Production activities may involve drilling of development wells, installation and operation of rigs and associated equipments, installation and operation of production facilities and restriction or abandonment of fishing activities. However, the nature and scale of potential production activities could not be assumed at this stage.

At present the major commercial activities in the area is fishing. According to the MOFAR there are 1990 fisher households and 22,500 dependents directly or indirectly for their livelihoods in the project area. For the people of the Mannar area, fishing is the main source to sustain their livelihoods. Due to the location of Gulf of Mannar close to pearl banks, seaweed beds, coral and lime stone reef areas, the area is environmentally very sensitive, biologically productive and rich in biodiversity. The proposed project area includes most productive shallow trawling grounds of Sri Lanka although now trawling has been banned since the late 1970s (Sivasubramanium and Maldeniya, 1985).

Fishers are also involved in shrimp fishery, lobster fishery, collection of holothurians, collection of oysters, and other edible bivalves and seaweed collection which are the other marine resource based activities. About 90% of the fishers are artisanal and the rest work in single day mechanized boat operations. The planned fisheries development activities of the government include distribution of fishing gear and boats and expansion of fishery related infrastructure in the area aiming at increased fish harvests to provide more livelihood opportunities to coastal communities.

The proposed project activities can pose a threat to sensitive coastal ecosystems and habitats in the coastal area including estuaries, mangroves, salt marshes, coral reefs, lime stone reefs, seaweed beds, pearl banks, sea grass beds, shrimp and finfish fishing grounds and the shallow continental shelf with high biodiversity.

Identified impacts of oil exploration activities on fishery resources and fishing include, movement restrictions of fish, discharge of pollutants, disturbances to fish due to sound waves, movement of offshore supply and crew change vessels, helicopter sounds and sound waves (NEERI, 2004).

Creating a navigational zone with a radius of 500 to 1,000 m around seismic vessels and oil platforms, abandoned platforms and their fragments on the sea bed, suspended well heads for a period of time, and abandoned debris on the sea bed can cause problems to fish populations and fishing activities. Mortality of fish during sound wave generations, disturbances to spawning and fish egg and larval developments have the potential to reduce the fishery resources. Only positive impact identified is that the abandoned structures after drilling operations may act as fish aggregation devices.

Chemical pollution due to discharge of drill mud, drill cutting, treated bilge water and treated sewage and accidental spills and blowouts (pH, Mn, Cr, Ni, Cu, Zn, Cd, Hg, Pb, CN, oil & grease, TPH omit and toxicity) are likely to affect the health of fishes and the ecosystem.

Increased sedimentation and turbidity could affect fish production in several ways. Reduced light penetration could lead to reduced photosynthesis which could lower the primary productivity and density of plankton available for fish and crustaceans. Oil spills, ballast water and oil and chemical pollution could affect the coral reefs that act as an important ecosystem, around which most of the current fisheries activities are concentrated. Other fishing activities for oysters and other shells, echinoderms and sea weeds are likely to be affected due to dredging and subsequent siltation. Increased sedimentation could lead to high levels of egg mortality due to adherence of particles to eggs. There can be some physical impacts on the present fish landing sites.

Conclusion

Oil exploration activities can significantly affect fishery resources off the northern province of Sri Lanka and the livelihood of the fishing communities in the bordering districts. The waste generated from the drilling operations has to be dealt with in a manner, in compliance to applicable MARPOL standards to reduce hazards and environmental impacts, and direct and indirect impacts on fishery resources. Preventive measures (e.g., avoidance of dredging during the breeding season of commercially important fish and crustaceans) have to be investigated. Any possible physical impacts on the fish landing sites need to be assessed. Plans need to be developed for obtaining compensation to the local communities in the event of reduced fishery activities, oil spills etc. and institutions for preparation of plans have to be identified.

There is no recent assessment of fishery resources and breeding seasons of commercially important fishes and crustaceans. Long term impacts of siltation and pollution on key species at different stages of their life cycle, assessment of livelihood status of communities and impacts on biodiversity are some of the areas to be investigated.

References

Berg.1971. Investigations on the Bottom Conditions and the Possibilities for Marine Prawn and Fish trawling on the North and East Coast of Ceylon. *Bull. Fish. Res. Stn. Ceylon.* 22(1 & 2) 53-88.

Blindheim, J, G. H. P. de Bruin & G. Saetersdal. 1979. A Survey of the Coastal fish resources of Sri Lanka, Report on Survey with the R/V Dr. Fridtjot Nansen.

BOBP, 1986. Summary Report of BOBP Fishing Trials and Demersal Resources Studies in Sri Lanka.BOBP/REP/23.

BOBP, 1989. Shrimp Fisheries in the Bay of Bengal. BOBP/WP/58.

George, M. J. 1973a. The lobster fishery resources of India. *Proc. Symp. Living Resources of the Seas around India, 1968 Mandapam Camp* p. 570-580.

George, M. J. 1973b. An assessment of the fishery resources for non-penaeid prawns in India. *Proc. Symp. Living Resources of the Seas around India, 1968 Mandapam Camp* p.557-562

Hussain, S. A., R. Sugathan, and R. Pandian. 1985. "Importance of Vedaranyam Swamp as a Major Ecological Entity in the South-east Coast of India." Symposium on Endangered Marine Animals and Marine Parks, Cochin, India: Pre-symposium publication. Vol. 3.

Ministry of Fisheries and Aquatic Resources (MOFAR), 2009. Fisheries Statistics.

Ministry of Fisheries and Aquatic Resources (MOFAR), 2010. Fisheries Statistics.

Ministry of Fisheries and Aquatic Resources (MOFAR), 2011. Fisheries Statistics.

National Environmental Engineering Research Institute (NEERI), 2004. Environmental impact assessment of proposed Sethusamudram ship canal project. 426pp

Piratheepa, S. and U. Edirisinghe. 2011. Shrimp species in coastal fishery in Kakkaaithivu coastal areas in Jaffna. Proc. of 17th annual Sessions SLAFAR . Colombo.

Sivalingam,S. 2005. General features and fisheries potential of Palk Bay, Palk Strait and its environs. *J. Natn. Sci. Foundation* Sri Lanka 33(4):225-232.

Sivasubramanium, K. and Maldeniya, R. 1985. A review of the results of demersal fish resources surveys beyond Sri Lanka. BOBP/WP/41.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-11

Development of closed seasons and areas in the Gulf of Thailand

Pirochana Saikliang
Marine Fisheries Research and Development Bureau, Department of Fisheries, Thailand.

*Correspondence e-mail: pirochas@hotmail.com

Received: 01 Mar 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Thailand has been placed in the top ten fisheries production countries in the world in marine capture fisheries. However, increasing demand for protein sources, together with the rapid development and improvement of fishing gear and fishing techniques has resulted in major stock reduction of the Indo-Pacific mackerel and some other commercially important pelagic species in the Gulf of Thailand (GoT). Therefore, the Department of Fisheries Thailand (Thai-DoF) planned to establish fisheries *refugia* or closed seasons and areas in some part of the Gulf of Thailand and prohibit some kinds of fishing gear. The DoF monitored the changes in status of aquatic resources and also the fishing methods with the aim at determining appropriate measures from time to time for sustainable use of pelagic species. In the past 60 years (1953-2013), Thai-DOF implemented a total of 13 fisheries management measures on the development of fishing gears and fishing techniques including "Gulf Closing" in the southern areas (Prachaup Khiri Khan, Chumphon, and Surat Thani) with the aim of conserving spawning and nursery areas of aquatic resources in the GoT. The measures for conserving Indo-Pacific mackerel were also used as a basis for formulation and development of other conservation measures. Cancellation and revision of these measures were also made from time to time according to the change of status of fisheries resources, and to effectively manage aquatic resources for sustainable exploitation.

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

Introduction

The marine capture fisheries of Thailand are highly significant both nationally and internationally with Thailand being among the top ten countries world-wide in terms of fisheries production. Capture fisheries are dominated by "trawl fisheries" which mainly harvest demersal species. Pelagic fisheries are also significant and total production of pelagic species in 2011 was about 37.89% of overall production, of which 66.12% was harvested from the Gulf of Thailand (GoT). Indo-Pacific mackerel (*Rastrelliger brachysoma*) is one of the most important pelagic species for the Thai people being considered as "good meat and delicious". However, increasing demand for protein sources together with rapid development and improvement of fishing techniques resulted in stock reduction of the Indo-Pacific mackerel and some other commercially important pelagic species in the Gulf of Thailand during the 1980s.

The Gulf of Thailand is one of the most highly productive shallow water areas resulting from the high sediment and organic inputs, including nutrients from river runoff, that provide suitable conditions for high natural productivity. The Gulf of Thailand also supports high biological diversity and a study has shown that there are more than 4,300 aquatic species here (Sukhavisidh, 1996). Inter-annual variations in climate, including extreme events, are neither as extreme nor frequent as in the Andaman Sea and together with the wide continental shelf these conditions support important fishing grounds and permit the use of a variety on fishing gears including trawl nets, surrounding nets, gillnets and a variety of smaller gear types.

Traditionally capture fisheries in Thailand first operated in near-shore waters using stationary fishing gears such as bamboo stake traps. In 1925, surrounding nets or purse seines were introduced from China. Subsequently fishing operations evolved from the initial use of two small boats pulling the net from the mother boat, to the use of only a single main boat. At the same time as the fishing technology changed, the size of fishing boats was increased and the means of propulsion changed from the original rowed boats, to sailing boats, and finally motorized vessels. Japanese trawlers with engines were also introduced in the 1930s, but were not readily adopted by Thai fishermen at that time.

During the early development, Thai marine fisheries focused mainly on harvesting pelagic fish and concentrated on development and improvement of fishing gear and methods to increase fishing efficiency. Following the use of purse seines operated by two boats and the change to a single large size fishing boat, the so-called “Thai purse seine/regular purse seine” or “auan-chaloum” has become the dominant technology used by Thai fishers for catching Indo-Pacific mackerel (Phasuk, 1979).

Since the 1930s, aquatic resources have been increasingly harvested to meet the market demand with a resultant decline in stocks. Since the 1950s the Department of Fisheries Thailand (Thai-DoF) has monitored the changes in the status of aquatic species and also the fishing methods used, with the aim of determining appropriate measures for the sustainable use of pelagic species. Various management measures have been promulgated including mesh size regulation, fishing zone delimitation, and establishment of fishing and closed seasons. One of the important measures was the “Gulf Closing” that has been implemented in the Gulf of Thailand to prohibit some fishing activities operating during the spawning and nursing periods. Concurrently, such measures have also been implemented in the Andaman Sea.

This report presents the development of marine fisheries management in the Gulf of Thailand over the past 60 years. During the course of implementation on fisheries management measures, focus has been paid to conserve Indo-Pacific mackerel. Later, other commercially important species have also been included under these measures.

A history of measures implemented

Period One:1953

No measures were established prior to 1953 for the conservation and management of any marine resources including the Indo-Pacific mackerel (Hongskul, 1975). In 1953 Thai-DoF recognized that the Indo-Pacific mackerel in the GOT had been exploited in substantial quantities, and a Notification of the Ministry of Agriculture and Cooperatives (MOAC), dated 25th August 1953, was issued in order to

Fig. 1. Closed areas in the earlier period

conserve the Indo-Pacific mackerel stock by prohibiting the use of some fishing gear and methods during their spawning period. The prohibition focused on the use of specific types of fishing gear (such as large-scale Chinese purse seine, Thai purse seine etc.) operating in the area of southern Chumphon Province to the southern Gulf of Thailand from the first day of the fourth waning moon to the full moon day of the sixth (Fig. 1). However, in practice fishing vessels continued to operate in the prohibited area during the closed season.

Period Two: 1954-1967

Due to rapid of improvements and development of new fishing gear and methods for catching pelagic fish in the Gulf of Thailand, the pelagic fish catch, particularly Indo-Pacific mackerel, increased. However, from 1957, the catch of Indo-Pacific mackerel started declining. The Thai-DoF established a Technical Committee for Indo-Pacific mackerel Investigation Program to study the causes for the decline, in response to the requests and complaints from fishers.

In 1960, some of the fishers changed their fishing gear to otter-board trawl, which was introduced from Germany. Even though the overall production from pelagic capture fisheries was high during that time, it was found that the quantities of Indo-Pacific mackerel displayed a decreasing trend. Therefore, Notification of MOAC, dated 18th March 1959, was issued to prohibit the use of some fishing gears and practices including the purse-seine and encircling gillnets in the areas identified as spawning grounds of the Indo-Pacific mackerel. Exceptions were given to those who received individual fishing licenses (Phasuk, 1982). In addition, this notification also aimed to obtain catch data of Indo-Pacific mackerel from the fishers, through the use of logbooks provided by the DoF. In practice all fishers applied for licences and none were refused. Consequently fishing effort remained much the same as before.

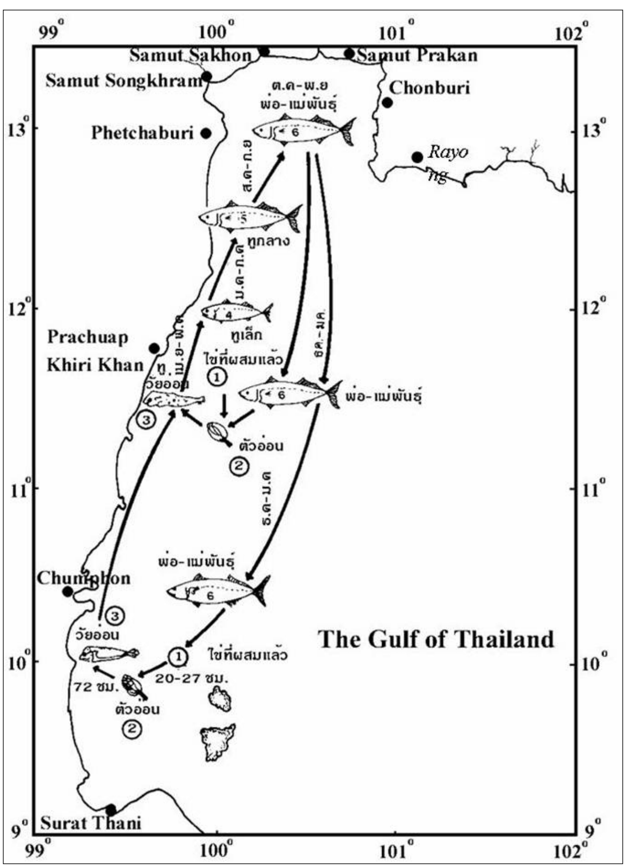


Fig. 2. Life cycle of the Indo-Pacific mackerel in the Gulf of Thailand (Boonprakob, 1974)

In 1962, Notification of the MOAC, dated 8th March 1962, was issued with the aim of defining the spawning duration of Indo-Pacific mackerel and to limit the mesh size in some fishing gear for catching small size Indo-Pacific mackerel. This was due to the heavy exploitation of the small size Indo-Pacific mackerel during the closed season. The closed season was extended for one month and divided into two periods as follows: The first from 15th January to 31st March which was the spawning period of Indo-Pacific mackerel; in this season the use of all types of fishing gear equipped with purse line and encircling gillnets were prohibited. The second from 15th April to 14th June which was the period of juvenile abundance; in this season the use of purse seine and mackerel encircling gillnets of mesh size smaller than 4.7 cm were prohibited. At the same time, Thai-DoF also issued the regulation that any fishers who wanted to engage in any fishing activity must receive individual permission in advance with the obligation to record catch data in the logbook (Phasuk, 1979). However, illegal and un-reported activities during the closed season continued to occur due to the DoF's weak capacity for law enforcement regulations. The life cycle of the Indo-Pacific mackerel in the Gulf of Thailand is shown in Fig. 2.

Period Three: 1968 to 1982

Overcapacity of fishing fleet continued and resulted in a serious problem over this period due to an increase in the number of fishing boats, as well as development and improvement of bottom trawlers in the Gulf of Thailand (Bunyubon and Hongskul, 1978). Modified trawlers for catching Indo-Pacific mackerel were developed and resulted in an increasing quantity of fish being caught by these vessels for many years (Boonprakob, 1974). In 1972, MOAC Notification dated 13th October 1972 was issued to prohibit the use of trawlers in the southern areas (Prachuap Khiri Khan, Chumphon, Surat Thani, and Nakhon Si Thammarat provinces), during the period from 1st February to 31st March. This regulation aimed to prevent trawlers from catching Indo-Pacific mackerel during the spawning period. This was based on the fact that between 17 and 22% of the catch taken from bottom trawlers and pair-trawlers was composed of spawners and juveniles.

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

Fisheries statistics for the Gulf of Thailand during 1974 to 1976 showed that Indo-Pacific mackerel juveniles continued to be exploited at a high rate, resulting in reduction of the number of mature individuals. The production of Indo-Pacific mackerel showed its lowest in 1977, when the catch was only half of that of the previous year. In 1977, a peak in the catch of Indian mackerel (*Rastrelliger kanagurta*) was recorded, which exceeded that of Indo-Pacific mackerel for the first time. The increase in Indian mackerel production probably resulted from the increased number of luring purse seine fishing vessels, from 100 in 1973 to 383 in 1977 (Phasuk, 1979).

Due to the shortage of gas in the domestic market, fishers started to lure fish by using lights generated by dynamo-motor, with capacities from 5 to 50 kW. The luring purse seine has become the common fishing practice since 1978 until the present (Sreungcheep, 1997). Over the period from 1979 to 1981, fishers began to use electronic equipments such as echo sounders and sonar for locating fish schools. Since then net hauler or power block had been used to minimize the number of crew during fishing operations.

Over the period from 1953 to 1977, it is recognized that a total of 5 Notifications related to management and conservation of Indo-Pacific mackerel were issued, aimed at protecting both the mature and juvenile stages of the Indo-Pacific mackerel. These notifications revised rules regarding the length of closed seasons, gear prohibition and other regulations that reflected changes in the status of the fishery. Control and enforcement of regulations were major constraints due to insufficient number of officials and surveillance vessels, and non-compliance of fishers in following the regulations (Phasuk, 1979). The fishers modified their gear and equipment in order to make their fishing gear different from those defined in the Notifications (Phusuk *et al.*, 1988).

It was found that the area of Prachuap Khiri Khan, Chumphon, and Surat Thani are also important as spawning and nursing grounds not only for the Indo-Pacific mackerel, but also for other aquatic species (Phasuk, 1982). It was obvious that during the years 1977 to 1983 the Thai DoF had attempted to revise the Notification issued in 1975 for effective management of marine capture fisheries, by prohibiting all types of fishing boats in order to protect not only Indo-Pacific mackerel but also other aquatic species (Phusuk *et al.*, 1988).

On the basis of the available data and information, the Pelagic Fisheries Investigation Unit of the Marine Fisheries Division, DoF had proposed to control the fisheries during the spawning and nursing period of Indo-Pacific mackerel by moving from closure of the whole area of the Gulf to closure of the specific spawning and nursing grounds for two months from 1st February to 31st March. Under this Notification, dated 13 October 1974, all types of fishing gears and methods were not allowed to operate, except the bamboo stake trap (Phasuk, 1982). The increasing number of trawlers in the Gulf resulted in the status of demersal resources reaching critical levels, since juveniles of both pelagic and demersal resources were in an over-exploited state.

Period 4: 1983 to 1997

During 1983 - 1984, large amounts of juvenile Indo-Pacific mackerel were caught contributing 27-30% to the total catch of mackerel (Srireungcheep, 1997). Therefore, Thai-DoF issued MOAC Notification dated 3rd March 1983, by revising the Notifications dated 19th October 1972 and 7th November 1986. All trawl nets and purse-seine with purse lines were not allowed to operate during the period from 1st February to 31st March (spawning period), and during 1st June to 31st July (nursery and juvenile period) for a total period of 4 months. This Notification was effective from 1st June 1983 to reduce the pressure of trawling and purse-seining on all demersal and pelagic resources especially the Indo-Pacific mackerel. However, this Notification was temporally suspended due to fishers' complaints, and then MOAC issued a Notification dated 6th May 1983 to support the cancellation. After 1984, the bamboo stake trap and encircling gillnet of mesh size larger than 4.7 cm were allowed to operate (Phasuk *et al.*, 1988).

Subsequently, MOAC issued Notification dated 28th November 1984 to revise the Notification dated 29th August 1983 by extending the closed season from 2 months to 3 months and again dividing it into two periods: the first phase, spawning period from 15th February to 31st March; the second phase, nursery and juvenile period from 1st April to 15th May of each year. Under this Notification, trawlers and otter board beam trawls were not permitted to operate during daytime and purse seines were prohibited for 45 days from 15th February to 31st March.

From 1980 onwards, the anchovy purse seine fishing fleets developed and expanded rapidly due to market driven demand, and the fishing fleet from the Andaman Sea moved into the Gulf of Thailand in the areas of Surat Thani and Chumphon Provinces. Anchovy fishers, who were affected by the existing measures, requested Thai-DoF to allow them to fish during the spawning period and noted that their fishing practices targeted mainly anchovies and had little by-catch and no effect on other economically important species (letter of complaint dated 2nd February 1984). Later, Surat Thani, Governor, requested the DoF to consider the proposal of anchovy fisheries and the Thai-DoF agreed to delay the implementation and instead issued a new Notification dated 11th January 1988. Based on this Notification, anchovy purse-seine was allowed to operate only in the daytime during closed season from 15th February 31st March.

The above Notifications reflected the problems of conflict among resource users, especially in Chumphon and Surat Thani Provinces. At the same time, the anchovy purse-seine fleet from the eastern port moved into the western part of the Gulf of Thailand with the use of light luring and small mesh size, which resulted in substantial catches of juveniles and other aquatic resources. Consequently, fishers from Chumphon and Surat Thani provinces requested the government to control the anchovy purse-seine fishery.

At the same time, Thai Fishermen Association submitted a complaint dated 14th April 1989 to DoF not to allow anchovy purse-seine to operate in the closed area and requested DoF to reconsider and repeal the measure for anchovy purse-seine. Together with the results from the Seminar on "Fishermen and Aquatic Animals Conservation" organized in Surat Thani province in December 1989, and the details of the joint meeting among governmental and private representatives on 8th March 1990, all parties agreed to delay the implementation of Notification dated 11th January 1988.

Thai-DoF issued the Order No. 7/2533 dated 3rd January 1990 with regard to appointment of the members of the committee to study and resolve the problems and complaints concerning anchovy fishing. The results showed that the distribution of anchovy eggs and larvae was extensive, covering the area from 1 - 40 nautical miles from shore during January to March. On the basis of this, Thai-DoF issued Notification dated 12nd February 1994, aimed to conserve anchovy resources, and prohibiting the use of some fishing gear that operated during spawning and nursery periods in specific areas. This Notification eventually caused cancellation of the Notification dated 11th January 1988. This also included the prohibition of daytime anchovy fishing during the period from 15th February to 15th May annually. This Notification resulted in the stabilisation of the Indo-Pacific mackerel catch in the Gulf of Thailand at about 90,000 metric tones annually for the next six years (Srireungcheep, 1997). In addition to the problems resulting from anchovy fishing, fishers tried to develop and change their fishing gears and methods to increase fishing efficiency, and to enable them to operate during the closed season. Indo-Pacific mackerel fishers modified their encircling gillnets (of mesh size over 4.7 cm) targeting mature Indo-Pacific mackerel and Indian mackerel by increasing the net length, which was not prohibited by the Notifications. The number of this type of gear increased rapidly (DoF, 1996). In the year 1996, it was found that the catch by using mackerel encircling gillnet from fishing boat of size less than 10 meters was approximately 90 kg/boat/trip. The catch by fishing boats of size 10 -14 m and > 14 m was 1,212 and 1,270 - 1,740 kg/boat/trip, respectively.

Period 5: 1998 to the present

From a study in 1998, it was found that average catch from the mackerel encircling gill net was 941 - 1,367 kg/trip during the prohibited period (in Prachaup Khiri Khan, Chumphon, and Surat Thani areas). More than 80% of the catch was Indo-Pacific mackerel mixed with Indian mackerel, carangids, other hardtail scad, flyingfishes, croakers and ponyfishes. This study found that the total length of individual Indo-Pacific mackerel ranged from 15.19 to 16.20 cm representing completely mature individuals (DoF, 1998). The encircling gill net fishing from February to June 1999 yielded a total fish catch of 6,316 tonnes, estimated as 86,365 mature individuals of Indo-Pacific mackerel. It was further calculated that such numbers of Indo-Pacific mackerel individuals could themselves produce 130,027 million mature individuals (Nakrobru and Saikliang, 2003).

At the same time, other developments were occurring in terms of fishing technology; fishers had improved the push nets by increasing the net size, using longer push sticks and operating with bigger boats and more powerful engines. Such gear is considered as a destructive fishing gear to various types of aquatic resources and benthic habitats. In addition, fishers modified the push net and anchovy purse-seine fishing boats to be used along with casting net, falling net, and lift net equipped with light for catching anchovy. A study from this type of fishing operation found that the catch included large numbers of juveniles of commercially important species. The results from the study on the status of marine fisheries development resulted in MOAC amending the 1984 Notification by issuing Notification dated 24th September 1999 encompassing areas of Prachuap Khiri Khan, Chumphon, and Surat Thani Provinces. The focus of this notification covered the spawning and nursery period from 15th February to 15th May annually, and specified prohibition of certain types of fishing gear as follows:

1. Pair trawl and bottom trawl changed to all types of motorized trawls except trawl net used from a single motorized boat of length less than 16 meters operating at night between sunset and sunrise.

2. Entangling net of mesh size lower than 4.7 cm, changed to entangling gillnet operated with motorized fishing boat for surrounding and entangling Indo-Pacific mackerel or similar method.

3. Surrounding net, the same as before, no revision.

4. Additional, prohibited fishing gears are: cast net, falling net and lift net that used generated electricity for catching anchovy; and push net that used motorized boats of length over 14 meters.

Following the announcement of these measures, various groups of fishers especially the Fishermen's Association of Lang-soun district, Chumphon Province did not accept them as they used mackerel encircling gillnet to catch Indo-Pacific mackerel during the closed season. The Thai-DoF sent an official team to explain the background and rationale of this measure that was issued based on scientific study. It was agreed to postpone implementation of the measures for a year (Notification dated 24th September 1999). During the intervening period, the Notification issued in 1984 was temporally used. In order to solve the problems that may occur in the area, multi-stakeholders committees were established in each province, consisting of representatives from each group of fishing gear users, and relevant governmental officials. Figure 3 shows the present closed areas.

Since then, the DoF proposed to MOAC to issue the Notification dated 10th February 2000 with regard to the prohibition of the use of some types of fishing gear in the area of Prachaup Khiri Khan, Chumphon, and Surat Thani during the closed season

Fig. 3. Present closed areas in the Gulf of Thailand.

(the 2nd edition). The main reason was to temporarily delay the implementation of the Notification dated 24th September 1999, that would be effective from 15th February to 15th May 2000. Consequently, fishers of Lang-soun district demonstrated and disagreed with this Notification. As a result of consultations with fishers on 22nd February 2001, permission was given for a joint scientific study on the use of the following fishing gear:

1. During the first 45 days (15th February to 31st March 2001), permission was given only for: beam trawl or bottom otter board (small trawl) that use only one single motorized boat and operate during the night time; push net and anchovy purse seine that operate during day time; lift net and anchovy cast net which are equipped with electric generator.

2. During the next 45 days (1st April to 15th May 2001), permission was given only for encircling gillnet that use together with motorized boat and use similar fishing method with Indo-Pacific mackerel purse-seine.

It was specified that this study would be carried out in collaboration between DoF, fishers and scientists, through a working committee. Subsequent to that, 23 fishers from Paknam Lang-soun submitted a plea to the Central Administrative Court for revision of the Notification dated 24th September 1999, the Minister of Agriculture and Cooperatives being the primary defendant and Thai-DoF as the co-defendant. The defendants were acquitted by the courts in 2004.

Points to be considered for conservation of aquatic resources in the three provinces

Following the prohibition of the use of mackerel encircling gill net resulting from the Notification dated 24th September 1999 there was a dramatic increase in the numbers of Indo-Pacific mackerel caught by drift gillnetters during 2002 and 2005. The catch composition was mainly medium and large sized Indo-Pacific mackerel, approximately 10 -15 and 8 - 10 individuals/kg, respectively. In addition, various demersal fish was also caught, e.g. red snapper, big eyes, lizard fishes, and wolf herring.

At the same time, some of fisher groups improved the fishing technique of drift gillnet fishing gear (targeting Indo-Pacific mackerel) by increasing the net depth from 50 - 80 meshes to 200 - 300 meshes. Fishing methods were also changed from nets setup straight, to nets set in circles and in zigzag manner. This type of gear was called "Auon-short" (gillnet). In 2005, the results from the follow-up study indicated that the catch rate of this gill net, operated using long-tail boats and inboard engine boats of length less than 10 m, was approximately 60 – 100 kg/day/boat, of which 85% was Indo-Pacific mackerel. The catch rate for those short nets operated by boat size over 10 m averaged 800 kg/day/boat, of which 77.49% was Indo-Pacific mackerel. It was also found that 75 - 98% of both males and females were fully mature.

Since these fishing gears are newly developed with high efficiency and mainly target large sized Indo-Pacific mackerel, the DoF is now considering appropriate measures to conserve the Indo-Pacific mackerel.

Conclusion

During the past 56 years (1953 - 2008), the Thai- DoF issued a total of 13 Notifications (specific management measures) relating to closures of fishing area in the Gulf of Thailand with the aim of conserving spawning and nursery stages of aquatic resources. The measures for conserving Indo-Pacific mackerel were used as the basis for the formulation and development of the other fishery resources in the same areas. Cancellation and revision of these measures were made from time to time in accordance with the change in status of the fisheries resources and the development of fishing practices with an attempt to effectively manage aquatic resources for sustainable fisheries.

References

Boonprakob U. 1974. Conclusion of Indo-Pacific mackerel's dynamic in the Gulf of Thailand for conservation on Indo-Pacific Mackerel. *Technical paper, Pelagic Fish Conservation Unit during 1967-1972* part 1. Survey and Research Division, Department of Fisheries. p. 203-231.

Bunyubon M. and V. Hongskhun. 1978. Conclusion of fishery situation, Demersal fish in the Gulf of Thailand in 1961-1975. *Demersal fish research No. 1/1981*. Marine fisheries Division, Department of Fisheries. p. 1-6.

Charyakul R. 1994. Spawning ground and spawning season of *Stolephorus heteroloba* (Ruppell) in Prachaup Khiri Khan, Chumphon and Surat Thani provinces. *Tech. pap. No.25/1994*. Upper Gulf Marine Fisheries Research and Development Center, Department of Fisheries. 256 pp.

Department of Fisheries. 1996. Summary of technical procedures on marine resource conservation at protected area Prachaup Khiri Khan, Chumphon and Surat Thani provinces in 1996. Particular of marine resource conservation during spawning period and habitat center in 1996.

Department of Fisheries. 1998. Summary of technical procedures on marine resource conservation at protected area Prachaup Khiri Khan, Chumphon and Surat Thani provinces in 1998. Particular of marine resource conservation during spawning period and habitat center in 1998.

Hongskul V. 1975. Marine Fisheries in Thailand. A Paper Present to the 1st Administered Seminar (Fisheries Development), Fish Market Organisation. p. 1-17.

Hongskul V. 1990. Anchovy fisheries problems. *Thai Fish. Gaz.* 43(5):349-353.

Nakrobru C. and P. Saikliang. 2003. The effect of Mackerel Encircling Gill Net Fishery of Indo-Pacific Mackerel parent stock in protected area, Prachuap Khiri Khan, Chumphon and Surat Thani provinces. *Tech. pap.* No. 14/2003. Marine Fisheries Division, Department of Fisheries. 35 pp.

Phasuk B. 1979. Situation of pelagic fishery in the Gulf of Thailand. *Thai Fish. Gaz.* 32(1): 27-50.

Phasuk, B. 1982. Pelagic fishery management in the Gulf of Thailand. *Technical paper No. 29/1982*. Pelagic Fisheries Section. Marine Fisheries Division, Department of Fisheries. 21 pp.

Phasuk B. M. Bunyubon, C. Vibhasiri, U. Sriruangcheep and C. Tantisawetrat.1988. Effective of fisheries resource enhancement on closed period in Prachaup Khiri Khan, Chumphon, Surat Thani and Khanom district, Nakhon Si Thammarat provinces. *Thai Fish. Gaz.* 41(3): 183-196.

Srireungcheep U. 1997. Changes in size composition of Rastrelliger neglectus (van Kamphen, 1907) caught from the Gulf of Thailand during 1968-1994. *Tech. pap.* No. 2/1997. Marine Fisheries Division, Department of Fisheries. 63 pp.

Sukhavisdh P. 1996. Checklist of Marine Fishes of Thailand. *Tech. pap.* No. 2/1996. Marine Resources Surveys Section, Bangkok Marine Fisheries Development Center, Marine Fisheries Division, Department of Fisheries. 120 pp.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-12

Fisheries *refugia*, marine protected areas, and fisheries use zoning: Some of the tools used in managing fisheries in the Philippines

Nygiel B. Armada
Ecosystem Improved for Sustainable Fisheries (ECOFISH) Project,
102 CTC Building, 2232 Roxas Boulevard, Pasay City 1301, Philippines.

*Correspondence e-mail: nygiel.armada@ecofish-ph.com

Received: 07 Mar 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

The issues tackled by many fisheries management interventions are practically the same, namely, a fisheries that is overcapitalized, increasing fishing effort, a resource base that is degraded due to destructive fishing practices, and resource users who are highly dependent on fisheries and its resource base. In response, fisheries managers have resorted to viable interventions that are deemed acceptable to government, resource users, and stakeholders.

This paper highlights approaches and practices in the establishment of fisheries *refugia* in selected sites in the countries surrounding South China Sea, and the establishment of fisheries sanctuaries in the Philippines. It will also touch on the consolidating role of marine spatial planning, particularly of fisheries use zoning, in enhancing fisheries management. These practices are primarily based on experience during the implementation of the UNEP-GEF South China Sea (SCS) Project, USAID's Fisheries Improved for Sustainable Harvest (FISH) Project in the Philippines, and the various interventions by research institutions, non-government organizations, and fisherfolk organizations. These include establishment of fisheries *refugia*, marine protected areas and network of marine protected areas. These initiatives were further enhanced by consolidating them with various interventions through marine spatial planning, specifically through zoning of various fisheries and other marine water uses.

Despite numerous successes, there are still key challenges that need to be addressed, namely, choosing the appropriate spatial scale for a given governance scale, ensuring equitable benefits to the target resource users, and addressing excessive fishing effort (the elephant in the room). There are current initiatives being conducted to 'right scale' fisheries management interventions, namely, to see to it that governance scale is compatible with the spatial scale of ecosystems being managed. Also, ecosystem modeling is being used as tool to right-size fishing effort to be able to address excessive fishing effort. Right-sizing of fishing effort can also be designed to respond to equity issue.

Keywords: Refugia, *MPA, zoning, EAFM, right-sizing, right-scaling.*

Introduction

The issues addressed by many fisheries management interventions are practically the same throughout the Asia Region, namely, a fisheries that is overcapitalized, persistently increasing fishing effort, a resource base that is degraded due to destructive fishing practices, and resource users who are highly dependent on fisheries and its resource base. In response, fisheries managers have resorted to viable interventions that are deemed acceptable to governments, resource users, and stakeholders. Typically, these are measures that are deemed non-threatening to the majority. Fisheries management measures that will result in the reduction of fishing effort are usually not acceptable to both the resource users and the local government executives.

For example, fisheries researchers have shown higher catch rates for stationary fishing gears (fish corrals) deployed at 400 meters or more from each other compared to those between 100 to 300 meters distance from each other in the near shore shallow water fisheries in Sapian Bay, Philippines (Fig. 1). A consensus to set the minimum distance of 500 meters between stationary gears was arrived at after a series of consultation with stakeholders. However, the management initiative failed primarily because pegging the minimum distance to 500 meters meant reduction of gears that can be deployed. Stakeholders and local governments sharing the bay could not agree on the actual limits in number of allowable fishing gears and their allocation. Both are threatened by the initiative - resource users fear losing their livelihood and the elected local government executives fear losing the political support of their constituents. Other initiatives to reduce gears also suffer similar fate.

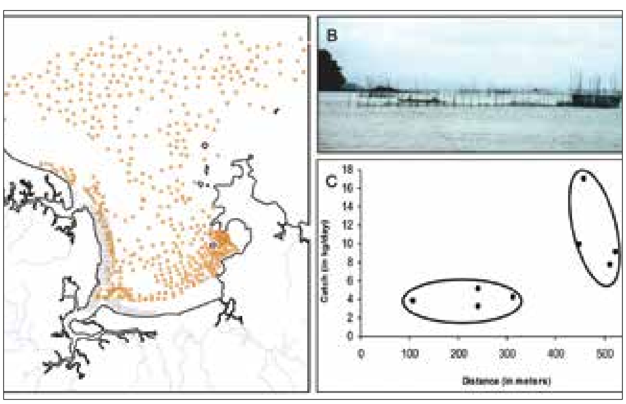


Fig. 1. Stationary fishing gears in Sapian Bay Philippines. (A) Spatial distribution of stationary fishing gears, (B) Example of stationary fishing gears (fish corrals), and C. Average catch rates of stationary fishing gears relative to their distances from each other.

In response, fisheries resource management practitioners in the Philippines have deliberately focused on non-threatening initiatives, particularly on the establishment of fisheries *refugia* and marine protected areas. These initiatives are further enhanced and made more effective through consolidating interventions like marine spatial planning, specifically through fisheries use zoning.

This paper highlights approaches and practices in the establishment of fisheries *refugia* in selected sites in the countries surrounding South China Sea, and the establishment of fisheries sanctuaries in the Philippines. It also examines the consolidating role of marine spatial planning, particularly of fisheries use zoning, in enhancing fisheries management. These are primarily based on experience from the implementation of the UNEP-GEF South China Sea (SCS) Project (UNEP, 2007, 2009) and USAID's Fisheries Improved for Sustainable Harvest (FISH) Project in the Philippines (FISH, 2010).

Fisheries *refugia*

The fisheries *refugia* concept as developed by the SCS project was based on the use of area-based or zoning approaches to fisheries management aimed at maintaining the habitats upon which fish stocks depend, as well as minimizing the effects of fishing on stocks of important species in areas and at times critical to their life cycle (UNEP, 2007). The fisheries *refugia* concept promotes sustainable use of fish stocks and their habitats. It focuses on fish life cycle and critical habitat linkages as the criteria for site selection. The common understanding is that fisheries *refugia* relate to specific areas of significance to the life cycle of particular species, and that they should be defined in space and time, and serve to protect spawning aggregations, nursery grounds, and migration routes.

A good example of the process of fisheries *refugia* establishment was the monthly spatial closure of selected seagrass areas in the FISH Project area during the lunar cycle spawning of rabbitfish (particularly *Siganus calaniculatus, S. spinus,* and *S. virgatus*). These rabbitfish species are observed to move among different marine habitats during the different stages in their life cycle, in coral reefs and in seagrass areas in particular. For *S. canaliculatus*, breeding or spawning seasons are estimated to occur from February through September as indicated by the high gonadosomatic index (GI) peaks during these months (Alcala and Alcazar, 1979). The highest peaks are found to occur during summer months of March-April and July-August. As with many other seagrass and reef fish species, rabbitfish show a prominent lunar rhythm. Takemura *et al.* (2004) found the biorhythm of rabbitfishes to follow the lunar cycle. Spawning appears to occur around the new moon, as indicated by mean GIs that are highest during the new moon of the lunar cycle. Spawning usually takes place at night or early morning, and coincides with outgoing tides.

During various consultation meetings, resource users and various stakeholders in the FISH Project sites shared a general perception of decline of rabbitfish in their catch. This was attributed to uncontrolled fishing, destructive fishing practices, and destruction of seagrass habitats. A consensus to manage the fisheries was arrived at. A series of activities was set into motion including a cross visit to model areas with successful rabbitfish management, literature review and sharing of information on the biology and life history of rabbitfish, and consultation workshops to generate possible management strategies for the specific species of rabbitfish found in the various areas.

Crucial in the consultation process was the resource-use mapping that identified the major fishing operations that exploit rabbitfish, their catch rates, fishing seasons, and fishing grounds. Also important was the fishers' observations on the spatial and temporal patterns of the occurrence of not only of adult rabbitfish spawning in the area, but also of the temporal pattern of the appearance of the juveniles as well. The information generated from the various activities served as basis for further discussion on specific policies and actions to ensure the sustainable use of the rabbitfish resource. The resource users and stakeholders themselves identified related issues, suggested possible management strategies, and outlined corresponding recommendations to address them. A common agreement was the adoption of a temporary fishing closure in seagrass areas during identified peak spawning period of rabbitfish, i.e. during the week of the new moon. However, the agreed duration of the fishing closure varied from one area to another, and this was heavily influenced by local knowledge and observations on the appearance of gravid rabbitfish before and after the new moon as well as the abundance of juveniles thereafter. Because fishing is the major source of income in the area, the duration of closure became a critical issue. In most areas, this was limited to just three days, during the third, fourth, and fifth night after the new moon, which is considered the peak spawning period. Banning fishing during this period entailed a significant sacrifice among the fishers since these are also the nights when their catch rates are high (Fig. 2) particularly due to spawning aggregation.

Considering that seagrass areas play a critical role in the life cycle stages of rabbitfish, mapping of seagrass areas was

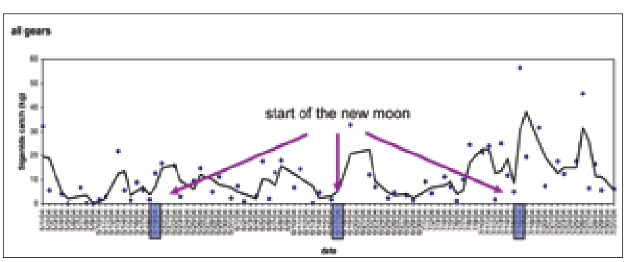


Fig. 2. Catch monitoring data from various gears catching *Siganus canaliculatus* in Danajon Bank, Philippines from May to July 2004, showing a pattern of high catch rates during and shortly after the new moon phases.

conducted to specifically delineate the areas to be covered by the seasonal closure. Other issues addressed were the need for uniformity of policy and its implementation across various local government units, the importance of regulating, if not banning the catching of juvenile rabbitfish, and the inclusion of a prohibition on the buying or selling of rabbitfish on declared temporal fishing closures. The final piece of the task was the drafting of a policy or, in most cases, an ordinance to legitimize the management initiative. This was supplemented by a management plan for rabbitfish fisheries.

Marine protected area and the network of marine protected areas

A typical Marine Protected Area (MPA) or fish sanctuary in the Philippines (Fig. 3) consists of a core zone (typically a strictly no-take zone) and a buffer zone (usually a limited take zone). Fishing using traditional gears such as fish pots and simple hook and lines are normally allowed in the buffer zone. The establishment of a managed marine area is always done with the participation of the community. The process normally includes site selection, determining the state of the habitat and resources to be protected (establishing the baseline), delineation of the area to be protected, development of the management plan, legitimizing the initiative through an ordinance or other policy instrument, and development of strategies for effective enforcement of the allowed and disallowed activities in the zones.

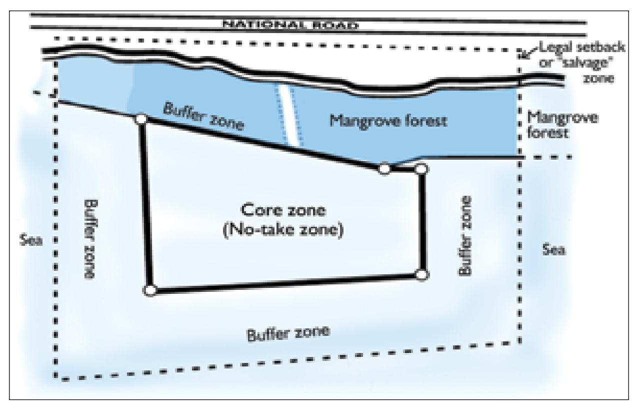


Fig. 3. A typical marine protected area or sanctuary in the Philippines consisting of a core zone and buffer zones (DENR, DA-BFAR and DILG, 2001).

As shown by the *refugia* experience as well as lessons from other fish sanctuary and MPA establishment in the Philippines, ownership of the intervention is a very important element for the sustained implementation and, ultimately, the success of marine managed or protected area initiatives. Ownership may not be achieved through a prescribed set of interventions or patented steps but it helps a lot if necessary elements are in place to ensure higher chances of success. The key elements include:

- Participatory approach (from planning to implementation)
- Information, education and communication (IEC)
- Legal instrument (ordinance, management plan)
- Establishment of an enforcement team
- Adhering to a form of MPA or marine managed area rating system

- Establishment of local MPA monitoring team
- Measuring and communicating the gains

As mentioned earlier, participatory approach, all the way from conceptualization of the idea of protecting or managing a marine area, to the planning, and ultimately to implementation, is the best assurance one can get to ensure success of the initiative. And for this, IEC - information and effectively communicating the information, plays a crucial role. Another key element is the legal instrument to legitimize the intervention. With proper and visible markings of boundaries and rules detailing the use of subsets of the protected or managed areas, resource users will be clearly guided by what was agreed upon during the consultations and planning processes. This, together with the establishment of an officially designated enforcement team, can increase the likelihood of properly implementing the initiative and achieving the desired impact.

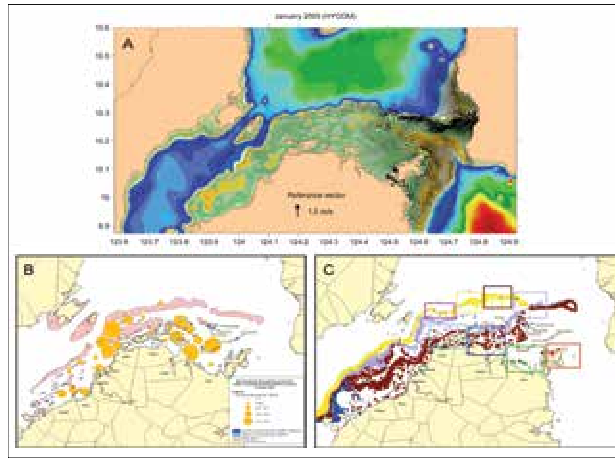


Fig. 4. The process of (A) hydrodynamic modeling (Villanoy *et al.* 2006), B) study on abundance of fish larvae (Campos *et al.* 2006), and (C) simulation of larval dispersal (Villanoy *et al.*, 2006) for the establishment of a network of marine protected areas in the Danajon Bank, Philippines.

Resource managers and resource users would like to see indications of the success of protected or managed area initiatives and this can only be achieved if proper indicators or rating system can be set in place for stakeholders to refer to in the course of the implementation. For this one would need a set of baseline information such as: coral cover, status of benthic community, fish biomass, as well as enabling instruments such as ordinances, management plans, and the establishment of an enforcement body, from which stakeholders can measure the progress of the initiative. This set of information gathering activities will have to be done on a regular basis to monitor progress. Ultimately, the information gathered from this exercise can likewise serve as the basis for communicating the biological and economic gains as a result of the marine protected or managed area intervention.

With the proliferation of MPAs in the country, the idea of setting them in place to form a network of MPAs became the logical next step. Having a scientific basis for the selection of marine protected areas so that they form and function as a network become crucial for the initiative to be effective. Scientific support is usually in the form of hydrodynamic modeling, studies on abundance of fish larvae, and a subsequent simulation of larval dispersal (Fig. 4). The idea was primarily to produce hydrodynamic models for the general circulation patterns within the confines of the area for the network of MPAs to provide an idea of the prevailing current patterns during monsoons and inter-monsoon as well as during prevailing tides. Subsequently, numerical simulations produced dispersal models to find out possible movement or larval drift. Simultaneously, a larval study was conducted to determine distribution and density of larvae. Together, this set of information was used by resource managers, resource users, and other stakeholders to determine ideal sites for planned marine protected areas, taking into consideration possible "sources" and "sinks" projected from the simulation and larval studies. With this set of information, candidate marine protected areas were assessed together with stakeholders and, through a consensus building process, some were rejected and other newly-recognized viable sites, even those not in the initial list, were encouraged.

The ever-increasing acceptance as well as popularity of MPAs and the establishment of a network of MPAs likewise opened up another level of challenge to the resource managers, resource management practitioners and academic institutions in the country. There is an on-going initiative to coordinate and consolidate all MPA and network of MPA activities. An MPA Support Network (MSN) is now in place and its objectives are to coordinate the support of academies, non-governmental organizations, and government institutions MPAs; maintain a database for participating MPAs; advocate continued development of policy for further enhancement of MPA initiatives; and oversee the monitoring and evaluation of MPAs. For the latter, MSN has standardized the MPA rating system through the development and implementation of the MPA Evaluation and Assessment Tool (MEAT).

Fisheries use zoning

The use of marine spatial planning (MSP) has so far been limited to the establishment and management of MPAs. However, there are also attempts in the region to use it on larger scales, for example, initiatives by the Partnerships in Environmental Management for Seas of East Asia (PEMSEA). In fisheries management, MSP or at least its fisheries use zoning component, is an effective tool for consolidating the range of management interventions, particularly in relation to the various marine spatial uses.

Because of the range of existing management paradigms and approaches that have been introduced in the region, it has to be understood from the very beginning that zoning as a tool does not replace any of the coastal and marine management tools already in place. In fact, it has to be highlighted that MSP or its fisheries use zoning component will only attempt to consolidate the various management initiatives by providing the spatial scale. It organizes where human activities can occur in a given coastal and marine space with the objective of encouraging compatibility of uses, reduce conflicts between human activities, and prevent conflicts between human uses and the environment (Ehler and Douvere, 2009). In the coastal and fisheries use context, zoning is meant to reduce conflicts among various capture fisheries activities, between capture fisheries and other sea uses (maritime, tourism and mariculture), and between human activities and marine environment, particularly in key habitats such as mangrove forests, seagrass beds and coral reefs. Some guiding principles adhered to in the process of establishing fisheries use zones included:

- Learning by doing such that it becomes participatory in every step.
- Use of stakeholder's and resource user's knowledge and the process to be adaptive.
- Building on existing initiatives.

Even for bodies of water with more or less similar fishing and water use activities, their development directions still differ from one another and this becomes apparent and crucial in the setting of zoning objectives and prioritization of water use activities. The entire fisheries use zoning activities were carried out following the process of clustering into at least three phases depending upon the technical capacity and pace of the stakeholders:

Phase 1
- Orientation and objective setting
- Mapping of current fisheries and other water uses
- Determining and evaluating interaction among the various uses to identify possible multiple use conflicts and use and habitat incompatibilities
- Mapping of current and future uses taking into consideration the interaction matrix, particularly, the resolution of conflicts

Phase 2
- Field validation with stakeholders and representatives of resource users
- Consultation with local government executives and legislators

Phase 3
- Drafting of activity guidelines
- Finalization of fisheries use zoning map
- Consultation with a broad base of stakeholders and resource users, and
- Legitimizing zoning plans through legislation or other kinds of policy instruments.

Fig. 5 shows an example of various documents resulting from the fisheries use zoning process. Shown are the map of current fisheries and other water uses (Fig. 5A); interaction matrix for the various uses to identify possible multiple use conflicts and use and habitat incompatibilities (Fig. 5B), activity guideline as results of field validation with stakeholders and representatives of resource users (Fig. 5C), and a digitized map incorporating information gathered during field validation and consultation with local government executives and legislators (Fig. 5D). The digitized fisheries use zoning map is also used during consultation with a broad base of stakeholders and resource users and during the drafting and legitimizing zoning plans through legislation, resolutions or other kinds of policy instruments.

The consultation process that accompanies zoning was always conducted in a highly participatory manner and the project saw to it that all sectors of the coastal community and stakeholders were represented. Workshops, that served both for training and consultation, became fora for interaction between decision-makers and resources-users, primarily the sustenance fisheries sector. This became staging points and opportunities for sustenance fishers to air their appeals and grievance to lawmakers and decision makers. It also became the forum for fisheries managers to exchange experiences with their colleagues. Likewise, in the process of developing fisheries management interventions, fishers' indigenous knowledge became significant inputs to the process of crafting the policy or, specifically, the ordinance that legitimizes the initiative.

Key challenges and the way forward

Managing the fisheries using an ecosystem approach

In the Philippines, the need to manage fisheries as an ecosystem is recognized by various sectors at different levels, from the community, resource users, fisheries management practitioners, academics, and hierarchy of the government. However, the country's legal framework entitles the local governments (municipalities or towns) to have jurisdiction over the waters from their coastlines to 15 km offshore. This complicates the implementation of an ecosystem approach to management since addressing an ecosystem issue or setting in place a broader intervention will mean dealing with multi-jurisdictional boundaries. On the other hand, it is also clear to most stakeholders that managing the fisheries and its resource base at the municipal level will not be enough since the spatial distribution of most harvestable fish and invertebrate stocks are beyond the political boundaries of the municipalities and therefore requires inter-local government cooperation. Unfortunately, the success of an inter-local government management initiative is dependent upon the cooperation of all local executives. A failure of one is a threat to the success of the entire initiative. In working towards an ecosystem approach, fisheries management interventions should always consider a defined ecosystem boundary as resource management unit. This leads us to the next challenge, spatial scale with a corresponding governance system.

Right-scaling

The USAID funded FISH Project experiences in the Philippines showed that in working towards an ecosystem approach there is a need for a governance system that addresses the various issues and implements the host of interventions for a chosen spatial scale or ecosystem. In the case of fisheries, it is a governance system that can support an ecosystem approach to controls and limits in fisheries resource exploitation activities in a defined boundary. For example, in the case of the Danajon Bank, Philippines (Fig. 6), the ecosystem approach was initiated with four municipalities as foci (the smallest rectangle), gradually expanded to nine municipalities, and further expanded to cover the rest of the 17 municipalities (bigger rectangle) constituting the Danajon Bank Double Barrier reef system (Armada *et al.,* 2009).

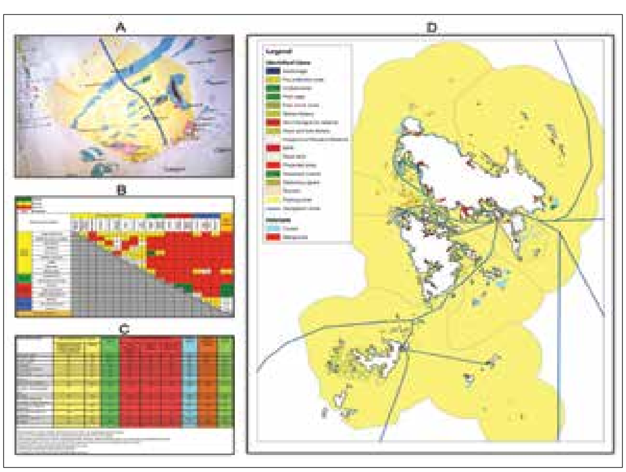


Fig. 5. Fisheries use zoning results into the development of: (A) current use map, (B) interaction matrix, (C) activity guideline, and (D) zoning map.

Scaling up the initiatives at an ecosystem level of the entire reef system was not just a challenge but also an opportunity to find out at what scale it will still be appropriate. However, expanding the ecosystem scale to cover the entire Camotes Sea (biggest rectangle) proved to be no longer feasible. The diversity of issues brought about by the increase in the spatial scale reached a point that it can no longer be addressed by a viable governance system. Due to the large area involved it became clear that the Camotes Sea ecosystem has to be subdivided into three sub-systems for a viable management scale or governance to work. It is quite obvious that the match between the spatial range of the ecosystem and the governance system is a very important consideration.

Equity for intended beneficiaries

Some initiatives, in particular those supported by the FISH Project, were able to show that a set of planned fisheries management interventions, with fish sanctuaries or marine protected areas playing pivotal roles, can result in an increase in overall harvest. However, this increase did not necessarily benefit the intended beneficiaries of the interventions, namely, the small-scale fishers. For example, the catch monitoring activities of the FISH Project in Danajon Bank, Philippines showed that harvests have increased in subsequent years, relative to the 2004 base period (Fig. 7). However, the increases in harvest were mostly due to increase in catch rates by relatively large-scale fishing gears using fine-meshed nets like the Danish seine, fish corral, stationary lift net, and round haul seine. These are also the fishing gears that require higher initial capital investment as well as maintenance. On the other hand, small-scale fishing gears like the multiple handline, bottom-set longline, and bottom-set gillnet did not benefit from the improved fish stock. Putting in place a governance mechanism by which small-scale fishers can really benefit from interventions still remains a challenge. Preferential use-right for small-scale fishery resource users is stated in many legislations around the region, but putting them into action, especially in the marine fisheries sector, still remains a challenge.

Right-sizing of fishing effort

Despite the various initiatives that specifically address conserving fish stocks and the resource base that support them, it appears that we still have failed to address the "elephant in the room"- the excessive fishing effort. Fishery management conferences and meetings always arrive at a consensus that there is excessive fishing effort and there is an urgent need to address this issue. Primarily, the way forward is to focus the ultimate thrust of fisheries management initiative on how to address this. There is an on-going attempt by the ECOFISH Project, a carry-over of the FISH Project, to address this issue. The main objective is to determine the right-size of fishing

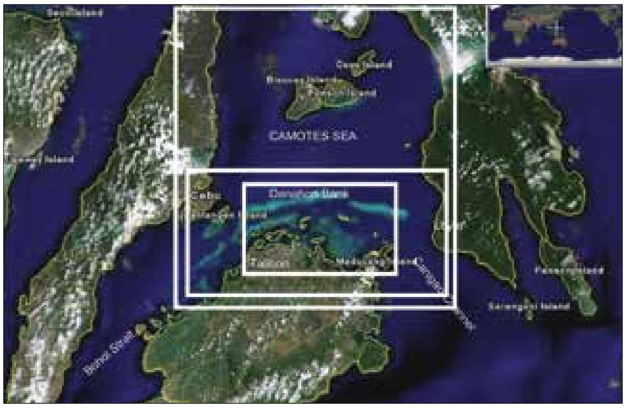
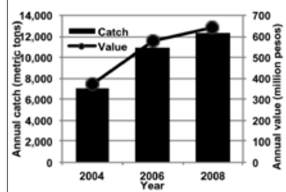


Fig. 6. Various spatial scales of FISH Project's fisheries management interventions in Danajon Bank, Philippines.

Annual landed catch (tons) in four municipalities in Danajon Bank, Philippines.

Municipalities	2004	2006	2008
Talibon	3,666	4,940	4,644
Bien Unido	1,968	2,626	4,426
Ubay	989	1,729	1,428
C.P. Garcia	413	1,571	1,873
TOTAL	7,037	10,867	12,370



Estimated annual landings (tons) of most often used fishing gears in four municipalities in Danajon Bank, Philippines.

Fishing gears	2004	2006	2008
Increased harvest:			
Drift gillnet	522	992	2,070
Hook and line	536	2,357	1,297
Danish seine*	634	1,496	1,271
Fish corral*	261	267	302
Stationary liftnet*	8	79	253
Round haul seine*	145	128	218
Decreased harvest:			
Multiple handline	185	381	15
Crab pot	137	150	64
Bottom-set longline	288	502	125
Bottom-set gillnet	726	546	484

* Active and fine-meshed fishing gears

Fig. 7. Result of catch monitoring of various fishing gears in four municipalities in Danajon Bank, Philippines.

Table 1. Distribution of the number of various fishing gears in the four municipalities in Danajon Bank, Philippines and estimation of appropriate numbers for purposes of allocation to establish the right size of fishing effort.

Fishing gear	Municipalities					Total	Ideal	Remarks
	Talibon	Trinidad	B. Unido	Ubay	CPG			
Blast fishing	14		33		8	55	0	ban
Bottom-set gillnet	133		42	282	208	665	600	reduce
Crab gillnet	484	5	177	164	256	1,086	1,000	reduce
Drift gillnet	37		36	164	179	416	420	ok
Spear w/compressor	96		25	28		149	150	ok
Danish seine	6		70	4		80	0	ban
Crab pot	97		38	74	34	243	210	reduce
Set gillnet w/plunger	41	10	77	68	12	208	210	ok
Beach seine	4		35	10		49	40	reduce
Simple hook and line	295	44	298	292	518	1,447	1,500	ok, possible increase
Otter trawl	7		28			35	0	ban
Crab liftnet	156	3	55	170	20	404	200	reduce
Fish corral	248	59	51	38	43	439	220	reduce
Bottom set longline	18		113	114	232	477	400	reduce
Drive-in gillnet	78		41	14	3	136	140	ok
Multiple handline	26		30		51	107	110	ok, possible increase
Fish trap	67		31	17	69	184	100	reduce
Trammel net	164	5	27	8		204	60	reduce
Encircling gillnet			14	8	15	37	40	ok
Handspear	289		32	35	34	390	200	reduce
Round-haul seine	4					4	0	ban
Stationary liftnet	4	1		52		57	20	reduce

effort that can be sustainably supported by a fisheries or an ecosystem. First, the process involves the development of an ecosystem model using Ecopath with Ecosim (Christensen *et al.,* 2005) for a given spatial and governance scale. This is followed by simulating the various scenarios with stakeholders to arrive at the appropriate number and allocation of the fishing gears among the various local government units and developing and implementing a process of allocating the appropriate fishing gear mix among the various local governments. To sustain the intervention, the allocations are incorporated into the fisheries management plans and legitimized through legislation or other policy instruments. The initiative has to be tied to other directly relevant initiative like registration and licensing and enforcement to ensure the success of their implementation. Currently, in the ECOFISH Project sites fishery data collection and inventory of fishing gears have been conducted, ecosystem models for a number of ecosystems have been constructed, and simulation to determine the appropriate number and mix of fishing gears is being conducted. Resulting from simulation, Table 1 provides example of the distribution of the number of different fishing gears in the four municipalities in Danajon Bank, Philippines and an estimation of appropriate numbers of fishing gear units for purposes of allocation to establish the right size of fishing effort. This model will be further refined through a process of validation and allocation with the various local government units. As with other management interventions mentioned above, a participatory approach and learning by doing, all the way from conceptualization of the idea of right-sizing of fishing effort, to planning, and ultimately to implementation, is the best approach to ensure success of the initiative.

References

Alcala, A. C. and S. N. Alcazar. 1979. Study on gonad morphology, oocyte development, gonad index, and fecundity in the rabbitfish, *Siganus canaliculatus* (Park).*Silliman J.*, 26 (2&3): 147-161.

Armada, N., A. T. White, and P. Christie. 2009. Managing fisheries resources in Danajon Bank, Bohol, Philippines: an ecosystem-based approach. *Coast. Manag.,* 37:3, 308-330

Campos, W. L., G, Genito, M. Noblezada, F. Nabuab, D. M. Estemadura, and A. Santillan. 2006. Determination of the abundance and distribution of plankton in FISH focal areas. Technical Reports submitted to the FISH Project. Ocean Bio and Marine Bio Labs, UPVFI, Miag-ao, Iloilo. 57pp.

Christensen V., C. Walters, and D. Pauly. 2005. Ecopath with Ecosim: a User's guide. Vancouver, BC: Fisheries Centre, University of British Columbia. 154p.

Ehler, C. and F. Douvere. 2009. Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. Paris: UNESCO.

Fisheries Improved for Sustainable Harvest (FISH) Project. 2010. FISH Document 53-FISH/2010. Completion Report. Tetra Tech EM, Inc., Mandaluyong City, Philippines. 252p.

Takemura, A., M. S. Rahman, S. Nakamura, Y. J. Park, and K. Takano. 2004. Lunar cycles and reproductive activity in reef fishes with particular attention to rabbitfishes. Fish Fish. 5: 317–328

UNEP, 2007. Procedure for Establishing a Regional System of Fisheries *Refugia* in the South China Sea and Gulf of Thailand in the context of the UNEP/GEF project entitled: *"Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand"*. South China Sea Knowledge Document No. 4. UNEP/GEF/SCS/Inf.4

UNEP, 2009.Terminal Report. Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand. UNEP/GEF/SCS Terminal Report.

Villanoy, C. L., O. C. Cabrera, M. M. Magno-Canto, M. C. Martin, E. E. Salamante and K. M. Silvano. 2006. Hydrodynamic and Dispersal Modeling in FISH Project Focal Areas. University of the Philippines-Marine Science Institute and the Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) Fisheries Improved for Sustainable Harvest (FISH) Project. 93 p.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-13

By-catch of tuna gillnet fisheries of Pakistan: A serious threat to non-target, endangered and threatened species

Muhammad Moazzam* and Rab Nawaz
WWF-Pakistan, 46-K, Block 6, PECHS, Karachi, Pakistan.

*Correspondence e-mail: mmoazzamkhan@gmail.com

Received: 17 Mar 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract
Tuna gillnet fishery of Pakistan employs more than 500 fishing boats that operate in offshore waters. In addition to tuna, gillnet also catches large quantities of by-catch fish species including billfishes, pelagic sharks, dolphin fishes as well as marine turtles and cetaceans, which are protected species. High by-catch of these non-target animals affects their population in the area. The paper provides information on by-catch and suggests measures that can be adopted as alternate fishing methods to minimize mortality of endangered and threatened cetaceans and turtles.

Keywords: *Tuna gillnet by-catch, enmeshment, mortality, cetaceans, sharks, turtles, whale shark.*

Introduction

Gillnet is the main fishing gear used for catching tuna and other large pelagic fishes in many countries of the world including Pakistan (IOTC, 2013). This net is considered to be an indiscriminate fishing gear which enmeshes not only target species (tuna) but also a large number of non-target animals (Tregenza *et al.*, 1997; Tregenza and Collett, 1998; Lewison *et al.*, 2004; Gillet, 2011). The non-target species (by-catch) includes some species which are considered protected or threatened such as cetaceans and turtles, and therefore, there is a general concern among conservationists about use of these indiscriminate nets (Lewison *et al.*, 2004).

Tuna fishing in Pakistan is based on large gillnets used onboard about 500 vessels which are dedicatedly engaged in catching large pelagic fishes (Moazzam, 2012). Information on species composition and mortality of these important fishes is not documented. In this paper an attempt is made to present data on by-catch of tuna gillnetting operations and to suggest measures that can be adopted as alternate fishing methods to minimize mortality of endangered and threatened species.

Material and methods

For making a review of the fishing practices, landings and disposal of the catch, information was obtained from published literature, statistical data and government archives. In addition, monitoring of by-catch through landings data at the major fish landing centers in Karachi as well as by posting a few observers onboard tuna gillnetters was initiated in 2012. The paper presents quantitative data on tuna landings, by-catch composition including frequency and seasonality, areas of fishing and some biological information on by-catch species. Data were collected from the landing centres intermittently since September 2011 and through observer programme from October, 2012 to September, 2013. No tuna gillnet operation was carried out during July and August, 2013.

Results

Historically, tuna gillnetting represents an important fishery in Pakistan. Fishing vessels from Pakistan operated not only in the coastal and offshore waters of Pakistan but also in the high seas including the waters of Somalia which is considered to be a rich fishing ground for tuna and tuna-like species. Tuna and other by-catch fish species are not consumed in Pakistan but the catches are exported in salted and dried form to Sri Lanka for centuries. However, in the last 10 years, it has been transported to neighboring countries in chilled form and only small quantities are exported in salted and dried form to Sri Lanka.

Fishing boats

The Pakistani tuna fleet consists entirely of locally made wooden boats. A study (Moazzam, 2012) carried out in two maritime provinces i.e. Sindh and Balochistan revealed that most of the boats operating from Karachi (Sindh) range from 15 to 25 m LOA (Fig. 1) whereas, those operating from Balochistan range from 10 to 15 m (Fig. 2). There are about 65 large boats (ranging from 20 to 30 m LOA) engaged in fishing trips of more than two months in comparatively deeper waters and have onboard freezing facilities.

Tuna fishing vessels are equipped with a hydraulic net hauling device as well as navigation equipments such as GPS and fish finders. Fish is stored in 6-8 insulated compartments each having a capacity of about 1 to 1.5 tonnes (t). In most tuna fishing vessels, the catch is stored with crushed block ice. The smaller tuna fishing vessels do not carry any communication equipment; however, a few larger vessels may have VHF and shortwave radios.

Fig. 2. Smaller tuna fishing boat (12.5 m) at Jiwani, Balochistan.

Fishing gears

Surface gillnetting using polyamide nets (Fig. 3) is used for catching tunas in Pakistan. It has stretched mesh size ranging between 13 cm and 17 cm (average: 15 cm) with a hanging ratio of 0.5 (Fig. 3 inset). The length of gillnet varies between 4.83 km and 11.27 km. The breadth of the net was reported to be 14 m. There are a few larger fishing boats operated from Karachi and Gwadar, which may have a gillnet of about 20 km length. There are variations in the length and specification between the nets. When targeting small tuna in neritic waters, nets with smaller mesh size are used. In almost all cases, tuna gillnets are set in the evening and hauled in the early morning.

Fig. 1. Larger tuna fishing boat (23 m) at high seas.

Fig. 3. Polyamide gillnet stored on board tuna fishing vessel at Karachi. Inset: stretched mesh.

Fishing grounds

Fishing boats engaged in tuna fisheries are mainly based in Karachi and Gwadar. A few tuna fishing boats are based in other coastal towns of Pasni, Sur and Pushukan (Balochistan). There used to be a substantially large tuna fleet which operated from Ormara and Jiwani in Balochistan but because of the diversion to Indian mackerel fishing, tuna gillnet operation from these towns has practically stopped.

The fishing boats from towns and cities along Balochistan operate within a radius of 40 to 50 km. However, boats based in Karachi have wider area of operation; some of them operate as far as 400 miles from the base station. Larger fishing boats also operate in high seas i.e. beyond the Exclusive Economic Zone of Pakistan. Previously about 150 to 200 large boats based mainly in Karachi, Gwadar and Jiwani used to catch tuna from areas beyond Pakistan territory mainly in Somali waters. Because of piracy issues, only a few tuna boats from Pakistan now operate in Somali waters.

Tuna landings and catch composition

Tuna is an important fishery in Pakistan contributing about 40,000 t annually (Fig. 4). Tuna landings in 2000 was recorded as 22,000 t which steadily increased to 40,900 t in 2010. A slight decrease was noticed in 2011 when it reached 39,300 t. Eight species of tuna are known from Pakistan, of which only five species i.e. yellowfin (*Thunnus albacares*), longtail (*Thunnus tonggol*), skipjack (*Katsuwonus pelamis*), kawakawa (*Euthynnus affinis*) and frigate (*Auxis thazard*) are caught in commercial quantities. Bigeye tuna (*Thunnus obesus*) is of rare occurrence in Pakistan and known from only a few specimens. Bullet tuna (*Auxis rochei*) and striped bonitos (*Sarda orientalis*) are also not common in Pakistan.

Analysis of landings data from Karachi Fish Harbour for four years i.e. from 2008 to 2011 indicated that catch composition of fishing boats operating in the neritic waters differs substantially from those operating in offshore waters

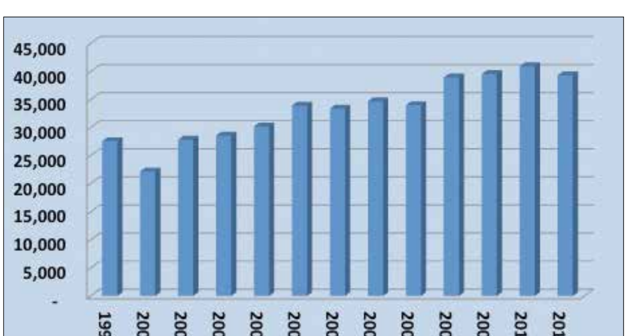


Fig. 4. Tuna landings (in tons) in Pakistan.

of Pakistan. Those operating in neritic waters predominantly caught long tail tuna (59%) and kawakawa (29%), with frigate (8%), yellowfin (2%) and skipjack tunas (2%) caught in smaller quantities (Fig. 5). In offshore operations, the skipjack tuna contributed 83%, followed by yellowfin tuna (12%). Contribution of all other species was about 5% (Fig. 6). Seasonal variation in overall species composition was noticed both in neritic and offshore waters.

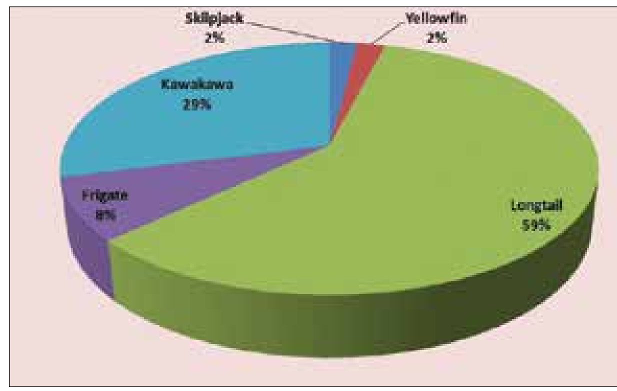


Fig. 5. Species composition in coastal tuna fisheries.

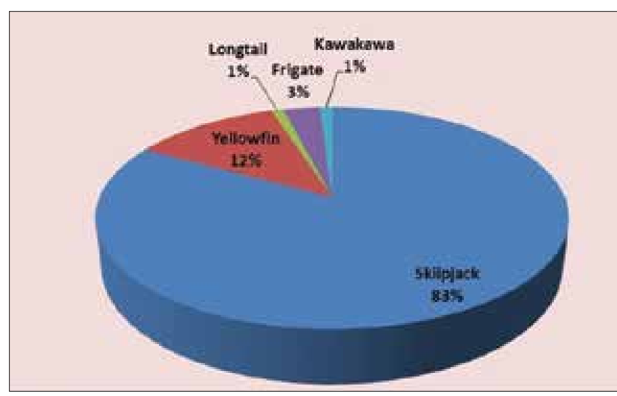


Fig. 6. Species composition in offshore tuna fisheries.

By-catch composition of gillnetters

Finfish

In addition to tuna, a number of other fish species of commercial importance were caught by vessels operating in both neritic and offshore waters. In the neritic waters, the by-catch consisted predominantly of talang queenfish (*Scomberoides commersonnianus*) followed by kingfish (*Scomberomorus commerson*), barracuda (*Sphyraena* spp.), dolphin fish (*Coryphaena hippurus*), Indo-Pacific sailfish (*Istiophorus platypterus*), thresher shark (*Alopias superciliosus*), silky shark (*Carcharhinus falciformis*), other requiem sharks and mantas. By-catch of tuna gillnetting in offshore deep waters consisted mainly of Indo-Pacific sailfish, marlin (*Makaria* *indica*), striped marlin (*Tetrapturus audax*), dolphin fish, thresher sharks and mako sharks (*Isurus oxyrinchus*). The data on by-catch of gillnet fishing was not recorded separately and therefore, it was not possible todetermine any historical trend in the catches.

Recent studies on the catches by four observers posted on tuna gillnetters showed that tuna species contributed about 67% to the total catch followed by other teleosts (23 %) and sharks and rays (9%) (Fig. 7). Turtles contributed about 0.6% and cetaceans about 0.4% to the total catch. The study further revealed that among teleosts, talang queenfish is the most dominant species in the by-catch (Fig. 8) whereas kingfish and dolphin fish each contributed 12%. Indo-Pacific sailfish contributed about 8% whereas other species contributed about 4%. It may, however, be pointed out that there was a marked seasonality in the composition of by-catch and data for an average annual catch is presented here.

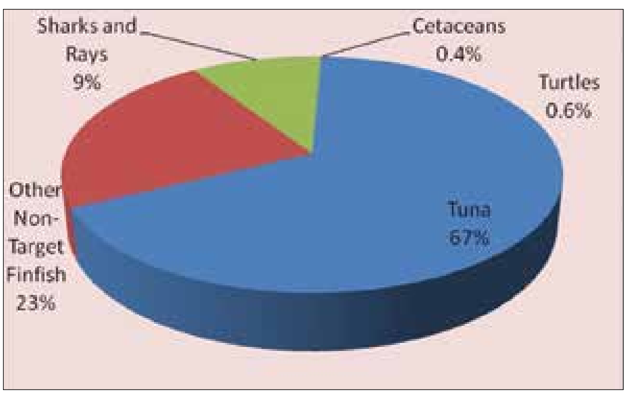


Fig. 7. Tuna and by-catch composition of tuna gillnet operation.

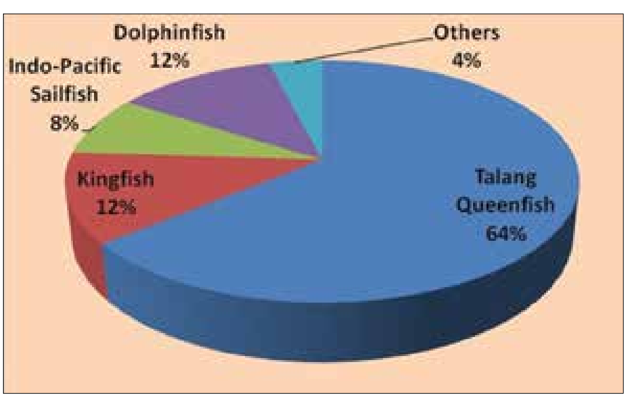


Fig. 8. Finfish (excluding sharks) by-catch of tuna gillnet operation.

During the study, 25 species of sharks were observed. Bigeye thresher (*Alopias superciliosus*), shortfin mako (*Isurus oxyrinchus*), silky shark (*Carcharhinus falciformis*), oceanic whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead (*Sphyrna lewini*) and great hammerhead (*Sphyrna mokarran*) were dominant in the catch. The most dominant species of shark was shortfin mako followed by bigeye thresher (Fig. 9) and silky shark whereas other species were comparatively rare in occurrence.

Fig. 9. Bigeye thresher shark (*Alopias superciliosus*) entrapped in tuna gillnet.

Whale shark (*Rhincodon typus*) was frequently observed in the coastal and offshore waters of Pakistan. It was previously reported that about 2 to 5 whale sharks got entangled in tuna gillnet every year (Moazzam, 2012). However, the data collected by the observers indicated that frequency of their enmeshment in the tuna gillnet was at least 4 times higher than previously reported. During a period of about 1 year, five whale sharks were enmeshed in four vessels, of which one died whereas other four were successfully released by the fishermen.

The study revealed that 10 species of rays were frequently found as by-catch. Pelagic stingray (*Pteroplatytrygon violacea*), bluespotted stingray (*Dasyatis kuhlii*), longheaded eagle ray (*Aetobatus flagellum*), Chilean devil ray (*Mobula tarapacana*), spinetail mobula (*Mobula japonica*), pygmy devil ray (*Mobula eregoodootenkee*) and Javanese cownose ray (*Rhinoptera javanica*) were represented in the catches of tuna gillnet. Of these, pelagic stingray, spinetail mobula and Chilean devil ray were noticed more frequently than other species.

Marine birds

No marine bird was found to be caught in gillnets during the study period. Enquiries showed that a single specimen of flesh-footed shearwater (*Puffinus carneipes*) got entangled in the gillnet during heaving process which was captured live and released by fishermen.

Turtles

Five species of marine turtles i.e. green turtle (*Chelonia mydas*), olive ridley (*Lepidochelys olivacea*), hawksbill (*Eretmochelys imbricata*), leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) are reported from Pakistan. During the study, only three species were observed to have enmeshed i.e. olive ridley (Fig. 10), green turtle and hawksbill. On an average, in each fishing trip 1-2 green turtles and 3 to 8 olive ridley turtles were entangled in tuna gillnets. Only about 3 to 5 % mortality of turtles was recorded. Most turtles were observed to be alive in the gillnets and in most cases fishermen released the enmeshed turtles. It is most interesting that no nesting of olive ridley turtle was observed in Pakistan during the last ten years but there is a large population of this species in the offshore waters. Hawksbill turtle was observed at least on three occasions during the study whereas one report of leatherback turtle was also recorded. Loggerhead turtle has not been found in the by-catch so far.

Fig. 10. Olive ridley turtle (*Lepidochelys olivacea*) entrapped in tuna gillnet.

Dolphins

Dolphins seem to be frequently entangled in tuna gillnets (Fig. 11). Spinner dolphin (*Stenella longirostris*), pantropical spotted dolphin (*Stenella attenuata*), striped dolphin (*Stenella coeruleoalba*) and bottlenose dolphins (*Tursiops truncates* and *T. aduncus*) were observed to get entangled in tuna gillnets. Although it is not possible to accurately estimate the number of dolphins killed every year in tuna gillnet operation, Moazzam (2012) estimated that 25- 35 dolphins are killed every month in gillnet operation. The present study reveals that on an average each tuna gillnet entraps about 60 dolphins annually and with a tuna fleet of about 500, the mortality of dolphins could reach about 30,000 annually. This, however, needs further studies to verify. Almost all dolphins enmeshed in the tuna gillnet operation die and are discarded.

Fig. 11. Striped dolphin (*Stenella coeruleoalba*) entrapped in tuna gillnet.

Whales

Baleen whales including blue whale (*Balaenoptera musculus*), sei whales (*Balaenoptera edeni*) and Arabian humpback (*Megaptera novaeangliae*) were reported to get entangled in tuna gillnets but such events are very rare. According to recent information, 1 to 2 whales are entangled every year and in

Fig. 12. Bryde'swhales *(Balaenoptera brydei)* entrapped in tuna gillnet and beached in Gwader (Photo Courtesy Abdul Rahim).

most cases fishermen try to release the entangled whales, but, the entangled whales die in some instances. In a survey of dead whales beached along the coast of Pakistan since 2008, three whales were observed to have nets entangled. Two of these were humpback whale and the third was a Bryde's whale (Fig. 12). Toothed whales do occur in Pakistan but only one such whale i.e. dwarf sperm whale (*Kogia sima*) was entangled in gillnet and died.

Discussion

Tuna gillnetting is an important fishery for Pakistan which annually contributes about 40,000 t of tuna in addition to large quantities of other teleosts and sharks as by-catch. In addition to commercially important species, gillnet operations in coastal and offshore waters catch large number of non-target species such as turtles and cetaceans. This is considered as a serious threat to these non-target species and some protection measures need to be taken up. In order to control the mortality of non-target species, it is suggested to divert the gillnet fleet to other modes of fishing such as long lining which is known for causing comparatively lower mortality to non-target species. Indian Ocean Tuna Commission and United Nations General Assembly resolutions warrant length of gillnet to be limited to 2.5 km. Reduction of the length of gillnets being used in Pakistan (presently >10 km) can also help in reducing the entrapment and mortality of non-target species. Use of techniques such as pingers and lights attached to the gillnets, which are known to deter or reduce entrapment of vulnerable species may also be attempted.

Acknowledgements

This paper forms a part of the study being undertaken with the assistance of Smart Fishing Initiatives (SFI), WWF-Pakistan and Indo-Pacific Cetacean Research and Conservation Fund (Government of Australia) which is greatly acknowledged. Participation in the Regional Fisheries Symposium, Kochi, India was made possible through funds from Mangroves for the Future, which is appreciated. Special thanks are due to Mr. Ghulam Qadir Shah, Coordinator, MFF-Pakistan whose help made it possible to attend the symposium. Assistance provided by Mr. Khalid Mahmood, Miss Saba Ayub and Mrs. Shazia Iqbal of the WWF-Pakistan's Tuna programme is highly acknowledged.

References

Gillett, R., 2011. By-catch in Small Scale Tuna Fisheries: A Global Study. *FAO Fish Aqua. Tech. Pap.* No.560, FAO, Rome.

IOTC 2013, Website - http://www.iotc.org/English/data/databases.php#dl visited on March16, 2014.

Lewison, R. L., L. B. Crowder, A. J. Read, and S. A. Freeman, 2004. Understanding impacts of fisheries by-catch on marine mega fauna. *Trends Ecol.* Evol.11:598-604.

Moazzam, M., 2012. Status report on by-catch of tuna gillnet operations in Pakistan. IOTC–2012–WPEB08-13.

Tregenza, N. J. C. and A. Collett, 1998. Common dolphin (*Delphinus delphis*) by-catch in pelagic trawl and other fisheries in the northeast Atlantic. *Rep. Intl. Whaling Commn.*, 48:453-459.

Tregenza, N. J. C., S. D. Berrow, P. S. Hammond, and R. Leaper, 1997. Harbour porpoise (*Phocaena phocaena* L.) by-catch in set gillnets in the Celtic Sea. *ICES J. Mar. Sci.*, 54: 896-904.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-14

Environment impacts of undulated surf clam dredging operation off Prachaup Kirikharn province, Thailand

Isara Chanrachkij*, Shettapong Meksumpum[1], Jarumas Meksampan[2] and Sangtian Aujimangkul[3]
SEAFDEC/TD, PO Box 97 Phrasamut-Chedi, Samutprakarn, 10290 Thailand
[1] Department of Marine Science, Faculty of Fisheries, Kasetsart University, Bangkok 10900, Thailand
[2] Department of Fisheries Biology, Faculty of Fisheries, Kasetsart University, Bangkok 10900, Thailand
[3] Department of Fisheries Management, Faculty of Fisheries, Kasetsart University, Bangkok 10900, Thailand.

*Correspondence e-mail: isara@seafdec.org

Received: 12 Apr 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract
Environment impacts of experimental dredging operations for the undulated surf clam, *Paphia* sp. around Paknam-Pran and adjacent coastal areas (Amphur Pranburi and Amphur Sam-roi-yod, Prachaup Khirikhan Province, Thailand) were investigated in collaboration with Department of Fisheries, Thailand. Data were collected on physical parameters from water samples at surface layer (30 cm below sea surface), and nutrient parameters from surface as well as overlying water (50 cm above bottom sediment level).

Results show that water quality changed by dredging operation in the following ways: the most significant impact was increase in Total Suspended Solids (TSS), and consequently, decrease in water transparency. Dissolved oxygen concentration was marginally higher in several stations after dredging, possibly due to disturbance caused by dredge boat propellers. Concentrations of Ammonium-Nitrogen (NH4+-N), Silicate-Silicon (Si(OH)4-Si) and Orthophosphate-Phosphorus (PO43--P) marginally increased in almost all stations after dredging. There is a possibility that increase in nutrient concentration may lead to occurrence of red tide during and after the surf clam dredge fishing season.

Keywords: *Paphia sp, total suspended solids, turbidity, dissolved oxygen, nutrients.*

Introduction

Undulated surf clam, *Paphia* sp. (Born, 1778) has been one of the important marine resources of Thailand since the commencement of its fishery. The Department of Fisheries, Thailand (DOF-Thailand) initially reported harvesting of undulated surf clam in 1973. Historically, surf clams were not a favorite food for Thai consumers. However, after development of canned and frozen products in 1977 for export, the surf clam has emerged as a product of high demand. In 2009, the undulated surf clam harvest was estimated to be around 17,763 metric tonnes, valued at approximately 7 million US $ for the raw product and at approximately 20 million US $ for the processed export product (Department of Fisheries, 2011)

Fishing technology to harvest undulated surf clam was improved from hand dredge to iron dredges operated from motorized fishing vessel. Nowadays, fishing operations are prevalent in the entire Gulf of Thailand as well as in the Andaman Sea, which has resulted in depletion of this resource. In some fishing grounds, 3 to 5 years are required for recovery of the resource. Negative impacts of dredge fishing to aquatic, physical and chemical environmental conditions are less understood compared to the biological impacts. The objective of this paper is to understand the impact of dredging operation on the physical and chemical environment parameters in Paknam-Pran and adjacent areas of Thailand by conducting experimental dredging. The results are expected to provide input for sustainable clam resource management.

Material and methods

Sampling area

Paknam Pran estuary and adjacent areas, Amphur (District) Pranburi and Amphor (District) Samroi Yod, Prachaup Khiri Khan Province, Thailand, are important fishing hotspots in the central part of Gulf of Thailand. Large and small scale fishing activities using various types of fishing gear, namely; gillnet, collapsible trap, squid cast net, purse seine and trawl are operated in the estuary and adjacent coastal area. Undulated surf clam (*Paphia undulata*) dredging is one of the fishing activities prevalent in this area. Department of Fisheries (1992) and Isara Chanrachkij (2012) have demarcated the fishing grounds around Prachaub Khirikarn Province from Paknam Pranburi Estuary to south of Sattakut Island (Fig. 1). The total fishing area is approximately 61.5 sq.km. (DOF, 1992).

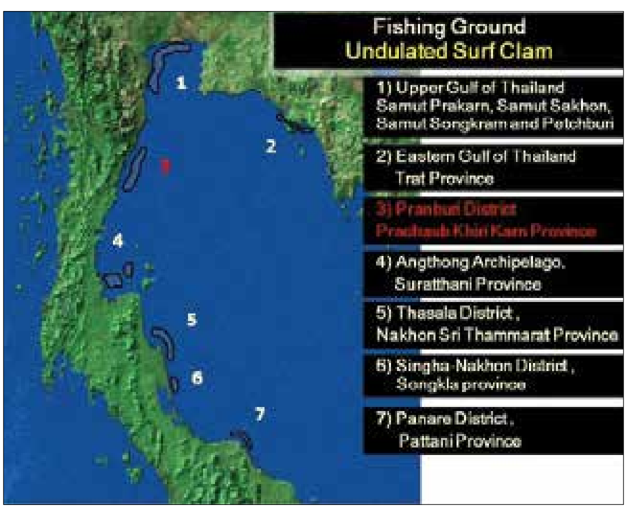


Fig. 1. Important fishing grounds of undulated surf clam (*Paphia* sp.) in Gulf of Thailand (source: Isara, 2012)

Fishing gear

The experimental dredge was made of a rectangular box shaped iron frame. The front portion was slightly higher than the rear side. The dredge was 220 cm in width (length of entrance), 100-110 cm in length (from entrance to rear side) and 12-16 cm in height (Fig. 2). The dredge slit had an interval of 1.2 cm. The weight of the dredge was approximately 80 kg. The frames were made of iron pipe with a diameter of 8-10 mm and 3 mm thickness. An iron plate, length equal to the width of dredge entrance, with a width of 8-10 mm and 3 mm thickness, was fixed at the mouth of the dredge, at an oblique angle at 30-40 degrees. Dredge pendants were made of iron chains. The dredge warp was a polypropylene (PP) rope, 4 strand Z twist and 24 mm diameter. The warp length was 2-3 times the sea depth.

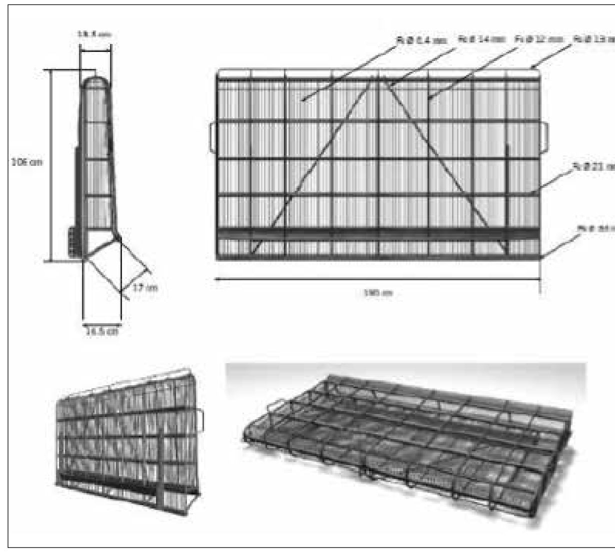


Fig. 2. Specification of iron dredge, entrance size 190 cm (source: modified from SEAFDEC, 2004)

Dredging operation

Six dredging tracks were fixed in four areas of Paknam Pranburi estuary and adjacent coastal areas, i.e. Pranburi Estuary, front of Kao Ka-lok and Ao Sam Roi Yod Bay Northern of Ko Sattakut Island. Two tracks (DG1-DG2 and DG3-DG4) were in the front of Paknam Pran estuary; one track (DG8- DG9, 2 times) was off Khao Karok; one track (DG13-DG14) was off Ao Sam Roi Yod Bay; and two tracks (DG15-DG16, 2 times, and DG15-DG17) were around Ban Bang Poo Bay (Fig. 3 and Table 1). In total, eight dredging operations were carried out. Before commencement of dredging, a speed boat was used for setting the position, sounding sea depth, and two flags were deployed to mark the starting and ending positions. Researchers onboard speed boat collected water samples before, during and after each operation. Dredging was conducted by the Department of Fisheries, Thailand research vessel, *R.V. Pramong 12*. Dredge was operated at stern deck with towing speed of 5-8 km/h. The duration of each dredging operation was 5-10 minutes, while an approximate distance of 1000 m was covered during the period. As the dredging ground between Ban Bang Poo bay and Ao Sam Roi Yod Bay was shallow (depth 3-5 m), the duration was reduced, thereby reducing the distance to 500 m. During dredging operations, researchers on speed boat conducted overlying water sampling on the dredging tracks. After completion of each operation, the dredge was heaved from sea bottom, and towed at sea surface for washing sediments out of the dredge.

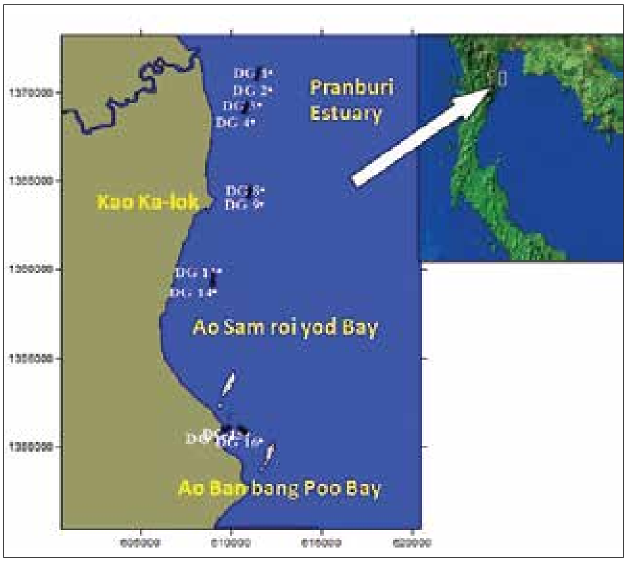


Fig. 3. Survey stations in the coastal waters of Amphur Pranburi District and adjacent area, Prachuap Khirikarn Province

Table 1 Position and coordinate of stations of dredging experiment

Station No.	Position (UTM*)	
	East	North
DG 1	612166	1371163
DG 2	612122	1370177
DG 3	611539	1369325
DG 4	611180	1368384
DG 8	611718	1364530
DG 9	611673	1363724
DG 13	609342	1359915
DG 14	609073	1358794
DG 15	610866	1350728
DG 16	611628	1350325
DG 17	609992	1350504

*UTM = Universal Transverse Mercator

Water sample collection and analysis

The geographical position of survey stations was recorded using GPS. Depth at survey stations was recorded by an echo sounder. Data on sea surface temperature (SST), salinity, dissolved oxygen (DO) and pH at surface layer (30 cm below sea surface) were collected using a multi-parameter environment monitor (YSI Model 600 QS). Transparency data was obtained by Secchi disc measurement. Data on water quality parameters, particularly concentration of nutrient parameters, i.e. NH4+-N, NO2-+NO3 -N, Si(OH)4-Si and PO43--P were collected using a vertical type water sampler from 30 cm below sea surface and overlying water (50 cm above bottom sediment). Water samples for nutrient analysis were pre-filtered through a 0.7 μm glass fiber filter (GF/F). Pre-filtering was done immediately at the sampling site in order to avoid degradation of samples. Nutrient concentration was analyzed in the laboratory using an auto-analyzer SKALAR segment flow. TSS was determined by freeze dryer method in the laboratory of Department of Marine Science, Faculty of Fisheries Kasetsart University, Bangkok.

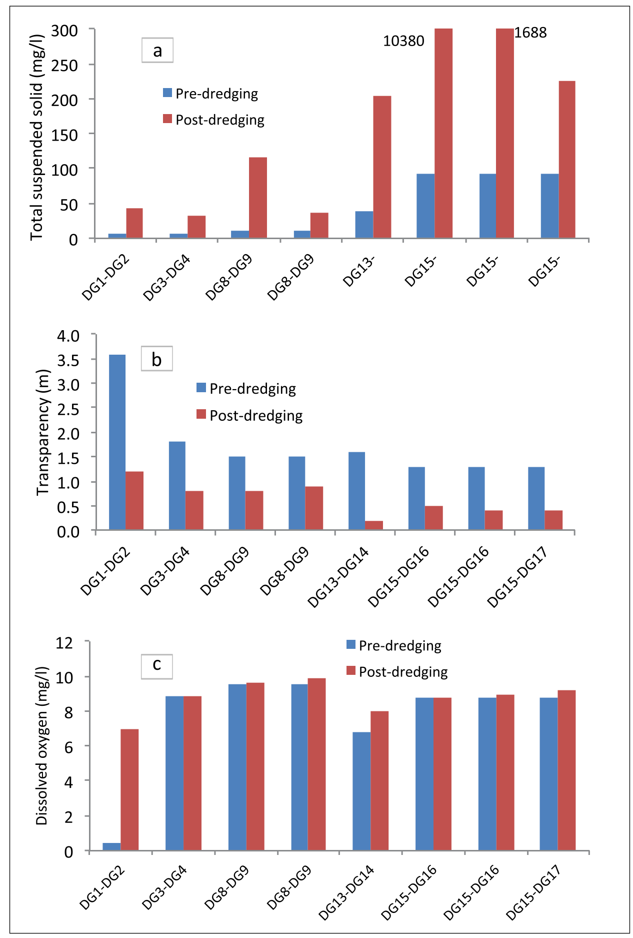


Fig. 4. Water quality in pre and post dredging operations; (a) Total Suspended Solid; (b) Transparency; (c) Dissolved Oxygen

Results

Sea surface temperature, salinity and pH did not show any significant difference in the tracks before and after dredging operation.

Total Suspended Solids (TSS)

The TSS substantially increased in all the tracks after dredging operation. Range of TSS pre-dredging was from 6.00 mg/l to 92.35 mg/l (Fig. 4a) with an average of 24.87 mg/l. The range of post-dredging was from 36.10 mg/l to 10,380.00 mg/l with

Fig. 5. Re-suspended sediment spreading at the sea surface while the dredge is being hauled

an average of 163.00 mg/l. Thus the average TSS increased by 6.5 times. While the dredge is hauled, dense re-suspension of sediment spread occurred in the sea surface (Fig. 5). Massive TSS increase from 92.35 mg/l to 10380 mg/l was found in the dredging track DG15-DG16. The lowest difference was in tracks DG8-DG9 where the TSS increased from 10.60 mg/l to 36.10 mg/l.

Sea water transparency

Sea water transparency substantially decreased in all the tracks after the dredging operations. The range of transparency in pre-dredging was recorded as 1.3 m to 3.6 m with an average of 1.5 m, while in post-dredging it was 0.2 m. to 1.2 m with an average of 0.65 m. Thus, the average transparency reduced by half after dredging. The transparency loss was maximum in tracks DG13-DG14, where it reduced from 1.6 m to 0.2 m (Fig. 4b).

Dissolved Oxygen (DO)

DO concentration marginally increased in almost all the tracks after dredging. Range of DO concentration during pre dredging was recorded as 6.42-9.52 mg/l with an average of 8.78 mg/l. Post-dredging DO concentration was in the range from 6.94 to 9.90 mg/l, with an average of 8.90 mg/l. While the highest difference in DO concentration was in tracks DG13-14 (6.83 mg/l to 8.03 mg/l), the DO remained constant in tracks DG3-DG4 (Fig.4c).

Ammonium-Nitrogen (NH4+-N)

Concentration of NH4+-N increased in all the tracks after the dredging operations, being substantial in a few tracks. The range of NH4+-N concentrations during pre-dredging was 7.52-10.80 μM with an average of 10.03 μM. The concentration ranged from 9.19 to 12.53 μM post-dredging with an average of 11.07 μM. The highest difference was found in tracks DG15-DG17, where it increased from 7.52 μM to 12.53 μM. Dredge track DG3-DG4 recorded the lowest difference in NH4+-N concentration between pre and post dredging, increasing from 10.03 μM to 10.44 μM (Fig. 6a).

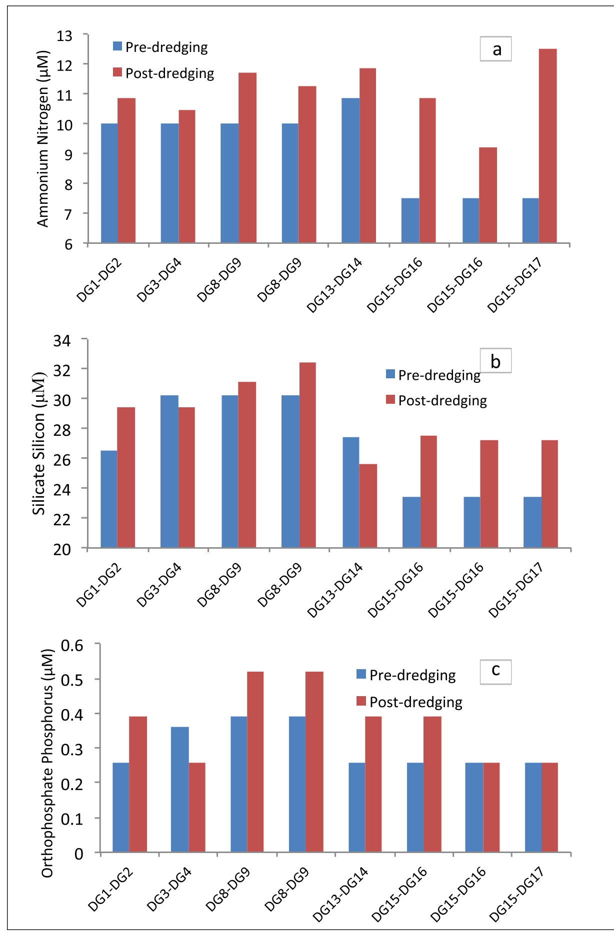


Fig. 6. Nutrient concentration in pre and post dredging operations; (a) Ammonium-Nitrogen (NH4+-N); (b) Silicate-Silicon (Si(OH)4 –Si); (c) Orthophosphate-Phosphorus (PO43--P)

Silicate-Silicon (Si(OH)4-Si)

Concentration of Si(OH)4-Si increased in some tracks after the dredging operations, i.e., DG1-DG2, DG8-DG9, DG15-16 and DG15-17. In two tracks, namely DG3-DG4 and DG13-14, the concentration marginally decreased. The range of Si(OH)4-Si concentration in pre dredging was 23.40-30.20 μM with an average of 26.85 μM. Post-dredging, the concentration ranged from 25.67 to 32.46 μM with an average of 28.75 μM. Track DG15-16 registered the highest difference between pre and post dredging, where it increased from 23.40 μM to 27.55 μM. In the track DG3-DG4, the Si(OH)4-Si concentration marginally decreased from 27.40 μM to 25.67 μM (Fig. 6b).

Orthophosphate-Phosphorus (PO43--P)

Concentration of PO_4^{3-}-P increased in five of the eight tracks after the dredging operation (Fig. 6c). The range of PO_4^{3-}-P concentration in pre dredging was 0.26-0.39 μM with an average of 0.29 μM. Post-dredging, the range was 0.26-0.52 μM with an average of 0.39 μM.

Discussion

The following changes were observed due to clam dredging operation: (i) Total Suspended Solid (TSS) increased by 6.5 times; (ii) consequently, water transparency reduced by half; (iii) dissolved oxygen concentration was marginally higher, which may be the result of propeller of the dredge vessel mixing air and seawater; and (iv) the nutrient sources of phytoplankton , i.e. Ammonium-Nitrogen, Silicate-Silicon and Orthophosphate-Phosphorus marginally increased. Si(OH)4-Si, an essential nutrient for diatoms was found in higher concentration in Ao Sam Roi Yod Bay; and NH4+-N was found in higher concentration around Paknam Pran estuary after dredging operation. Nutrient enhancement by dredging operation would directly influence the concentration of chlorophyll *a*. By the combinations of all these factors, the growth of phytoplankton would be enhanced, potentially causing red tide phenomenon after the dredging season.

High turbidity directly impacts the respiration of marine organisms, particularly the slow swimming demersal fishes (Siri and Permsak, 1985). The sediments block gas exchange in the gills and cause mortality of marine animals by hypoxia. Sediment cover and low turbidity also affect hatching of fish eggs. Pelagic fish and fast swimming fish may escape from turbid areas. Hall and Spencer (1999) recorded the picture of beam trawl track on sandy bottom in Adriatic Sea and reported that suspended sediments from trawling reduced light penetration and underwater visibility from 20 m to 0 m at a height of 1 m above sea bottom. They also reported that it takes 15 hours for the area to return to natural visibility. Chayarat (2007) reported that suspended solids and reduced transparency resulted in a shallower eupohotic zone. The primary productivity, in particular Chlorophyll *a*, reduces in areas of high turbidity.

Acknowledgements

The authors express their deep appreciation to Government of Thailand for extending financial support for the study through SEAFDEC/TD, under the consideration of Secretary-General and Chief of Training Department of SEAFDEC, Dr. Chumnarn Pongsri.

The authors would like to express deep appreciation to Department of Fisheries, Thailand to provide funding support and Research Vessel, Pramong 12, to conduct dredging trial operation; the environmentalist craftsmen under Faculty of Fisheries and Coastal Development Center (CDC), Kasetsart University, for their full support during the field surveys; Dr. Boontarika Thongdonphum, Dr. Phattira Kasemsiri, Mr. Parauhas Channual and Ms. Nissara Thawonsode for their kind help to conduct water quality analysis and preparation of figures. The authors also express gratitude to Dr. Worawit Wanchana, Head of Capture Fisheries Technology Division and his staff for support and Mr. Aussanee Munprasit, Assistant SEAFDEC/TD Department Chief (Retired) for his comments on the manuscript.

References

Chayarat, T. 2007. Relationships between Environmental Factors and Production Potential of Razor Clam (*Solen* spp.) at Don Hoi Lord, Samut Songkhram Province. Thesis Master of Science, Department of Marine Science, faculty of Fisheries, Kasetsart University, Thailand. 219 pp. (In Thai)

Department of Fisheries Thailand. 1992. Undulated Surf Clam in Thailand. Marine Fisheries Division, Department of Fisheries, Bangkok, Thailand. 62 pp. (In Thai)

Department of Fisheries Thailand. 2011. Fisheries Statistics of Thailand. Information Technology Center, Department of Fisheries, Bangkok, Thailand. 91 pp. (In Thai)

Hall-Spencer J.M. 1999. Effect of Towed Demersal Fishing Gear on Biogenic Sediments: A 5- Year-Study. Institute of Biomedical and Life Sciences, Graham Kerr Building, University of Glasgow, Scotland. 15 pp.

Isara Chanrachkij. 2012. Environmental Impacts of Undulated Surf Clam (*Paphia* spp.) Dredge Fishing: Case Study in Paknam Pranburi Estuary and Adjacent Areas, Pranburi District and Sam Roi Yot District, Prachaub Khiri Khan Province, Thesis Master of Science, Department of Marine Science, Faculty of Fisheries, Kasetsart University, Thailand. 354 pp. (In Thai).

SEAFDEC/TD. 2004. Fishing Gear and Method in Southeast Asia I: Thailand. Revised edition. Training Department, Southeast Asian Fisheries Development Center. Samutprakarn. 416 pp.

Shettapong Meksumpum. 1998. Red Tide. Department of Marine Science, Faculty of Fisheries, Kasetsart University, Thailand. 81 pp. (In Thai)

Available online at: www.mbai.org.in doi: 10.6024/jmbai.2014.56.1.01750s-15

Assessment of sand extraction and use in coastal fishery communities of Cambodia

Hoy Sereivathanak Reasey
Department of Natural Resource Management and Development, Royal University of Phnom Penh, Room 216, Building A, Russian Federation Blvd., Toul Kork, Phnom Penh, Cambodia.

*Correspondence e-mail: reasey@mail.com

Received: 05 Jun 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Coastal resources need to be maintained in order to support livelihoods and well-being of coastal resource-dependent communities, as well as to provide a balanced set of ecosystem goods and services. However, development projects, including infrastructure projects such as ports, modern settlements, resorts and tourist destinations, have been implemented at an alarming rate along the coastal areas of Cambodia in recent decades. In addition to these development projects, coastal areas have been exposed to sand extraction and related activities, all resulting in the coastal environment facing negative consequences. In order to identify, measure and analyze the above issues, a causal framework "DPSIR" model developed by European Environmental Agency (EEA) has been used. This model has five key elements namely, Driving Forces, Pressures, State (environmental change), Impacts and Responses . Based on household surveys and focus group discussions, the following observations have been made: environmental problems are a consequence of two key driving forces of sand extraction and use activities, and infrastructure developments taking place within Kampot port and the development projects in the Special Economic Zone (KSEZ). The coastal resources face varying levels of degradation; in addition to decreasing biodiversity, there have also been significant changes in other ecosystem elements and changes in environmental qualities. Social problems such as changes in traditional occupations, outward migration, conflicts and mental stress have also occurred. As a result of alteration of mangrove forests, the livelihoods of communities are also affected. In order to resolve these problems local authorities and fishing communities have responded with demonstrations, conflict mediation, mangrove replantation, and job alternatives but with limited success thus far.

Keywords: *Boeng Tuk Commune, Kampot Province, coastal ecosystem, DPSIR model.*

Introduction

Coastal areas, like other ecosystems such as tropical forests and wetlands, are vital to maintain a balance within the natural and social environments through the provision of ecosystem goods and services. Coastal resources, such as coral reefs, sea grass beds and mangroves are important for local environments, biodiversity and communities; providing them livelihood security and protecting communities from natural disasters such as storms, erosion and salinity intrusion (Sarker *et al*., 2010). Among the coastal provinces of Cambodia, Kampot Province has been identified for its development potential. The Kampot Special Economic Zone (KSEZ) was created in order to develop an international sea port with a total development cost of 80 million US Dollars (JICA, 2010). Together with shipways and a deep sea water port, several activities taking place in the area, such as sand dredging (Johnsen and Munford, 2012; Marschke, 2012), expansion of seashores and other infrastructure constructions cause many environmental problems to the local communities in Cambodia's coastal areas. Increased construction activity has led to greater demand for construction materials, especially sand for construction activities, building of dykes and seashore expansion activities. These infrastructure developments, plus dredging of the deepwater port and shipways would invariably cause coastal erosion, disrupt coastal ecosystem process, reduce sea water quality, and damage coastal habitats, such as mangroves, sea grasses and coral reefs. Lovell (2005) argued that extensive environmental impacts would occur with any sand extraction. This might be due to precipitating erosion or sand transport which would alter the environment and hence, the composition of organisms. It has been already documented that fish yields have declined, having a direct impact on Cambodia's coastal resource dependent dwellers (Sek Som, 2007; CES, 2008; Seak, 2011). So far, there have been no detailed studies to assess the impact of sand mining activities on the coastal provinces of Cambodia, implying that there is an urgent need to understand the DPSIR aspects in order to ensure appropriate planning, policy recommendations and environmental protection mechanisms. This understanding is necessary for the long-term protection of coastal community livelihoods and ensuring sustainable development of coastal areas. This study aims to identify the impact of sand extraction and use activities on the Kampot coastal fishery community, by applying a DPSIR model as suggested by the European Environmental Agency 1999 (EEA).

Material and methods

Both quantitative and qualitative methods were used to collect primary data for identification, measurement and analysis of the DPSIR framework components. Research activities were divided into two phases; an action phase and an analysis phase, as listed below:

(i) Field selection: Selection of location, including stakeholder identification;

(ii) Field data collection: Direct observation, informal focus group discussions, key informant interviews, workshop, and household questionnaire surveys with fishing communities, local authorities and other external stakeholders; and

(iii) Analysis: Detailed and systemic analysis of the five DPSIR framework elements.

Study site

The research was conducted entirely within Rolous and Kep Thmey villages, Boeng Tuk Commune in Tuek Chhu District, Kampot Province (Fig. 1), largely at the construction sites of development projects in the KSEZ. Boeng Tuk Commune is located about seven kilometres from Kampot provincial town. The commune area is 2,467 ha area and is characterized by coastal plains, with Bokor Mountains nearby. The area has a number of construction projects and sand extraction activities. There are two coastal fishing communities in the area: Rolous and Kep Thmey villages, both of which are totally dependent on coastal resources.

Fig. 1. Map of Kampot Province and the study site

Research approach

The DPSIR framework was used to identify and analyze the five key elements (Fig. 2).

The DPSIR framework is a model recommended by the EEA for the development of Integrated Environmental Assessment Strategies, and provides the indicators needed to enable

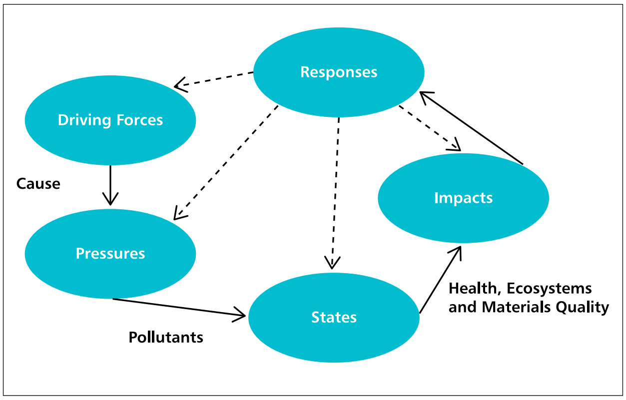


Fig 2. The DPSIR Assessment Framework (adapted from Kristensen, 2004)

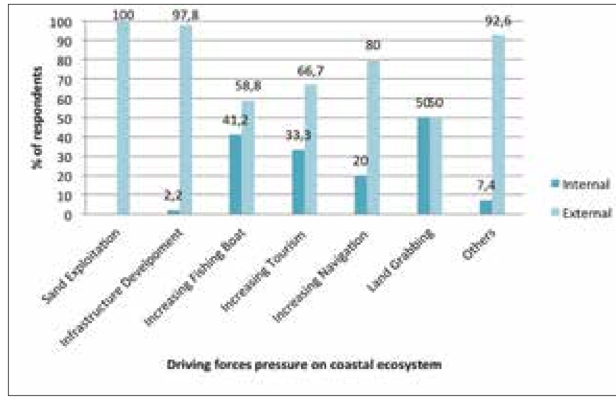


Fig 3. Driving forces which exert pressure on coastal ecosystem (% of respondents)

provision of feedback to policy makers on the environmental impacts of political choices made. This framework focuses on five key areas associated with change: driving forces, pressures, states, impacts and responses, and these five areas are linked (Kristensen, 2004).

Field data collection

Sampling approach: A rule of thumb method was used to ascertain the number of households needed to create a suitable sample from the two coastal fishing villages of Rolous (344 households) and Kep Thmey (432 households), with 25% of the total of 776 households randomly selected, making a sample size of 194 households for the survey. These households were the target for the household surveys.

Focus group discussions: Twelve active fishermen and fisherwomen living in the two villages were selected for group discussion. A visualization technique was used to develop a social map and a natural resources map, to ascertain the zoning areas and to gather other qualitative information.

Key informant interviews: Key informants, such as the village chiefs, the commune council chief, the heads of fishing community, and representatives from government agencies and non-governmental organizations were interviewed.

Results

DPSIR elements analysis

Driving Forces: Based on results from household interviews and focus group discussions, it was identified that sand extraction and infrastructure development in the study site are the key factors behind the problems faced by the local communities (Fig. 3).

Pressures: The above two critical driving forces exerted pressure on coastal biodiversity and communities' livelihoods. All the surveyed households responded that sand extraction activity exerted maximum pressure; 97.8% of the respondents identified infrastructure development taking place within Kampot international port and KSEZ development projects as other driver for exerting pressure.

State: More than 70% of the respondents noticed that seagrasses, seaweeds, flower crabs (*Portunus pelagicus*), mangroves and sea fishes have significantly reduced (Fig. 4), their populations were also observed to have reduced rapidly within a short time span (Table 1). While more than 50% of the respondents reported the populations of several other exploited fish species were reduced , relatively less number of respondents (less than 50%) opined reduction in the populations of marine mammals, marine reptiles and coral reefs. This may be due to conservation measures taken to protect these species.

Besides the decreasing biodiversity, there have been significant changes to the physical characteristics of the ecosystem. High level of changes in water turbidity (41.2%)

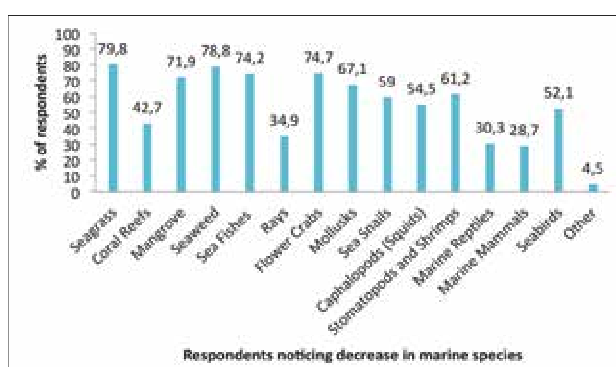


Fig 4. Percentage of respondents noticing decrease in marine species

Table 1. Respondents' view (%) on decrease of marine species in the study area

Marine Species	Percentage Decrease (%)				
	Very Small	Small	Medium	Large	Very Large
Seagrasses	7.1	9	17	35.9	31
Coral reefs	14	15	23	25	23
Mangroves	7	7	12.4	34.5	39.1
Seaweeds	2	1	18	44	35
Rays	22	4	10	34	30
Other sea Fishes	2	2	28	49	19
Stomatopods and prawns	3.2	1	24.4	51.4	20
Flower Crabs	2	2	17.4	57.1	21.5
Sea snails	0	4	13	48	35
Cephalopods (squids)	2	1	24	50,5	22,5
Other molluscs	1	3.3	13.5	42.5	39.7
Marine reptiles	18	8	29.5	29.5	15
Marine mammals	22	9	27.5	27.5	14
Seabirds	5.5	3	20	42.9	28.6

and salinity intrusion (41.7%) have been identified by the respondents (Table 2).

In addition to the environmental problems, social problems have started to occur. For instance, 90.4% of the respondents

Table 2. Respondents' views (%) on changes in physical characteristics of ecosystem

Characteristics	Levels of change (% respondents)		
	Low	Medium	High
Erosion	36.8	52.6	10.5
Water turbidity	35.3	23.5	41.2
Wind strength	57.3	32	10.7
Noise pollution	38.2	47.1	14.7
Air pollution	13.1	53.1	33.8
Salinity intrusion	27.8	30.6	41.7

were professional fishers, of which 56% had to change their occupation to construction and factory workers outside of their home land. However, 38.8% of the respondents said that being a fisherman had a higher level of livelihood stability than that of a waged worker.

Impacts: In terms of changes to the environment, the surveyed households rated pollution as having from a very low to a very high level of impact. For instance, 36.4% of households recognised water pollution while 22.5% complained of air and noise pollution (Table 3).

Of the households surveyed, 27.5% said that the habitats of the flower crabs have altered in recent years (Fig. 5), and

Table 3. Respondents' views (%) on types and levels of pollution impact

Types of pollution	%	Impact Levels				
		Very Low	Low	Medium	High	Very High
Air pollution	22.5	10.3	7.7	38.5	35.9	7.7
Water pollution	36.4	14.5	9.7	37.1	21	17.7
Land pollution	18.5	10.7	17.9	25	35.7	10.7
Noise pollution	22.5	22.9	20	28.6	11.4	17.1

of these 64.2% stated that the impacts have been high. In addition to Flower Crabs, 22.8% said that some of the sea fish are facing habitat loss. All the respondents noted that the loss of marine mammal habitats is a serious problem.

Significant impacts were reported on livelihoods, with 54.5% of the households surveyed complaining that their daily

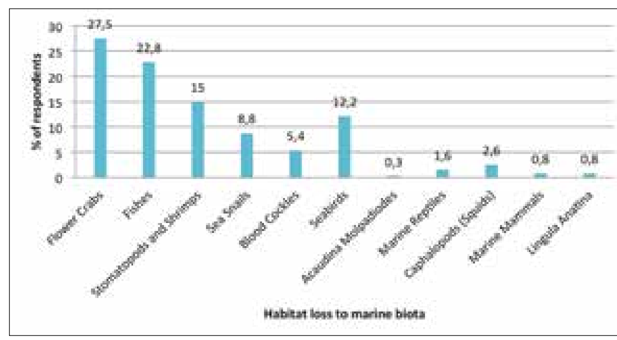


Fig 5. Respondents' views (%) on habitat loss to marine biota

income had reduced following a decrease in abundance of economically important species. About 57.9% claimed that incomes have decreased along with fishing yields when compared to the past (Fig. 6). In addition, about 45.5% claimed that they now face difficulties having lost their traditional occupation as fishers, 29.2% said they are in debt and 39.9% stated that a number of fishermen have had to move to other provinces or abroad in order to find new jobs. Another significant impact felt by the local communities has

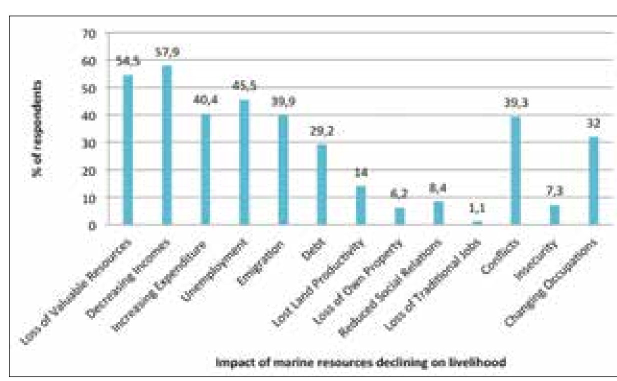


Fig 6. Respondents' view (%) on livelihood

been the rise in the number of conflicts; 39.3% said that conflicts now occur within the communities due to sand extraction activities and development projects.

Moreover, health and sanitation issues have also started to cause problems. Of the respondents, 47.2% stated that they now suffer from fever and headache due to the noise pollution coming from the construction activities (Table 4). A significant percentage of the respondents also reported not having proper toilets.

Table 4. Respondents' views on health and sanitation problems

Health Problem	Percentage	Level of impact (%)		
		Low	Medium	High
No proper toilet	48.3	65.1	26.7	8.2
Dirty water	10.1	33.3	38.9	27.8
Malnutrition	28.1	42	34	24
Mental problem	3.9	42.9	0	57.1
High blood pressure	19.7	57.1	20	22.9
Headache and dizziness	47.2	78.6	11.9	9.5
Throat inflammation	6.7	75	16.7	8.3
Irritated eyes	11.8	71.4	14.3	14.3
Gastritis	28.1	66	20	14
Skin problems	5.1	44.4	44.5	11.1
Malaria	16.3	51.7	27.6	20.7
Dengue fever	21.9	41	35.9	23.1

In terms of social-cultural issues within the study communities, conflicts have become a problem in recent times, and 79.8% of the households surveyed said that conflicts regularly take place between villagers and the developers (private investment companies), and 69% said it is having a significant impact on their lives (Table 5). A low percentage of villagers mentioned that conflicts take place between local authorities and developers, as well as among villagers, though 44.4% and 55.6% of the respondents, respectively, said that this has a low impact.

Responses: There were large differences on how the interviewees responded to the challenges. More than half of them (53.4%) said that they have decided to face to the problems, with 12.4% saying that they are proactive in replanting mangroves, though 47.9% said this has not been very effective (Table 6). About 24.7% stated that the communities have responded by cleaning the surroundings themselves, with 61.4% saying that this response has been reasonably effective. The communities' advocacy rights are supported by local NGOs, though 87.7% of the respondents said they are not very effective.

On the issue of conflict, 40.4% said they have noticed conflicts taking place between the villagers and the developers, and that mediatory efforts are very effective in settling the disputes (Table 7).

Table 5. Respondents' view (%) on social and cultural impacts and their severity

Social and Cultural Impacts	%	Severity of impact (%)		
		Low	Medium	High
Breakdown in solidarity	15.2	40.7	44.5	14.8
Insecurity	11.8	50	31.8	18.2
Conflicts between the authorities and developers	5.1	44.5	11.1	44.4
Conflicts between the authorities and villagers	18	28.1	37.5	34.4
Conflicts between villagers and the developers	79.8	15.5	15.5	69
Conflicts among villagers	5.1	55.6	22.2	22.2
Lost place of worship	3.4	0	28.6	71.4
Loss of fishing culture	4.5	25	25	50

Table 6. Responses (%) to issues and their effectiveness

Responses	%	Effectiveness levels		
		Low	Medium	High
Mangrove replanting	12.4	47.9	39.1	13
Loans	11.2	70	20	10
New occupations	18	53.1	43.8	3.1
Community financing	18.5	54.5	27.3	18.2
Cleaning the local environment	24.7	18.2	61.4	20.4
Advocacy	59	87.7	9.5	2.8
Mediation	20.8	64.9	27	8.1
Legal solutions	23	81	14.3	4.8
Migration	12.4	63.6	27.3	9.1

Table 7. Respondents' views (%) on conflict types and effectiveness of mediation efforts

Conflicting parties	Roots of conflict	(%)	Effectiveness of Mediation		
			Low	Medium	High
Between authorities and developers	Overlapping territory	1.7	100	0	0
Between villagers and authorities	Protests and responses	7.9	76.9	23.1	0
Between villagers and developers	Development activities	40.4	90.3	6.9	2.8
Among villagers	Land-grabbing	0.6	0	100	0

Discussion

Two main driving forces (sand extraction and infrastructure development) in addition to a number of others have led to environmental problems amongst the local fishing communities. Rizvi and Singer (2011) and Johnsen and Munford (2012) have noted that human development activities are one of the key driving forces behind the negative environmental trends in Cambodia's coastal zone, and have identified sand dredging around the Koh Kong and Kampot coastal areas as the main issue. The dredging of sand without the use of adequate safeguards also is a risk to life. A related issue is the reported incidence of oil spills from the dredging vessels, leading to water pollution in the area.

As highlighted in an initial environmental impact assessment carried out by the CES (2008), the coastal resources and community livelihoods are under significant pressure in the study area. Biodiversity levels have been reduced by construction activities such as drainage and the reclamation of mangrove wetlands in order to expand the harbor, as well as land fill activities. These activities have also had an impact on livelihoods, degrading marine fishing resources, creating obstacles for saltpan irrigation, fragmenting the fishing zones, damaging crab nurseries, as well as creating dust and noise pollution.

These pressures have led to changes in the state of the ecosystem. Sek Som (2007) reported that turbidity of seawater has increased and debris from construction sites and drainage pipes pollute the area. Transportation activities also tend to pollute the water with waste and oil. Based on information from the focus group discussions held in Rolous village, some of the most valuable marine resources such as seaweeds, rays, sea snails (*Noble volute*), blood cockles (*Arca granosa*), sea cucumbers (Holothuroidea), sharks, whales, sea turtles and blue-barred parrot fish (which has declined most rapidly), mangroves, sea grasses, shrimp and squid in addition to the leopard cat (*Prionailurus bengalensis*) are in jeopardy. Since 2002, the leopard cat has been placed on the Least Concern (LC) list by the International Union for the Conservation of Nature (IUCN). Based on interviews with local communities, the leopard cat was earlier seen inside the mangrove forest, but there have been no recent sightings due to habitat loss and hunting. In addition to these species, cranes, moorhens, Lesser Whistling Duck (*Dendrocygna javanica*) sea snakes and the crab (*Galene bispinosa*) are also declining in numbers at a rapid rate. From communities' perceptions, Seak (2011) reported that the development projects in Boeng Touk Commune had a negative effect in both community livelihoods and the environmental quality.

According to the findings of Johnsen and Munford (2012), there are strong indications of widespread sea grass habitat destruction due to the degradation of water quality as a result of increased turbidity caused by forest clearing, sand dredging and reclamation activities. During the focus group discussion in Rolous village, the villagers said that dust from the construction activities has caused significant air pollution problems in the village, and that this is having large impact on the environmental quality and the health of locals. Otay *et al.* (2003) reported that extraction from shallow areas may modify near shore wave conditions, affect erosion and deposition rates, and alter benthic habitats and near shore circulation. Due to mangrove and sea grass habitat degradation along with decreasing fish yields, 40.4% of the surveyed households said that they needed to change their traditional fishing practices, having to go further offshore to catch fish, and spend more on gasoline as a result. Beside the natural environmental impacts, local communities are also facing a number of social problems. The household survey and focus group discussions revealed that each village has its own social network, plus groups such as savings groups, fishery community groups, crab banks, mangrove forest groups and funeral support associations. Unfortunately, some of these groups have recently been dissolved, and in fact, the fishery community group in Rolous village had to be dissolved because around 800 ha of community land around the village was taken over for one of the development projects. Seak (2011) states that because of tourist resort and international sea port development projects, Roluos fishery community disappeared in 2010, as the village's fishing ground was granted to the port developers. As a result of these developments, conflicts occurred between the fishers and developers, and among the fishers.

Sek Som (2007) has expressed concerns of relevant provincial departments and local authorities over the likely impacts of the projects. The villagers tried their best to protect their fishing grounds against the developers by organizing protests, but were not considered. A number of local people responded by finding alternative jobs and/or have migrated outside, while those remaining have continued to advocate for compensation to be paid for the loss of jobs and earnings due to the development projects. The local authorities, in particular, have played an important role in helping to mediate between the developers and villagers. However, thus far only verbal agreements have been made by the developers promising to provide job opportunities, introducing electricity to the villages, developing a small fishing port, building toilets and compensating the villagers with 500 US dollars each in cash.

There are a number of ways in which the issues may be addressed, these are listed below:

- A mediation mechanism and formal agreement between community and developer should be established.

- Local communities and authorities should be involved in development planning.
- Ecosystem based approach should be integrated into Environmental Management Planning of the port.
- A full Environmental Impact Assessment should be strictly in place.
- Scaling up Integrated Coastal Management (ICM) approach should be considered.

References

CES. 2008. Initial Environmental Impact Assessment of Land Fill on Expansion Coastal Area for International Port Project. CES Co., Ltd. Cambodia, p. 17, 23, 32.

JICA. 2010. Integrated development strategy for coastal area. Japan, p. 18, 22.

Johnsen, S. and G. Munford. 2012. Country Environment Profile: Kingdom of Cambodia. European Union Delegation To Cambodia, p. 11-12, 24.

Kristensen, P. 2004. The DPSIR Framework. UNEP, Kenya, p. 1-4.

Lovell, E. 2005. Environmental Impact Assessment of Sand Resource Extraction North of Tongatapu. SOPAC Technical Report 387, South Pacific Applied Geoscience Commission, Fiji, 35p.

Marschke, M. 2012. Life, fish and mangroves: resource governance in coastal Cambodia. University of Ottawa Press, 48p.

Otay, E. N.; P. A. Work and O. S. Börekçi. 2003. Effects of Marine Sand Exploitation on Coastal Erosion and the Development of Rational Sand Production Criteria. Bogazici University, Turkey, 1p.

Rizvi, A.R. and U. Singer. 2011. Cambodia Coastal Situational Analysis. IUCN, Cambodia, 49p.

Sarker, S., Kuri, K. C. and Md. S. M. Chowdhuri. 2010. Mangrove: A Livelihood Option for Coastal Community of Bangladesh. *Bangladesh Res. Publ. J.*, ISSN: 1998-2003, 3(4): 1188-1189.

Seak Sophat. 2011. Impacts of Port Construction and Resort Development on Coastal Communities in Boeng Touk Commune, Toek Chhou District, Kampot Province. FACT, Cambodia, p.15,17,21.

Sek Som. 2007. Initial Evironmental Impact Assessment on the project of International Port and Special Econmic Zone. Phnom Penh, Cambodia: Seksom Co., Ltd. p. 14-17, 26.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-16

Assessment of low value bycatch and its application for management of trawl fisheries

A.P Dineshbabu*, Sujitha Thomas and E. Vivekanandan
Central Marine Fisheries Research Institute, Cochin 682018, India.

*Correspondence e-mail: dineshbabuap@yahoo.co.in

Received: 10 Jun 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

The estimated annual average catch by trawlers operating from Mangalore Fisheries Harbour (southwest coast of India) was 124,105 tonnes during 2008-2011. Of the total catch, 63.9% was landed as high-value catch (HVC) for human consumption, 14.7% as low-value bycatch (LVB), and 11.4% was discarded at sea. However, during the four years, the contribution of LVB to the trawl catch substantially increased from 2.5% to 24.6%; and the discards reduced from 18.1% to 5.9%. As demand for raw material from fish meal plants is increasing, trawlers are encouraged to target LVB. Trawl bycatch consisted of 205 species/groups, of which 147 were finfishes, 4 bivalves, 7 cephalopods, 21 crabs, 3 stomatopods, 3 lobsters and several miscellaneous groups. About 34% of the LVB by weight and 63% by number were juveniles of 45 commercially important species. Mapping spatio-temporal abundances of juveniles of four important demersal fish species showed that the distributions of juveniles occurred along vast coastal stretches for several months in a year. Exploitation of large quantities of juvenile and sub-adult fishes potentially contributes to growth overfishing, reduced economic returns to fisheries and loss of biodiversity; and therefore threatens the sustainable exploitation of resources. A few potential management options such as the use of bycatch reduction devices, spatial and temporal closures to trawling and fisheries *refugia* are discussed. Assessing the net economic value of benefits and losses due to LVB is required to achieve sustainable management of trawl fisheries.

Keywords: *Fisheries bycatch, overfishing, biodiversity loss, ecosystem, fisheries sustainability*

Introduction

Trawling has become one of the most efficient technological interventions in the history of marine fisheries. It has been adopted widely throughout the world and has contributed greatly to increased marine fish production. However, largely due to indiscriminate operations, bottom trawling has caused physical and ecological disturbances to the sea bottom and the ecosystem (Jennings and Kaiser, 1998). In India, the trawl fleet has contributed 51% to the marine fish landings during 2008-2012 (CMFRI, 2012). Due to intense dragging of the sea bottom and the use of very small cod-end mesh size (15 to 20 mm knot-to-knot), extensive damage to marine biota, including fish, along the Indian coast was recognised about 15 years ago (Devaraj and Vivekanandan, 1999). Being a relatively non-selective gear, the trawls retain most of the biota that is caught. This catch includes (i) high-value catch (HVC)- fishes, crustaceans and molluscs, which are directly used for human consumption; (ii) low-value bycatch (LVB)- not used for human consumption, but used in fish meal plants, which include juveniles of high-value fishes and adults of small-sized fishes; and (iii) discards-at-sea, which include non-edible and occasionally edible biota (Dineshbabu *et al.*, 2013).

The demand for aquaculture feed has increased in recent years, with the proliferation of aquaculture. In India, the quantity of fish meal used in feed production for shrimp and carp culture in 2001 was 41,000 tonnes and 200,000 tonnes, respectively (Smith *et al.*, 2005). Using these estimates and assuming that this trend would have continued, FAO (2010) estimated the fish meal used in India to be about 270,000 tonnes by 2010. The demand for fish meal has been reflected in the emergence of a large number of fish meal plants in the country. In Karnataka (southwest coast) alone, 23 fish meal/fish oil factories with a handling capacity of 20 to 350 tonnes /day each have been registered in the last five years (Ponnuswamy *et al.*, 2012).

The main source of raw material for these fish meal plants is the LVB from trawlers. As the demand for fish meal increased, trawlers were encouraged to target LVB. Trawlers have started to concentrate in areas of abundance of juveniles with small cod-end mesh size. This is causing significant concern regarding the sustainability of marine resources. The objectives of the present paper are to (i) quantify the volume and species composition of LVB at Mangalore Fisheries Harbour, (ii) identify areas and seasons where juveniles occur, and (iii) suggest options for reducing such bycatch.

Material and methods

Catch data on commercial bottom trawlers were collected from Mangalore Fisheries Harbour in Karnataka, southwest coast of India (Fig. 1) from 2008 to 2011.

Fig. 1. Trawlers at Mangalore Fisheries Harbour

Data were collected twice a week. The catch was classified as those landed for direct human consumption, as LVB for fish meal plants, and as discards-at-sea. Monthly estimates were made on trawl effort, catch and species composition by random sampling. Along with catch data, the market prices of the two landed categories were also collected. Unsorted LVB samples were analysed to determine the juvenile composition at species level. Crew members onboard sampled trawlers collected data under the supervision of observers. Fishing crew were instructed on how to store unsorted portions of the catch, which would have been otherwise discarded. These samples were labelled, preserved in ice and stored in the fish-hold. After each cruise, the preserved samples were brought to the laboratory and analysed. The geographical positions of trawling areas were noted and the data collected were used for spatial mapping of the abundance of juveniles of a few dominant species.

Results

Trawl catch: The estimated annual average catch by trawlers operating from Mangalore Fisheries Harbour was 124,105 tonnes during 2008-2011. During the four year period, the catch fluctuated by about 10% each year. Of the total catch, 63.9% was landed as high-value catch (HVC) for human consumption, 14.7 % as LVB and the remaining 11.4% was discarded at sea. However, the composition of catch in the three categories changed during the four year period. While the LVB substantially increased from 3,144 t in 2008 to 30,737 t in 2011, discards reduced from 22,696 t to 7,359 t during the same years (Fig. 2). Consequently, the contribution of LVB to the trawl catch substantially increased from 2.5% to 24.6%; and the discard component decreased from 18.1% to 5.9%. Surprisingly, the HVC contribution to the catch reduced by nearly 10%, i.e., from 79.4% to 69.5% within the four year period (Fig. 3).

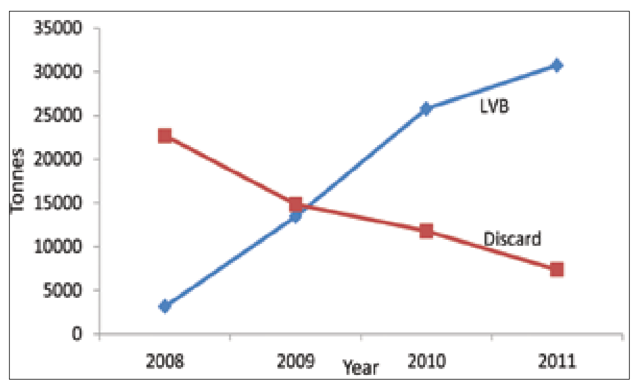


Fig. 2. Low-value bycatch and discard-at-sea by trawlers at Mangalore Fisheries Harbour

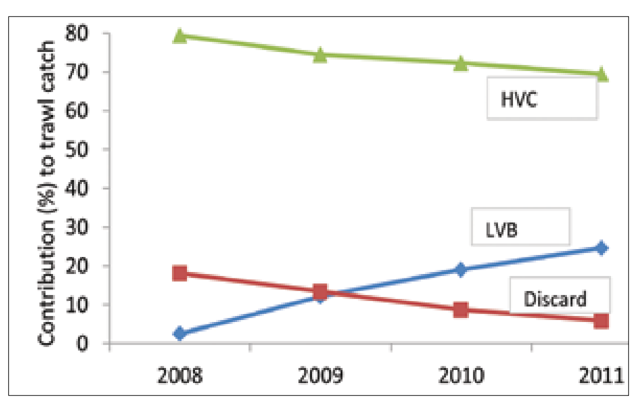


Fig. 3. Contribution of HVC, LVB and discard to trawl catch at MFH during 2008-2011

Table 1. Composition of LVB of trawlers from Mangalore Fisheries harbour during 2008-2009; the landings are represented as annual average values.

Species	Landing as LVB (t)	Juveniles in LVB (%)	Months of juvenile occurrence	Depth range (m)
Lagocephalus inermis	994	50	Nov to Apr	10-70
Sardinella longiceps	566	50	Oct to Jan	10-50
Leiognathus spp.	558	50	Oct to June	10-60
Nemipterus randalli	483	100	Sept to June	20 -170
Saurida undosquamis	458	80	Sept to June	30 -90
Dussumeria acuta	369	80	Sept to May	10-50
Nemipterus japonicus	362	100	Dec to May	20 -70
Trichiurus lepturus	331	100	Sept to June	10-60
Saurida tumbil	305	90	Sept to June	30 -150
Platycephalus spp.	302	80	Sept to June	20 -150
Decapterus spp.	277	80	Sept to Nov	16 -55
Lesser sardines	225	50w	Sept to May	10-55
Priacanthus hamrur	173	90	Sept to May	43 -150
Anchovies	110	20	Jan to Apr	10-50
Eels	101	50	Oct to Dec	20-150
Cynoglossus spp.	95	50	Oct to Apr	10-90
Sepia spp.	93	100	Sept to Jan	20-120
Charybdis spp.	86	100	Sept to Mar	20-120
Epinephelus spp	81	100	Aug to Jan	20 -120
Trachypenaeus sp	70	50	Nov to May	20-50
Solenocera choprai	50	50	Sept to May	50-120
Lactarius lactarius	25	100	Nov to Mar	10-90

Composition of LVB

The composition of LVB was analysed during the years 2008 and 2009 and showed rich biodiversity of the trawl bycatch, constituted by 205 species/groups, of which 147 were finfishes, 4 bivalves, 7 cephalopods, 21 crabs, 3 stomatopods, 3 lobsters and several miscellaneous groups including jellyfish, sponges, sea snakes, echinoderms etc. LVB comprised a large quantity of juveniles of commercial and non-commercial fishes (Table 1). About 34% of the LVB by weight and 63% by number were juveniles of 45 commercially important species. It is estimated that annual average bycatch of juveniles of the threadfin bream *Nemipterus randalli* alone was 483 t by weight and about 50 million by number. Table 1 also shows that the juveniles of one species or another occurred throughout the year. The juveniles are caught from a depth range of 10 to 170 m.

Economic value of LVB

The average price for LVB increased from Rs. 4/kg in 2008 to Rs.12/kg in 2011 with a total value of Rs. 2.8 million (= 0.05 million US$) in 2011. The composition of the LVB determined the price of LVB where finfishes were in higher demand because they were better raw material for fishmeal and fish oil production. The price of the LVB occasionally went up to Rs. 16 (= $0.25) per kg, which was more than the price of some species of fish used directly for human consumption. In 2011, about 2,600 t of oil sardine, 1,800 t of lesser sardines and more than 32,000 t of *Decapterus* spp. were taken as LVB, mainly because the landing of these fishes as LVB fetched a better price. Moreover, fishes landed for human consumption have to be preserved properly in ice in the fish hold, which increases the cost and occupies the limited space available. On the other hand, the LVB is simply dumped on the deck without any preservation. Hence, the fishermen often find LVB more remunerative, especially for those categories which fetch low prices for human consumption. During seasons of high abundance of small pelagic species, there is a glut in the market of such fish, driving the fishermen to divert a part of their catches as LVB, which otherwise would have been used for human consumption.

Spatial and temporal abundance of juveniles of demersal fishes

Several demersal fishes contribute to the trawl fishery off Mangalore. As the area is also a spawning ground for many species, the fishing grounds are abundant with spawners, juveniles and sub-adults, leading to rich recruitment of juveniles into the fishery (Table 1). Threadfin breams are one of the major demersal fish groups, which are in demand as juveniles in the fishmeal industry as well as adults for *"surimi"* production (Dineshbabu and Radhakrishnan, 2009). The whitefish, *Lactarius lactarius* and the grouper *Epinephulus diacanthus* are also important commercial species off Mangalore. Analysis of spatial and temporal distributions of catches of these fishes showed that juveniles of *Nemipterus*

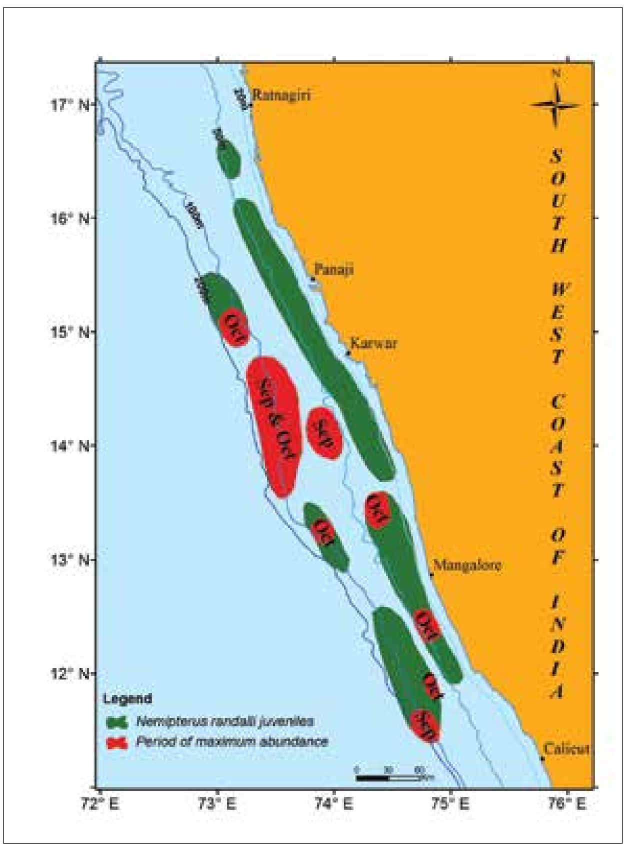


Fig. 4. Juvenile distribution of *Nemiperus randalli* in trawling grounds of Karnataka and their period of maximum abundance

randalli (Fig. 4) and *E. diacanthus* (Fig. 5) were available in large areas of the trawl fishing grounds in almost all months, whereas juveniles of *N. japonicus* (Fig. 6) and *L. lactarius* (Fig. 7) were restricted to smaller areas and were not observed in all months. Peak abundance of juvenile *N. randalli* was from August to October and *E. diacanthus* was during August and September. Peak juvenile abundance of *N. japonicus* and *L. lacatrius* occurred in November. In terms of vertical distribution, the juveniles of *N. randalli* had a wide distribution from 20 m to 170 m depth, *E. diacanthus* juveniles from 20 to 120 m, *N. japonicus* juveniles from 20 to 70 m, and *L. lacatarius* from 10 to 50 m depth (Figs. 4 to 7).

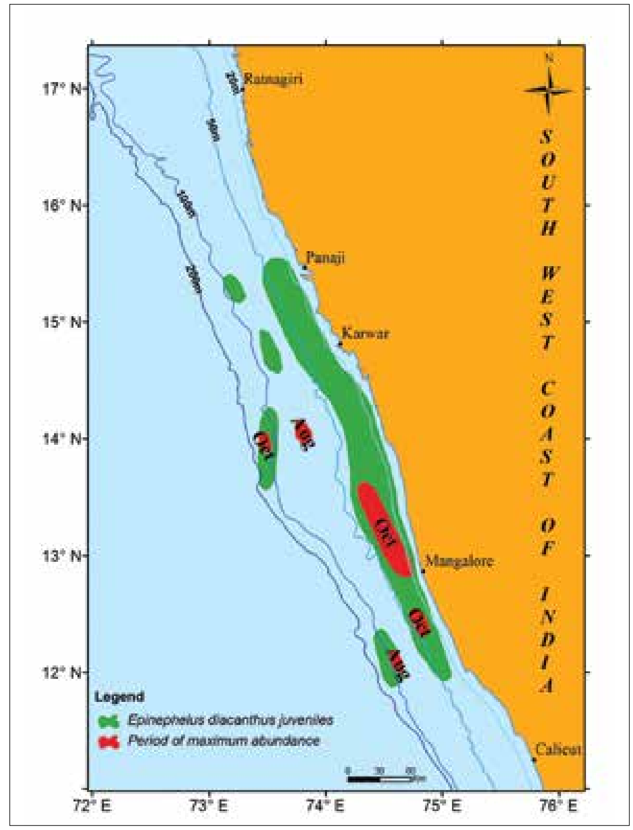


Fig. 5. Juvenile distribution of *Epinephelus diacanthus* in trawling grounds of Karnataka and their period of maximum abundance

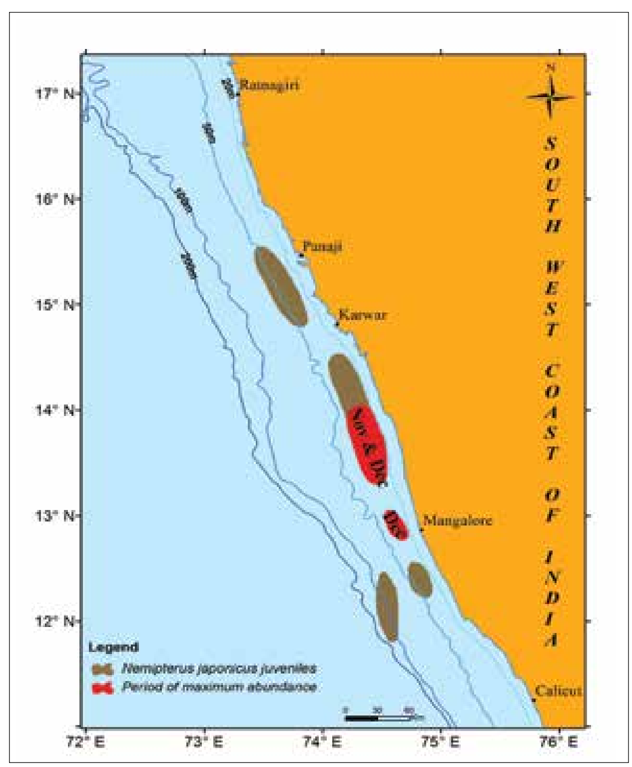


Fig. 6. Juvenile distribution of *Nemipterus japonicus* in trawling grounds of Karnataka and their period of maximum abundance

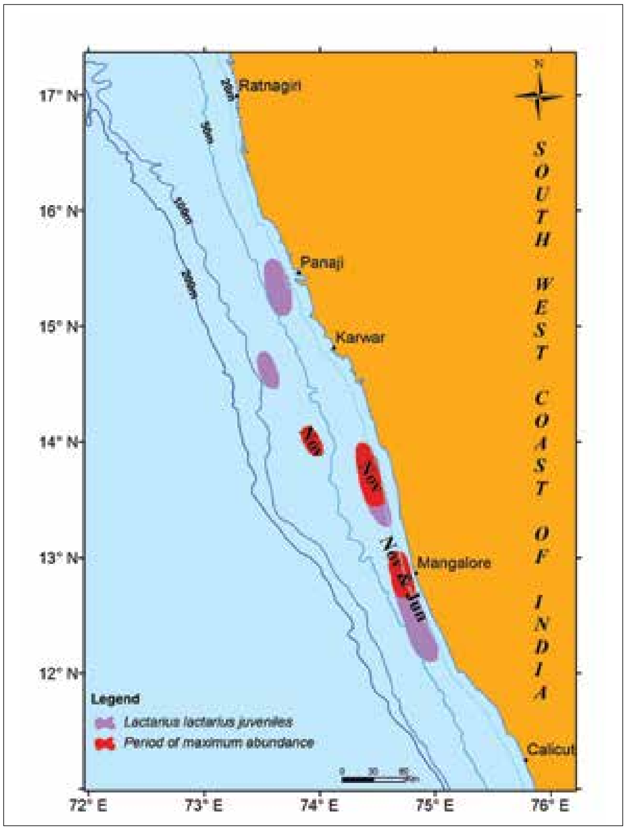


Fig. 7. Juvenile distribution of *Lactarius lactarius* in trawling grounds of Karnataka and their period of maximum abundance

Discussion

The volume of low value bycatch from trawlers increased substantially during 2008-2011 off Mangalore. Continuous monitoring in later years also showed that the trend continued after 2011 at Mangalore as well as along the rest of the Indian coast. Increasing demand from the aquaculture sector for protein-rich feed and a consequent better price and returns for the LVB has encouraged the trawlers to target LVB. In particular, this occurred in fishing grounds where juveniles are in greater abundance, where trawlers reduce the cod-end mesh size of their nets, reduce discards-at-sea, and even occasionally divert a portion of the "high-value" catch as fish meal. This situation is very different from that reported in 1999 when bottom trawlers along the Karnataka coast discarded more than 0.2 million tonnes (Menon *et al*., 2000). Diverting discards into LVB is also a trend observed in several other countries, especially in Asia where aquaculture is gaining importance. Alverson *et al*. (1994) observed that the Chinese shrimp trawl fleet discarded very little of the non-shrimp catch and all the bycatch was used as feed for the Chinese aquaculture industry. The fishery is, therefore, gradually turning into a culture-based trawl fishery. These industries, which depend on a supply of low value fish, generate significant income and jobs to local communities. While reducing discards and landing the catch is a sound strategy in one sense, targeting fishing grounds to exploit juveniles of commercially important fishes is a major concern. When exploitation targets large quantities of juvenile and sub-adult fishes, it contributes to growth overfishing, reduced economic returns from fisheries (Sathiadhas and Narayanakumar, 2002) and threatens the sustainable exploitation of resources (Dineshbabu and Radhakrishnan, 2009).

Another major cause for concern is the mortality of marine biota which is non-edible and has no commercial value. This category consists of adults of non-commercial fishes and other non-edible biota such as echinoderms, crustaceans such as stomatopods, a few species of crabs and several other invertebrates. In addition, the trawlers also interact with endangered, threatened and protected species (ETP) like corals, and charismatic species such as turtles and marine mammals. Large scale exploitation of these categories is a threat to overall biodiversity, which can have a long-term impact on the ecosystem (Thrush and Dayton, 2002; Bijukumar and Deepthi, 2006).

The estimated annual raw material requirement for the fishmeal and fish oil factories in Karnataka alone has been estimated as 200,000 tonnes (Ponnuswamy *et al*., 2012). While only a portion of this demand is available now, the capture and landing of LVB is likely to increase significantly in the future. Hence, it is important to implement effective measures to reduce LVB as soon as possible. Gear modifications are among the potential measures that can improve species and size selectivity of trawl nets and reduce by-catch and particularly reduce the mortality of juveniles and ETP species. In India, the Central Institute of Fisheries Technology has developed a bycatch reduction device for charismatic species as well as a juvenile fish excluder device. This device has angled metal grids and net meshes that reduce the bycatch of undersized fish and shrimps (Pravin *et al*., 2013). Successful use of bycatch reduction devices in many fisheries by several developed and developing countries has been reported by Kennelly (2013).

Spatial and temporal closures to trawling in areas and seasons of juvenile and spawner abundance, as well as in ecologically and biologically sensitive areas, would be another effective option to minimise bycatch. In this context, the concept of fisheries *refugia* deserves consideration (Paterson *et al*., 2012). For such a measure, however, extensive spatial and temporal maps on juvenile abundance and their habitats need to be prepared.

Any management initiative to reduce bycatch will have negative consequences on fish meal plants and other associated industries. Such impacts on economic and social interests will also have a strong effect on the acceptability of management measures. This is an important consideration that should be integrated into any trawl fishery management plan so that negative impacts on the fishery are minimized (APFIC, 2014). While bycatch is a driver of biodiversity loss, resource depletion and long-term economic loss to fisheries, it also helps to enhance economic benefits to trawl fishers and associated industries (even if it is for a short-term), in addition to having other social benefits such as job creation. In this context, it is important to assess the net economic value of such benefits and losses when designing an inclusive approach towards the management of trawl fisheries.

References

Alverson, D.L., M.H. Freeberg, M.H., J.G. Pope, and S.A.Murawski, 1994. A global Assessment of fisheries bycatch and discard.*FAO Fish. Tech. Pap.* 339, 233p

APFIC. 2014. Regional Guidelines for the Management of Tropical Trawl Fisheries in the Asian Region. Asia-Pacific Fisheries Commission, 86 pp.

Bijukumar, A. and G.R. Deepthi, 2006. Trawling and by-catch: Implications on marine ecosystem. *Curr. Sci.*, 90: 922-931.

CMFRI, 2012. Annual Report 2011-2012. Central Marine Fisheries Research Institute, Cochin. 186p.

Devaraj, M and E. Vivekanandan, 1999. Marine capture fisheries of India: Challenges and opportunities, *Curr. Sci.* 76 (3):314-332.

Dineshbabu, A.P and E.V. Radhakrishnan,., 2009. Trawl fishery of juvenile fishes along Mangalore-Malpecoast of Karnataka and its impact on fish stock. *Asian Fish. Sci.*, 22 (2): 491-500.

Dineshbabu, A.P., E.V. Radhakrisnnan, Sujitha Thomas, G. Maheswarudu, P.P. Manojkumar, A.J. Kizhakudan, S.L. Pillai, R. Chakraborty, J. Jose, P.T. Sarada, P.S. Sawant, K.K. Philipose, V.D. Deshmukh, J. Jayasankar, S. Ghosh, M. Koya, G.B. Purushottama and G. Dash, 2013. An appraisal of trawl fisheries of India with special reference on the changing trends in bycatch utilization. *J. Mar. Biol. Ass. India*, 52: 69-78.

FAO. 2010. The state of world fisheries and aquaculture, 2010. Food and Agriculture Organization of the United Nations, Rome, 2010, 197p.

Jennings, S. and M.J, Kaiser., 1998. The effect of fishing on marine ecosystems. *Adv. Mar. Biol.*, 34: 201-352.

Kennelly, S.J. 2013. Solving bycatch problems: successes in developed countries and challenges for protein-poor countries. In: E. Vivekanandan, Maeve Nightingale and N.M. Ishwar, (Eds), Ecosystem Approaches to the Management and Conservation of Fisheries and Marine Biodiversity in the Asia Region. Regional Symposium, Extended Abstracts, Cochin, p.123-125.

Menon, N. G., P. Nammalwar, , P. U. Zacharia, and I. Jagadis, 2000. Investigations on the impact of coastal bottom trawling on demersal fishes and macrobenthos. Central Marine Fisheries Research Institute, Cochin, Annual Report 1999–2000, pp. 55-57.

Paterson, C.J., J.C. Pernetta, S. Siraraksophon, Y. Kato, N. C. Barut, P. Saikliang, O.Vibol, P. E. Chee, T.N. Nguyen, N. Perbowo, T. Yunanda, N. B. Armada, 2012. *Fisheries refugia*: A novel approach to integrating fisheries and habitat management in the context of small-scale fishing pressure, *Ocean Coast. Manag.*, 33(3): 1-16.

Ponnusamy, K., K. Ambasankar and A. G. Ponniah, 2012, Production and marketing of fish meal in India - a study. *Indian J. Fish.* 59 (1): 147-149.

Pravin, P., T.R. Gibinkumar, S. Sabu and M.R. Boopendranath, 2013. Bycatch reduction devices. In: E. Vivekanandan, Maeve Nightingale and N.M. Ishwar, (Eds), Ecosystem Approaches to the Management and Conservation of Fisheries and Marine Biodiversity in the Asia Region. Regional Symposium, Extended Abstracts, Cochin, p. 117-120.

Sathiadhas, R. and R. Narayana Kumar, 2002. Environmental economic analysis of inshore fishery resource utilization of coastal Kerala. Final Report 2001-2002. EERC Working Paper Series: MES-3,MoEF, IGIDR, Mumbai & World Bank.

Smith, S., E. Lindebo and D. Staples, 2005. Asian Fisheries today-The production and use of low value trash fish from marine fisheries of the Asia Pacific region, Asia-Pacific fishery commission, Food and Agriculture Organization of the United Nations, RAP Publication 16, 38p.

Thrush, S. F. and P. K. Dayton, 2002. Disturbance to marine benthic habitats by trawling and dredging: Implications for marine biodiversity. *Ann. Rev. Ecol. Syst.*, 33: 449-473.

Available online at: www.mbai.org.in
doi: 10.6024/jmbai.2014.56.1.01750s-17

Checklist of Chondrichthyans in Indian waters

Akhilesh K. V*[1], K. K. Bineesh[2], A. Gopalakrishnan[1], J. K. Jena[3], V. S. Basheer[2] and N. G. K. Pillai[1]

[1]Central Marine Fisheries Research Institute, P.B.No.1603, Ernakulam North, P.O., Kochi-682 018, Kerala, India.
[2]National Bureau of Fish Genetic Resources, CMFRI campus, P.B.No.1603, Ernakulam North, P.O., Kochi-682 018, Kerala, India
[3]National Bureau of Fish Genetic Resources, Canal Ring Road, P.O. Dilkusha, Lucknow - 226 002, U.P., India.

*Correspondence e-mail: akhikv@gmail.com

Received: 23 Jun 2014, Accepted: 30 Jun 2014, Published: 15 Oct 2014

Original Article

Abstract

Conservation, management and sustainable utilisation of biological resources depend on the accurate identification of exploited taxa, which emphasises the need for systematic taxonomic research. Chondrichthyans (sharks, rays, skates and chimaeras) are considered to be one of the most vulnerable exploited marine resources, however, the basic taxonomic study of these groups in Indian waters needs improvement to achieve better management for their sustainable exploitation. We discuss issues concerning chondrichthyan taxonomic research in India and provide an extended, updated checklist of chondrichthyans listed/reported from Indian waters, together with comments on their occurrence.

Keywords: *Chondrichthyans, checklist, taxonomy, status, India, diversity, management, conservation.*

Introduction

India has many different climatic, ecological and bio-geographical zones, and diverse faunal and floral groups in its ecosystems. Conservation and management of this diversity is important to maintain the equilibrium of ecosystems and for their potential human usage. Conservation, management and sustainable utilisation depend on the quantitative and qualitative assessment of biodiversity, taxonomic identity and understanding the taxa of concern (Narendran, 2001; Agnarsson and Kuntner, 2007; Prathapan *et al*., 2009).

Large amounts of research funding and effort have been invested to provide an inventory of the biodiversity of India. However, our current taxonomic and systematic knowledge on certain groups are inadequate, scattered and mostly unorganised (Narendran, 2001; Hariharan and Balaji, 2002; Kumaran, 2002; Aravind *et al*., 2004; Das *et al*., 2006; James, 2010; Vishwanath and Linthoingambi, 2010; Wafar *et al*., 2011). Understanding the fauna and its diversity in specific habitats/ecosystems/regions of the country, with their distribution patterns and phylogeography, is an important baseline for future studies and for the formulation of conservation and management plans.

Chondrichthyans include all cartilaginous fish species commonly called sharks, rays, skates and chimaeras. They are widely distributed in all the world's oceans, but are most diverse in the tropical and subtropical Indo-Pacific Ocean (Bonfil, 2002). Chondrichthyans are one of the most vulnerable groups due to their biological characteristics. Global concern over these apex predators is increasing as high exploitation rates are decreasing their stocks (Smith *et al*., 1998; Baum *et al*., 2003; Garcia *et al*., 2008; Dulvy *et al*., 2014). Documenting chondrichthyans in specific regions and understanding their taxonomy and diversity in particular ecosystems are very important for conservation and management of these decreasing resources.

Chondrichthyan research is limited in India despite its rich diversity, long history and huge fishery. An impediment to chondrichthyan research in India is a lack of comprehensive taxonomic studies/revisions and conclusive checklists. This paper presents an extended, updated checklist of chondrichthyans reported from Indian waters, together with comments on their taxonomic status and validity of occurrence.

Material and methods

The chondrichthyan checklist presented in this paper is based on a review of available publications, monographs and catalogues on their diversity, taxonomy, life history (biology, food and feeding, stock assessments), ecology and fishery; along with reports of exploratory surveys from Indian seas. Chondrichthyans identified from field and exploratory surveys conducted during 2008-2013 by the authors and information shared by colleagues are also included in the list. Validity status and occurrence from the region was confirmed and evaluated following recent publications and Eschmeyer (2014). The IUCN assessment category (IUCN, 2013) for each species is also listed.

Results

Diversity and taxonomic status of Indian chondrichthyans

Chondrichthyans found in Indian waters have been catalogued by several researchers, but an exhaustive inventory remains elusive. Day (1889) reported 69 species, Misra (1952) reported 52, Misra (1969) reported 114 species and Talwar and Kacker (1984) reported 76 species. Raje *et al*. (2002) listed 110 elasmobranch species, Venkataraman *et al*. (2003) prepared a field identification handbook on sharks containing 72 species, and Raje *et al*. (2007) listed 84 elasmobranchs from the commercial fishery. These publications during different periods have therefore recorded between 52 and 114 species occurring in the Indian seas.

This study provides a checklist of 227 chondrichthyan species (from 11 orders and 41 families) recorded/listed from Indian seas (Table 1). In this combined list, 27 species (12%) have questionable status with regard to their occurrence because their distributional range does not fall within Indian seas as per recent studies. For example, the yellow spotted catshark *Scyliorhinus capensis* (Smith, 1838) is known only from the southeast Atlantic Ocean and off South Africa in the Indian Ocean (Compagno, 1984) but is listed as occurring in India (Gunther, 1870; Day, 1878). A further 41 species (18%) listed from India need confirmation. These may have distributional ranges including India or parts of Indian seas, but require taxonomic reports for confirmation. Excluding species with uncertain status and several undescribed common species, the valid species from Indian waters total 155. This includes more than 40 additional species over those reported by previous workers (Raje *et al*., 2007), but we believe the list is still incomplete.

Chondrichthyan species diversity in Indian seas is higher than that reported in many other tropical Indian Ocean countries or regions such as the Arabian Gulf (43 sharks) (Moore *et al*., 2012), Sri Lanka (92 elasmobranchs) (Moron *et al*., 1998; De Silva, 2006), Maldives (51 elasmobranchs) (Anderson and Hafiz, 2002) and Thailand (145 elasmobranchs) (Vidthayanon, 2002). However, a higher number (137-207 species) have been reported from Indonesia (White *et al*., 2006; Fahmi, 2010).

The taxonomic problems with regard to Carcharhiniformes, Squaliformes and Myliobatiformes are yet to be resolved, which could lead to a greater known diversity in Indian seas. e.g., of the 24 squaliform shark species listed from India, 54% have uncertain status. The deep-sea chondrichthyans of India form a mostly overlooked group. Many species belonging to the same genera look alike and are possibly widely distributed. Genetic and specific morphological data are needed to the clarify taxonomic status of deep-sea chondrichthyans from Indian waters.

Many descriptions of chondrichthyans from Indian waters by earlier ichthyologists have been synonymised or are considered invalid at present (Table 2). But, several such species have been recently revalidated by advanced studies with wider geographic sampling (Marshal *et al*., 2009; Ebert *et al*., 2010; White *et al*., 2010a,b,c), which suggests many additional species could be revalidated through studies in the future.

Not all the species listed currently as being from India are available in collections, which increases the difficulty in resolving taxonomic issues. While the checklist was supposed to give the reference collection numbers (see Compagno *et al*., 2005; Ebert *et al*., 2013), the absence of Indian specimens and appropriate cataloguing hindered this effort. Clearly, national museums and reference collections should strive to have specimens of all the Indian species in custody.

The confusion and inconsistency in species identification due to the usage of invalid/misapplied names, complex taxonomic histories and presence of several undescribed species in commercial fisheries, are impediments in resolving species listings. In turn, this results in poor reporting on catch, exports and management at a species level. There is also significant confusion persisting for similar-looking species occurring in Indian seas, which need to be critically studied and compared through collaborative studies.

Conservation status of Indian chondrichthyans

Excluding the species with uncertain status (questionable and those which need confirmation), the total number of Indian chondrichthyan species are 155, of which 3% are listed as Critically Endangered (CR), 5% are Endangered (EN), 26% are Vulnerable (VU), 21% are Near Threatened (NT), 8% are of Least Concern (LC), 27% are Data Deficient (DD) and 10% are Not Evaluated (NE) (Table 1, Fig. 1).

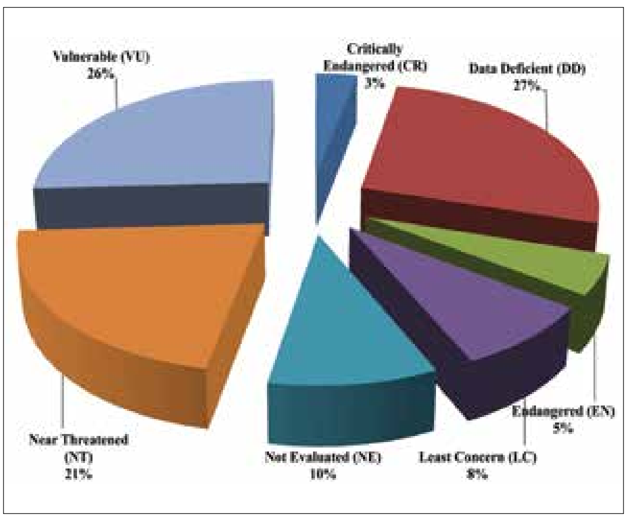


Fig 1. Conservation status of Indian chondrichthyans.

In 1999, the FAO developed a framework for the conservation of sharks, which recommended all States to prepare management policies and develop a National Plan of Action (NPOA) to identify information gaps, issues and priorities for the conservation and management of sharks. Despite several international commitments, there has been little action to better understand, manage and protect elasmobranch species in India other than the Indian Wildlife (Protection) Act, 1972. At present India does not have a National Plan of Action for the conservation and management of sharks, but the preparation of plans for regional management is underway. In 2013, shark finning was prohibited by the Ministry of Environment and Forests, Government of India.

The Indian Wildlife (Protection) Act, 1972 lists 10 elamsobranchs in Schedule I part 2(A) in MoEF, 2001, which have to be identified accurately in the field to ensure their protection. But the absence of *Carcharhinus hemiodon* (Müller and Henle, 1839), *Glyphis glyphis* (Müller and Henle, 1839) and *Glyphis gangeticus* (Müller and Henle, 1839) in recent collections questions the availability of these species, the possibility of their extinction, or them being mis-identified (see Compagno *et al*., 2003; Compagno, 2007; Compagno *et al*., 2009). Another species listed in IWPA, 1972 is *Himantura fluviatilis* (Hamilton, 1822), which is considered as a junior synonym of *Pastinachus sephen* (Forsskål, 1775) (Eschmeyer, 2014). Recently *P. sephen* was considered as a complex with new species described and resolved (Last *et al*., 2005, 2010 a,b), of which at least two are available in India. The National Biodiversity Action Plan (NBAP, 2008) has stated that the "implementation of Biological Diversity Act and National Environmental Policy 2006 would be difficult without having adequate number of trained taxonomists". Resolving taxonomic ambiguities is, thus, the first step towards evolving a comprehensive conservation plan for chondrichthyans from Indian waters.

Discussion

This century has been called the century of extinctions (Dubois, 2003, 2010). Over-exploitation and habitat degradation/ alteration are major concerns causing biodiversity declines and extinction of species. There is an urgent need for cataloguing biodiversity before several species become extinct without humans even knowing of their existence. Proper identification of species is necessary for cataloguing and monitoring biodiversity (Vecchione and Collette, 1996), with taxonomic accuracy in reports, publications and datasets being crucial, because these form the foundation of management and policy (Kholia and Jenkins, 2011).

Recent taxonomic studies on chondrichthyans around the world (e.g. in Indonesia, Taiwan and Australia) have resulted in descriptions of many new species and have increased the resolution of species complexes (Last, 2007; Last *et al*., 2008a,b; Last *et al*., 2008a, b, 2010c). This suggests that a systematic taxonomic study of this group in Indian waters, with wide regional sampling, molecular studies, and comparisons would identify a greater diversity of this group and validate many of the currently used names in India.

In recent years, several species have been added to the elasmobranch faunal lists of Indian seas (Akhilesh *et al*., 2010; Babu *et al*., 2011; Benjamin *et al*., 2012; Kizhakudan and Rajapackiam, 2013; Bineesh *et al*., 2014) due to the extension of fishing to newer and deeper grounds. According to White and Last (2012), Indian waters are poorly known for its elasmobranch fauna and more scientific exploration and investigations are needed in the region. In particular, examples and case studies in White and Last (2012) suggest the need for more studies with molecular support and wide geographical sampling which would validate several unrecognized species.

In recent years, the use of molecular and genetic data has allowed the discrimination of species with morphological similarity and overlapping characters. Hebert *et al*. (2003) proposed a global identification system for animals by using the mitochondrial gene, cytochrome c oxidase subunit 1 (COI) to differentiate the vast majority of animal species, including the discovery of new or cryptic species. DNA barcoding techniques (i.e., sequencing a region of mitochondrial cytochrome oxidase I gene) for rapid and accurate species identification including their life stages will be a useful tool. In India, such advanced technologies have been used on chondrichthyans by Pavan-Kumar *et al*. (2013) and Bineesh *et al*. (2014).

In this checklist, we have tried to include recent additions to chondrichthyan fauna, with recent taxonomic changes, but there still are many unrecognized species occurring in Indian seas and several others with misapplied names. Research institutes and Universities in India should form a network for cataloguing marine biodiversity, with multinational and multi-institutional collaboration where necessary, in the interests of conservation.

Acknowledgements

We thank the Director, Zoological Survey of India and S.S. Mishra (ZSI, Calcutta) for their support to Bineesh during his visit to ZSI. Thanks are also due to W. White, P. Last (CSIRO, Australia), and D. A. Ebert (PSRC, USA) for their support and comments on the manuscript. Juergen Pollerspock (Shark References, Germany) provided missing references. Simon Weigmann (University of Hamburg, Germany) shared information and publications. We also Thank Muktha Menon (CMFRI, Visakhapatnam), G. B. Purushothama (CMFRI, Mumbai), Sajna Ali and K. M. Sandhya (CIFRI, Barrckpore), G. B. Sreekanth, (ICAR Research Complex for Goa), K. K. Prajith (CIFT, Veraval), M. Hashim and Vinu Jacob (CMLRE, Kochi), R. R. Kumar and S. Venu (Pondicherry University, Andaman Islands) for sharing information.

Table 1. Checklist of chondrichthyans reported/listed from Indian waters

Order /Family	Species	Validity in India	IUCN status (Global)
CHIMAERIFORMES			
RHINOCHIMAERIDAE	*Neoharriotta pinnata* (Schnakenbeck, 1931)		DD
	Neoharriotta pumila Didier & Stehmann, 1996	Needs confirmation	DD
	Rhinochimaera atlantica Holt & Byrne, 1909	Questionable	LC
	Harriotta raleighana Goode & Bean, 1895	Questionable	LC
CHIMAERIDAE	*Chimaera monstrosa* Linnaeus, 1758	Questionable	NT
	Hydrolagus cf. *africanus* (Gilchrist, 1922)		DD
HEXANCHIFORMES			
HEXANCHIDAE	*Hexanchus griseus* (Bonnaterre, 1788)		NT
	Hexanchus nakamurai Teng, 1962	Needs confirmation	DD
	Heptranchias perlo (Bonnaterre, 1788)		NT
	Notorynchus cepedianus (Péron, 1807)	Needs confirmation	DD
ORECTOLOBIFORMES			
HEMISCYLLIIDAE	*Chiloscyllium arabicum* Gubanov, 1980		NT
	Chiloscyllium griseum Müller & Henle, 1838		NT
	Chiloscyllium indicum (Gmelin, 1789)		NT
	Chiloscyllium plagiosum (Bennett, 1830)		NT
	Chiloscyllium punctatum Müller & Henle, 1838		NT
	Chiloscyllium hasselti Bleeker, 1852	Needs confirmation	NT
	Chiloscyllium burmensis Dingerkus & DeFino, 1983	Needs confirmation	DD
STEGOSTOMATIDAE	*Stegostoma fasciatum* (Hermann, 1783)		VU
GINGLYMOSTOMATIDAE	*Nebrius ferrugineus* (Lesson, 1831)		VU
	Ginglymostoma cirratum (Bonnaterre, 1788)	Questionable	DD
RHINCODONTIDAE	*Rhincodon typus* Smith, 1828		VU

LAMNIFORMES			
ODONTASPIDIDAE	*Carcharias taurus* Rafinesque, 1810		VU
	Odontaspis ferox (Risso, 1810).		VU
	Odontaspis noronhai (Maul 1955)		DD
ALOPIIDAE	*Alopias pelagicus* Nakamura, 1935		VU
	Alopias superciliosus (Lowe, 1841)		VU
	Alopias vulpinus (Bonnaterre, 1788)		VU
LAMNIDAE	*Carcharodon carcharias* (Linnaeus,1758)	Questionable	VU
	Isurus oxyrinchus Rafinesque, 1810		VU
	Isurus paucus Guitart Manday, 1966		VU
PSEUDOCARCHARIIDAE	*Pseudocarcharias kamoharai* (Matsubara, 1936)		NT
CARCHARHINIFORMES			
SCYLIORHINIDAE	*Apristurus indicus* (Brauer, 1906)	Questionable	DD
	Apristurus investigatoris (Misra, 1962)		DD
	Apristurus microps (Gilchrist, 1922)	Questionable	LC
	Apristurus saldanha (Barnard, 1925)	Questionable	LC
	Apristurus canutus Springer & Heemstra, 1979	Questionable	DD
	Atelomycterus marmoratus (Anonymous [Bennett], 1830)	Need additional reports	NT
	Cephaloscyllium silasi (Talwar, 1974)		DD
	Cephaloscyllium sufflans (Regan, 1921)	Questionable	LC
	Halaelurus buergeri (Müller & Henle, 1838)	Questionable	DD
	Halaelurus natalensis (Regan, 1904)	Questionable	DD
	Halaelurus quagga (Alcock, 1899)		DD
	Halaelurus boesemani Springer & D'Aubrey, 1972	Needs confirmation	DD
	Bythaelurus lutarius (Springer & D'Aubrey, 1972)	Needs confirmation	DD
	Bythaelurus hispidus (Alcock, 1891)		DD
	Holohalaelurus punctatus (Gilchrist, 1914)	Needs confirmation	EN
	Scyliorhinus capensis (Müller & Henle, 1838)	Questionable	NT
PROSCYLLIIDAE	*Eridacnis radcliffei* Smith, 1913		LC
	Eridacnis sinuans (Smith, 1957)	Questionable	LC
	Proscyllium magnificum Last & Vongpanich, 2004		NE
PSEUDOTRIAKIDAE	*Planonasus* sp. (Sensu Akhilesh *et al.*, 2010)		NE
TRIAKIDAE	*Iago omanensis* (Norman, 1939)		LC
	Iago sp. A [*Sensu* Compagno *et al.*, 2005]		NE
	Mustelus mangalorensis Cubelio, Remya & Kurup, 2011	Holotype possibly lost	NE
	Mustelus mosis Hemprich & Ehrenberg, 1899		DD
HEMIGALEIDAE	*Chaenogaleus macrostoma* (Bleeker, 1852)		VU
	Hemigaleus microstoma Bleeker, 1852		VU
	Paragaleus randalli Compagno, Krupp & Carpenter, 1996		NT
	Hemipristis elongata (Klunzinger, 1871)		VU
CARCHARHINIDAE	*Carcharhinus altimus* (Springer, 1950)		DD
	Carcharhinus amblyrhynchoides (Whitley, 1934)		NT
	Carcharhinus amblyrhynchos (Bleeker,1865)		NT
	Carcharhinus albimarginatus (Ruppel,1837)		NT
	Carcharhinus amboinensis (Müller & Henle, 1839)		DD
	Carcharhinus brevipinna (Müller & Henle, 1839)		NT

	Carcharhinus dussumieri (Müller & Henle, 1839)		NT
	Carcharhinus falciformis (Müller & Henle, 1839)		NT
	Carcharhinus hemiodon (Müller & Henle, 1839)		CR
	Carcharhinus leucas (Müller & Henle, 1839)		NT
	Carcharhinus limbatus (Müller & Henle, 1839)		NT
	Carcharhinus longimanus (Poey, 1861)		VU
	Carcharhinus macloti (Müller & Henle, 1839)		NT
	Carcharhinus melanopterus (Quoy & Gaimard, 1824)		NT
	Carcharhinus obscurus (Lesueur,1818)		VU
	Carcharhinus sealei (Pietschmann, 1913)	Needs confirmation	NT
	Carcharhinus sorrah (Müller & Henle, 1839)		NT
	Galeocerdo cuvier (Péron & Lesueur, 1822)		NT
	Glyphis gangeticus (Müller & Henle, 1839)		CR
	Glyphis glyphis (Müller & Henle, 1839)	Needs confirmation	EN
	Lamiopsis temminckii (Müller & Henle, 1839)		EN
	Lamiopsis tephrodes (Fowler, 1905)	Needs confirmation	NE
	Loxodon macrorhinus Müller & Henle, 1839		LC
	Negaprion acutidens (Rüppell, 1837)		VU
	Prionace glauca (Linnaeus, 1758)		NT
	Rhizoprionodon acutus (Rüppell, 1837)		LC
	Rhizoprionodon oligolinx Springer, 1964		LC
	Scoliodon laticaudus Müller & Henle, 1838		NT
	Triaenodon obesus (Rüppell, 1837)		NT
SPHYRNIDAE	*Eusphyra blochii* (Cuvier, 1817).		NT
	Sphyrna lewini (Griffith & Smith, 1834)		EN
	Sphyrna mokarran (Rüppell, 1837)		EN
	Sphyrna zygaena (Linnaeus, 1758)		VU
	Sphyrna tudes (Valenciennes, 1822)	Questionable	VU
SQUALIDAE	*Squalus blainville* (Risso, 1827)	Needs confirmation	DD
	Squalus acanthias Linnaeus, 1758	Needs confirmation	VU
	Squalus megalops (Macleay, 1881)	Needs confirmation	DD
	Squalus mitsukurii Jordan & Snyder, 1903	Needs confirmation	DD
	Squalus cf. *lalannei* Baranes, 2003		DD
CENTROPHORIDAE	*Centrophorus moluccensis* Bleeker, 1860	Needs confirmation	DD
	Centrophorus uyato Rafinesque, 1810	Needs confirmation	NE
	Centrophorus cf. *granulosus* (Bloch & Schneider, 1801)		VU
	Centrophorus lusitanicus (Bocage & Capello, 1864)	Needs confirmation	VU
	Centrophorus squamosus (Bonnaterre, 1788)		VU
	Centrophorus atromarginatus Garman, 1913		DD
	Centrophorus cf. *zeehaani* White, Ebert & Compagno, 2008		NE
	Deania profundorum (Smith & Radcliffe, 1912)		LC
ETMOPTERIDAE	*Centroscyllium ornatum* (Alcock, 1889)		DD
	Centroscyllium fabricii (Reinhardt, 1825)	Needs confirmation	LC
	Etmopterus granulosus (Günther, 1880)	Needs confirmation	LC
	Etmopterus pusillus (Lowe, 1839)		LC
	Etmopterus spinax (Linnaeus, 1758)	Needs confirmation	LC

	Etmopterus baxteri Garrick, 1957	Needs confirmation	LC
	Etmopterus lucifer Jordan & Snyder, 1902	Needs confirmation	LC
SOMNIOSIDAE	*Centroselachus crepidater* (Bocage & Capello, 1864)		LC
	Zameus squamulosus (Günther, 1877)		DD
ECHINORHINIDAE	*Echinorhinus brucus* (Bonnaterre, 1788)		DD
	Echinorhinus cookei Pietschmann, 1928	Questionable	NT
PRISTIFORMES			
PRISTIDAE	*Anoxypristis cuspidata* (Latham, 1794)		EN
	Pristis microdon Latham, 1794		CR
	Pristis pectinata Latham, 1794	Needs confirmation	CR
	Pristis pristis (Linnaeus, 1758)		CR
	Pristis zijsron Bleeker, 1851		CR
SQUATINIFORMES			
SQUATINIDAE	*Squatina squatina* (Linnaeus, 1758)	Questionable	CR
	Squatina africana Regan, 1908	Needs confirmation	DD
TORPEDINIFORMES			
TORPEDINIDAE	*Torpedo panthera* Olfers, 1831	Needs confirmation	DD
	Torpedo fuscomaculata Peters, 1855	Needs confirmation	DD
	Torpedo sinuspersici Olfers, 1831	Needs confirmation	DD
	Torpedo marmorata Risso, 1810		DD
	Torpedo zugmayeri Engelhardt, 1912		NE
NARCINIDAE	*Benthobatis moresbyi* Alcock, 1898		DD
	Narcine brunnea Annandale, 1909		NE
	Narcine lingula Richardson, 1840		DD
	Narcine prodorsalis Bessednov, 1966	Needs confirmation	DD
	Narcine timlei (Bloch & Schneider, 1801).		DD
	Narcine cf *oculifera* Carvalho, Compagno & Mee, 2002		DD
	Narcine maculata (Shaw, 1804)		DD
NARKIDAE	*Heteronarce prabhui* Talwar, 1981		DD
	Narke dipterygia (Bloch & Schneider, 1801)		DD
RAJIFORMES			
RHINIDAE	*Rhina ancylostoma* Bloch & Schneider, 1801		VU
RHYNCHOBATIDAE	*Rhynchobatus laevis* (Bloch & Schneider, 1801)		VU
	Rhynchobatus australiae Whitley, 1939		VU
	Rhynchobatus djiddensis (Forsskål 1775)		VU
	Rhynchobatus palpebratus Compagno & Last, 2008		NE
RHINOBATIDAE	*Glaucostegus granulatus* (Cuvier, 1829)		VU
	Glaucostegus halavi (Forsskål, 1775)		DD
	Glaucostegus obtusus (Müller & Henle, 1841)		VU
	Glaucostegus thouin (Anonymous, 1798)		VU
	Glaucostegus typus (Anonymous [Bennett] 1830).		VU
	Rhinobatos annandalei Norman, 1926		DD
	Rhinobatos annulatus (Müller & Henle, 1841)	Needs confirmation	LC
	Rhinobatos holcorhynchus Norman, 1922	Needs confirmation	DD
	Rhinobatos lionotus Norman, 1926		DD
	Rhinobatos punctifer Compagno & Randall, 1987		DD

	Rhinobatos variegatus Nair & Lal Mohan, 1973		DD
ZANOBATIDAE	*Zanobatus schoenleinii* (Müller & Henle, 1841)	Questionable	DD
ANACANTHOBATIDAE	*Cruriraja andamanica* (Lloyd, 1909)		DD
RAJIDAE	*Amblyraja reversa* (Lloyd, 1906)	Needs confirmation	DD
	Dipturus sp. A (Sensu Bineesh *et al*., 2013)		NE
	Dipturus johannisdavisi (Alcock, 1899)		DD
	Dipturus crosnieri Seret, 1989	Needs confirmation	VU
	Fenestraja mamillidens (Alcock, 1889)		DD
	Leucoraja circularis (Couch, 1838)	Needs confirmation	VU
	Okamejei powelli (Alcock, 1898)		DD
	Okamejei sp. A		NE
	Raja miraletus Linnaeus, 1758	Questionable	LC
	Raja texana (Chandler, 1921)	Questionable	DD
	Rostroraja alba (Lacepède, 1803)	Questionable	EN
MYLIOBATIFORMES			
HEXATRYGONIDAE	*Hexatrygon bickelli* Heemstra & Smith, 1980		LC
PLESIOBATIDAE	*Plesiobatis daviesi* (Wallace, 1967)		LC
DASYATIDAE	*Dasyatis bennetti* (Müller & Henle, 1841)	Needs confirmation	DD
	Dasyatis centroura (Mitchill, 1815)	Questionable	LC
	Dasyatis chrysonota (Smith, 1828)	Questionable	LC
	Dasyatis lata (Garman, 1880)	Questionable	LC
	Dasyatis microps (Annandale, 1908)		DD
	Dasyatis pastinaca (Linnaeus, 1758)	Needs confirmation	DD
	Dasyatis thetidis Ogilby, 1899	Needs confirmation	DD
	Himantura alcockii (Annandale, 1909)		NE
	Himantura draco Compagno & Heemstra, 1984	Needs confirmation	NE
	Himantura uarnacoides (Bleeker, 1852)		VU
	Himantura fai Jordan & Seale, 1906		LC
	Himantura fava (Annandale, 1909)		NE
	Himantura gerrardi (Gray, 1851)		VU
	Himantura granulata (Macleay, 1883)		NT
	Himantura imbricata (Bloch & Schneider, 1801)		DD
	Himantura cf. *imbricata* (Bloch & Schneider, 1801)		NE
	Himantura jenkinsii (Annandale, 1909)		LC
	Himantura leoparda Manjaji-Matsumoto & Last, 2008		VU
	Himantura marginata (Blyth, 1860)		DD
	Himantura pastinacoides (Bleeker, 1852)		VU
	Himantura polylepis Bleeker, 1852		EN
	Himantura uarnak (Forsskål, 1775)		VU
	Himantura undulata (Bleeker, 1852)		VU
	Himantura walga (Müller & Henle, 1841)		NT
	Neotrygon kuhlii (Müller & Henle, 1841)		DD
	Pastinachus sephen (Forsskål, 1775)		DD
	Pastinachus atrus (Macleay, 1883)		NE
	Pteroplatytrygon violacea (Bonaparte, 1832)		LC
	Taeniura lymma (Forsskål, 1775)		NT

	Taeniura meyeni (Müller & Henle, 1841)		VU
	Urogymnus asperrimus (Bloch & Schneider, 1801)		VU
GYMNURIDAE	*Gymnura japonica* (Schlegel, 1850)	Needs confirmation	DD
	Gymnura cf micrura (Bloch & Schneider, 1801)		DD
	Gymnura zonura (Bleeker, 1852)		VU
	Gymnura poecilura (Shaw, 1804)		NT
	Gymnura tentaculata (Müller & Henle, 1841)	Needs confirmation	DD
MYLIOBATIDAE	*Aetobatus flagellum* (Bloch & Schneider, 1801)		EN
	Aetobatus ocellatus (Kuhl, 1823)		NE
	Aetobatus narinari (Euphrasen, 1790)	Questionable	NT
	Aetomylaeus vespertilio (Bleeker, 1851)		EN
	Aetomylaeus nichofii (Bloch & Schneider, 1801)		VU
	Aetomylaeus maculatus (Gray, 1834)		EN
	Aetomylaeus milvus (Müller & Henle, 1841)		NE
	Myliobatis aquila (Linnaeus, 1758)	Questionable	DD
MOBULIDAE	*Manta alfredi* (Kreft, 1868)		VU
	Manta birostris (Walbaum, 1792)		VU
	Mobula mobular (Bonnaterre, 1788)	Needs confirmation	EN
	Mobula japanica (Muller & Henle, 1841)		NT
	Mobula diabolus (Shaw,1804)		NE
	Mobula thurstoni (Lloyd, 1908)		NT
	Mobula eregoodootenkee (Bleeker, 1859)		NT
	Mobula kuhlii (Müller & Henle, 1841)		DD
	Mobula tarapacana (Philippi, 1892)		DD
RHINOPTERIDAE			
	Rhinoptera javanica Müller & Henle, 1841		VU
	Rhinoptera jayakari Boulenger, 1895		NE
	Rhinoptera sewelli Misra, 1947		NE
	Rhinoptera brasiliensis (Müller,1836)	Questionable	EN

Table 2. List of chondrichthyans described from India and their present status

Species described from India	Type area	Present status/valid as
Aetobatis indica Swainson, 1839	Vizagapatanam, India	Synonym of *Aetobatus ocellatus* Kuhl, 1923
Aetoplatea tentaculata Müller & Henle,1841	?Indian Seas	Valid as *Gymnura tentaculata* (Müller & Henle, 1841)
Bengalichthys impennis Annandale,1909	Balasore Bay, Orissa coast, India	Synonym of *Narke dipterygia* (Bloch & Schneider, 1801)
Benthobatis moresbyi Alcock, 1898	Laccadive Sea, India	Valid as *Benthobatis moresbyi* Alcock, 1898
Carcharias (*Hypoprion*) *hemiodon* Muller & Henle,1839	Puduchery, India	Valid as *Carcharhinus hemiodon* (Müller & Henle, 1839)
Carcharias (Physodon) muelleri Müller & Henle, 1839	Bengal, ? India	Synonym of *Scoliodon laticaudus* Müller & Henle, 1838
Carcharias (Prionodon) bleekeri Duméril,1865	Puducherry, India	Synonym of *Carcharhinus sorrah* (Müller & Henle, 1839)
Carcharias (Prionodon) dussumieri Muller & Henle,1839	Puduchery, India	Valid as *Carcharhinus dussumieri* (Müller & Henle, 1839)
Carcharias (Prionodon) palasorra Bleeker, 1853	Pala sorrah of Russell (1803)	Possible synonym of *Scoliodon laticaudus* Müller & Henle, 1838
Carcharias (Prionodon) temminckii Muller & Henle,1839	India	Valid as *Lamiopsis temminckii* (Müller & Henle, 1839)
Carcharias malabaricus Day, 1873	Cochin, Calicut, India	Synonym of *Carcharhinus dussumieri* (Müller & Henle, 1839)
Carcharias sorrah kowa Bleeker, 1853	Vizagapatam, India	Synonym of *Rhizoprionodon acutus* (Rüppell, 1837)

Carcharias sorrakowah Cuvier, 1829	on Sorra Kowah of Russell (1803)	Possibly synonym of *Scoliodon laticaudus* Müller & Henle, 1838
Carcharias watu Sarangdhar & Setna, 1946	India	Synonym of *Carcharhinus hemiodon* (Müller & Henle, 1839)
Centrophorus rossi Alcock, 1898	Off Travancore coast, India	Synonym of *Centroscymnus crepidater* (Bocage & Capello, 1864)
Cephaloptera kuhlii Muller & Henle,1841	India	Valid as *Mobula kuhlii* (Müller & Henle, 1841).
Ceratoptera orissa Lloyd, 1908	Puri, Orissa coast, Bay of Bengal	Possible synonym of *Manta birostris* (Walbaum, 1792)
Cestracion leeuwenii Day, 1865	Malabar coast, India	Synonym of *Sphyrna lewini* (Griffith & Smith, 1834).
Dicerobatis eregoodoo Cantor, 1849	Type locality includes Coromandel, India	Synonym of *Mobula eregoodootenkee* (Bleeker, 1859)
Dicerobatis thurstoni Lloyd, 1908	India	Valid as *Mobula thurstoni* (Lloyd, 1908)
Galeocerdo tigrinus Muller & Henle, 1839	Puduchery, India	Synonym of *Galeocerdo cuvier* (Péron & Lesueur, 1822)
Ginglymostoma muelleri Günther, 1870	India	Synonym of *Nebrius ferrugineus* (Lesson, 1831)
Hemigaleus balfouri Day,1878	Coromandel coast, India	Synonym of *Chaenogaleus macrostoma* (Bleeker, 1852)
Hemipristis pingali Setna, 1946	India, Mumbai	Synonym of *Hemipristis elongata* (Klunzinger, 1871)
Mustelus mangalorensis Cubelio, Remya & Kurup, 2011	Mangalore	Uncertain/holotype couldn't be located
Myliobatis eeltenkee Rüppell, 1837	Type locality includes Vizagapatanam, India	Synonym of *Aetobatus ocellatus* (Kuhl,1823)
Myliobatis nieuhofi var. *cornifera* Annandale, 1909	Balasore, Orissa	Uncertain
Narcine brunnea Annandale, 1909	Bay of Bengal, Hoogli	Valid as *Narcine brunnea* Annandale, 1909
Narcine indica Henle, 1834	Tharangambadi, India	Synonym of *Narcine timlei* (Bloch & Schneider, 1801)
Narcine microphthalma Dumeril, 1852	Malabar coast, India	Synonym of *Narcine timlei* (Bloch & Schneider, 1801)
Pentanchus (Parapristurus) investigatoris Misra, 1962	Andaman Sea	Valid as *Apristurus investigatoris* (Misra, 1962)
Proscyllium alcocki Misra,1950	Andaman Sea	Synonym of *Eridacnis radcliffei* Smith, 1913
Raja fluviatilis Hamilton, 1822	Ganges	Synonym of *Pastinachus sephen* (Forsskål, 1775)
Raja asperrima Bloch & Schneider, 1801	Mumbai, India	Valid as *Urogymnus asperrimus* (Bloch & Schneider, 1801)
Raja bicolor Shaw, 1804	Indian Seas	Uncertain as *Narcine bicolor* (Shaw, 1804)
Raja diabolus marinus Bloch & Schneider, 1801	India	Synonym of *Manta birostris* (Walbaum, 1792)
Raja flagellum Bloch & Schneider, 1801	Coromandel	Valid as *Aetobatus flagellum* (Bloch & Schneider, 1801)
Raja fluviatilis Hamilton, 1822	Ganges, India	Synonym of *Pastinachus sephen* (Forsskål, 1775)
Raja guttata Shaw, 1804	Based on Russell (1803)	Synonym of *Aetobatus ocellatus* (Kuhl, 1823)
Raja imbricata Bloch & Schneider, 1801	Tarangambadi, India	Valid as *Himantura imbricata* (Bloch & Schneider, 1801)
Raja johannisdavisi Alcock, 1899	off Travancore, India	Valid as *Dipturus johannisdavisi* (Alcock, 1899)
Raja poecilura Shaw, 1804	Vizagapatam, India, (on Russell, 1803)	Valid as *Gymnura poecilura* (Shaw, 1804)
Raja sancur Hamilton, 1822	Ganges, India	Synonym of *Pastinachus sephen* (Forsskål, 1775)
Raja timlei Bloch & Schneider, 1801	Tarangambadi, India	Valid as *Narcine timlei* (Bloch & Schneider, 1801)
Raja dipterygia Bloch & Schneider, 1801	Tharangambadi, India	Valid as *Narke dipterygia* (Bloch & Schneider, 1801)
Rhina ancylostomus Bloch & Schneider, 1801	Coromandel coast, India	Valid as *Rhina ancylostoma* Bloch & Schneider, 1801
Rhinobatos variegates Nair & Lal Mohan, 1973	Gulf of Mannaar	Valid as *Rhinobatos variegatus* Nair & Lal Mohan, 1973
Rhinobatus (Rhinobatus) tuberculatus Bleeker, 1853	Suttiwarah of Russell (1803)	Uncertain
Rhinobatus (Rhinobatus) obtusus Müller & Henle, 1841	Pondicherry, Malabar, India	Valid as *Rhinobatos obtusus* Müller & Henle, 1841
Rhinobatus annandalei Norman, 1926	Mouth of the Hooghli, India	Valid as *Rhinobatos annandalei* Norman, 1926
Rhinobatus armatus Gray, 1834	India	Synonym of *Glaucostegus typus* (Anonymous [Bennett], 1830)
Rhinobatus laevis Bloch & Schneider, 1801	India	Valid as *Rhynchobatus laevis* (Bloch & Schneider, 1801)
Rhinobatus lionotus Norman, 1926	Mouth of the Hooghli, India	Valid as *Rhinobatos lionotus* Norman, 1926
Rhinoptera sewelli Misra 1946	Calicut, India	Valid as *Rhinoptera sewelli* Misra, 1946
Rhinoptera adspersa Müller & Henle, 1841	India	Synonym of *Rhinoptera javanica* Müller & Henle, 1841
Rhynchobatus laevis Müller & Henle, 1841	Mumbai and Malabar, India	Synonym of *Rhynchobatus djiddensis* (Forsskål, 1775)

Scoliodon ceylonensis Sarangdhar & Setna, 1946	Mumbai, India	Synonym of *Loxodon macrorhinus* Müller & Henle, 1839
Scoliodon laticaudus Müller & Henle, 1838	India	Valid as *Scoliodon laticaudus* Müller & Henle, 1838
Scyliorhinus (Halealurus) silasi Talwar, 1974	Off Kollam, Arabian Sea	Valid as *Cephaloscyllium silasi* (Talwar, 1974)
Scyllium hispidum Alcock, 1891	Andaman Sea	Valid as *Bythaelurus hispidus* (Alcock, 1891)
Scyllium maculatum Gray, 1830	?India	Synonym of *Atelomycterus marmoratus* (Anonymous [Bennett], 1830)
Scyllium quagga Alcock, 1899	Laccadive Sea, India	Valid as *Halaelurus quagga* (Alcock, 1899)
Squalus caudatus Gronow, 1834	Indian Seas	Synonym of *Chiloscyllium indicum* (Gmelin, 1789)
Squalus palasorrah Cuvier, 1829	Vizagapatam and Madras, India	Uncertain as *Scoliodon palasorrah* (Cuvier, 1829)
Squalus semisagittatus Shaw, 1804	Based on Russell (1803)	Uncertain
Squalus zebra Shaw, 1804	Indian Seas	Synonym of *Stegostoma fasciatum* (Hermann, 1783)
Stegostoma carinatum Blyth, 1847	India	Synonym of *Stegostoma fasciatum* (Hermann, 1783)
Trygon alcockii Annandale 1909	Puri, Orissa Coast. India	Uncertain as *Himantura alcockii* (Annandale, 1909) or a possible synonym of *Himantura gerrardi* (Gray, 1851)
Trygon atrocissimus Blyth, 1860	India	Uncertain
Trygon bleekeri Blyth, 1860	Calcutta, India	Synonym of *Himantura uarnacoides* (Bleeker, 1852)
Trygon chindrakee Cuvier, 1853	Based on Russell (1803)	Uncertain
Trygon crozieri Blyth, 1860	?Arakan coast, India	Synonym of *Dasyatis zugei* (Müller & Henle, 1841)
Trygon ellioti Blyth, 1860	Calcutta fish market, India	Synonym of *Himantura uarnak* (Gmelin, 1789)
Trygon favus Annandale, 1909	off Orissa, Bay of Bengal	Questionably valid as *Himantura fava* (Annandale, 1909)
Trygon gerrardi Gray, 1851	India	Valid as *Himantura gerrardi* (Gray, 1851)
Trygon jenkinsii Annandale,1909	off Ganjam	Valid as *Himantura jenkinsii* (Annandale, 1909)
Trygon marginatus Blyth, 1860	Calcutta fish market, India	Valid as *Himantura marginata* (Blyth, 1860)
Trygon nuda Günther,1870	Indian Seas	Uncertain
Trygon russellii Gray, 1834	India	Questionably the same as (juvenile of) *Himantura leoparda* Manjaji, 2004
Trygon variegatus M'Clelland, 1841	Calcutta, India	Synonym of *Himantura uarnak* (Gmelin, 1789)
Trygon walga Müller & Henle, 1841	Ganges, India	Valid as *Himantura walga* (Müller & Henle, 1841)
Urogymnus asperrimus var. *krusadiensis* Chacko, 1944	Gulf of Mannar	Possible synonym of *Urogymnus asperrimus* (Bloch & Schneider, 1801)
Urogymnus laevior Annandale, 1909	Malpe	Uncertain
Zygaena indica van Hasselt, 1823	Vizagapatam, India	Synonym of *Sphyrna lewini* (Griffith & Smith, 1834)
Zygaena laticeps Cantor, 1837	Bay of Bengal	Synonym of *Eusphyra blochii* (Cuvier, 1816)

References

Agnarsson, I. M. and Kuntner, 2007. Taxonomy in a Changing World: Seeking Solutions for a Science in Crisis. *Syst. Biol.*, 56(3):531-539.

Akhilesh, K. V, M. Hashim, K. K. Bineesh, C. P. R. Shanis and U. Ganga, 2010. New distributional records of deep-sea sharks from Indian waters. *J. Mar. Biol. Ass. India*, 52 (1): 29-34.

Anderson, R. C. and A. Hafiz, 2002. Elasmobranch Fisheries in the Maldives. In, Fowler, S. L., Reed, T. M. and Dipper, F. A. (Eds). Elasmobranch Biodiversity, Conservation and Management: Proceedings of the International Seminar and Workshop, Sabah, Malaysia, July 1997. IUCN SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. xv + 258 pp.

Aravind, N. A., K. N. Ganeshaiah and R. Uma Shanker. 2004. Croak, croak, croak: Are there more frogs to be discovered in Western Ghats?. *Curr. Sci.*, 86: 1471-1472.

Babu, C., S. Ramachandran and B. C. Varghese. 2011. On a new record of sixgill sting ray *Hexatrygon bickelli* Heemstra and Smith, 1980 from south-west coast of India. *Indian J. Fish.*, 58 (2): 137-139.

Baum, J. K., R. A. Myers, D. G. Kehler, B. Worm, S. J. Harley and P. A. Doherty. 2003. Collapse and conservation of shark populations in the Northwest Atlantic. *Sci.*, 299: 389-392.

Benjamin, D., J. V. Rozario, D. Jose, B. M. Kurup and M. Harikrishnan. 2012. Morphometeric characteristics of the Ornate eagle ray *Aetomylaeus vespertilio* (Bleeker, 1852) caught off Cochin, southwest coast of India. *Int. J. Env. Sci.* 3(1): 685-688.

Bineesh, K. K., A. Gopalakrishnan, J. K. Jena, K .V. Akhilesh, V. S Basheer and N. G. K. Pillai. 2013. Sharks and rays in Indian commercial fisheries: need for revision of taxonomy. In: Regional Symposium on Ecosystem Approaches to Marine Fisheries & Biodiversity, October 27-30, 2013, Kochi.

Bineesh, K. K., K. V. Akhilesh, K. A. Sajeela, E. M. Abdussamad, A. Gopalakrishnan, V. S. Basheer and J. K. Jena. 2014. DNA Barcoding Confirms the Occurrence Rare Elasmobranchs in the Arabian Sea of Indian EEZ. *Middle-East J. Sci. Res.*, 19 (9): 1266-1271.

Bonfil, R. 2002. Trends and Patterns in World and Asian Elasmobranch Fisheries. In: Fowler, S. L., Reed, T. M. and Dipper, F. A. (Eds). Elasmobranch biodiversity, conservation and management: Proceedings of the International Seminar and Workshop in Sabah, July 1997. IUCN SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK

Compagno, L. J. V. 1984. FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2. Charcharhiniformes. *FAO Fisheries Synopsis* No. 125, v. 4 (pt 2): 251-655.

Compagno, L. J. V. 2007. *Glyphis gangeticus*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 10 April 2014.

Compagno, L. J. V., P. R. Last, J. D. Stevens and M. N. R. Alava. 2005. Checklist of Philippine Chondrichthyes. *CSIRO Marine Laboratories Report* No. 243: 103 pp

Compagno, L.J.V., W. White and S. Fowler. 2003. *Carcharhinus hemiodon*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 10 April 2014

Compagno, L. J. V., J. Pogonoski and D. Pollard 2009. *Glyphis glyphis*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 10 April 2014.

Das, S., P. S. Lyla and S. A. Khan 2006. Marine microbial diversity and ecology: importance and future perspectives. *Curr. Sci.*, 90 (10): 1325-1335.

Day, F. 1878. The fishes of India; being a natural history of the fishes known to inhabit the seas and fresh waters of India, Burma, and Ceylon. Part 4: i-xx + 553-779

Day, F. 1889. The Fauna of British India Including Ceylon and Burma. Fishes. Vol. I. Taylor and Francis, London.

De Silva, R. I. 2006. Taxonomy and Status of the Sharks and Rays of Sri Lanka. The Fauna of Sri Lanka. In Bambaradeniya, C.N.B. (Ed), 2006. Fauna of Sri Lanka: Status of Taxonomy, Research and Conservation. The World Conservation Union, Colombo, Sri Lanka and Government of Sri Lanka. 294-301.

Dubois, A. 2003. The relationships between taxonomy and conservation biology in the century of extinctions. *Comptes Rendus Biol.*, 326 (1): 9-21.

Dubois, A. 2010. Zoological nomenclature in the century of extinctions: priority vs. 'usage'. *Org. Divers. Evol.*, 10: 259-274.

Dulvy, N. K., S. L. Fowler, J. A. Musick, R. D. Cavanagh, P. M. Kyne, L. R. Harrison, J. K. Carlson, L. N. K. Davidson, S. V. Fordham, M. P. Francis, C. M. Pollock, C. A. Simpfendorfer, G. H. Burgess, K. E. Carpenter, L. J. V. Compagno, D. A. Ebert, C. Gibson, M. R. Heupel, S. R. Livingstone, J. C. Sanciangco, J. D. Stevens, S. Valenti, W. T. White. 2014. Extinction risk and conservation of the world's sharks and rays. eLife, 3: e00590 DOI: 10.7554/eLife.00590. 1-34.

Ebert, D. A., W. T. White, K. J. Goldman, L. J. V. Compagno, T. S. Daly-Engel, and R. D. Ward. 2010. Resurrection and redescription of *Squalus suckleyi* (Girard, 1854) from the North Pacific, with comments on the *Squalus acanthias* subgroup (Squaliformes: Squalidae). *Zootaxa*, 2612: 22-40.

Ebert, D. A., H. C. Ho, W. T. White, and M. R. De Carvalho. 2013. Introduction to the systematics and biodiversity of sharks, rays, and chimaeras (Chondrichthyes) of Taiwan. *Zootaxa*, 3752: 5-19

Eschmeyer, W. N. (Ed) 2014. Catalogue of Fishes: Genera, Species, References.(http://research.calacademy.org/research/ichthyology/catalog/fishcatmain.asp).Electronic version accessed 01/2/2014.

Fahmi. 2010. Sharks and rays in Indonesia. *Mar. Res Indonesia*, 35, (1), 43-54.

García, V. B., L. O. Lucifora, and R. A. Myers. 2008. The importance of habitat and life history to extinction risk in sharks, skates, rays and chimaeras. *Proc. R. Soc.. Biol. Sci.*, 275: 83-89.

Günther, A. 1870. Catalogue of the fishes in the British Museum. Catalogue of the Physostomi, containing the families Gymnotidae, Symbranchidae, Muraenidae, Pegasidae, and of the Lophobranchii, Plectognathi, Dipnoi, ...[thru] ... Leptocardii, in the British Museum. v. 8: i-xxv + 1-549.

Hariharan, G.N. and P. Balaji, 2002. Taxonomic research in India: Future prospects. *Curr. Sci.*, 83(9):1068-1070.

Hebert, P. D. N., A. Cywinska, S. L. Ball, & J. R. deWaard. 2003. Biological identifications through DNA barcodes. *Proc. . R.l Soc.. Biol. Sci.*, 270: 313-322.

IUCN. 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 01 May 2014.

James, P. S. B. R. 2010. Taxonomic status of marine pelagic fishes of India, research priorities and conservation strategies for the sustainability of their fisheries. *Indian J. . Anim. Sci.* 80 (4): 39-45.

Kholia, B. S and C. R. F. Jenkins. 2011. Misidentification makes scientific publications worthless - save our taxonomy and taxonomists. *Curr. Sci.,* 100(4):458-461.

Kizhakudan, S. J. and S. Rajapackiam. 2013. First report of the crocodile shark *Pseudocarcharias kamoharai* (Matsubara, 1936) from Chennai, southeast coast of India. *J. Mar. Bio. Ass. India*, 55 (1): 86-88.

Kumaran, P. L. 2002. Marine mammal research in India - a review and critique of the methods. *Curr. Sci.*, 83 (10): 1210-1220.

Last, P. R. 2007. The state of chondrichthyan taxonomy and systematics. *Mar. Freshw. Res.*, 58, 7-9.

Last, P. R., B. M. Manjaji and G. K. Yearsley. 2005. *Pastinachus solocirostris* sp. nov., a new species of stingray (Elasmobranchii: Myliobatiformes) from the Indo-Malay Archipelago. *Zootaxa*, 1040: 1-16.

Last, P. R., W. T. White and J. J. Pogonoski. 2008a. (Eds.). Descriptions of New Australian Chondrichthyans. *CSIRO Marine and Atmospheric Research* 022: 1-368.

Last, P. R., W. T. White, J. J. Pogonoski and D. C. Gledhill. 2008b. (Eds.). Descriptions of new Australian skates (Batoidea: Rajoidei). *CSIRO Marine and Atmospheric Research* Paper No. 021:1-181.

Last, P. R., W. T. White and J. J. Pogonoski. 2010a. (Eds). Descriptions of new sharks and rays from Borneo. *CSIRO Marine and Atmospheric Research* Paper. No. 032: 1-166.

Last, P. R. and B. M. Manjaji-Matsumoto. 2010b. Description of a new stingray, *Pastinachus gracilicaudus* sp nov. (Elasmobranchii: Myliobatiformes), based on material from the Indo-Malay Archipelago. In: Descriptions of new sharks and rays from Borneo. *CSIRO Marine and Atmospheric Research Paper* No. 032: 115-127.

Last, P. R., Fahmi and G. J. P. Naylor. 2010c. *Pastinachus stellurostris* sp. nov., a new stingray (Elasmobranchii: Myliobatiformes) from Indonesian Borneo. In: Descriptions of new sharks and rays from Borneo. *CSIRO Marine and Atmospheric Research* Paper No. 032: 129-139.

Marshall, A. D., L. J. V. Compagno, and M. B. Bennett. 2009. Redescription of the genus *Manta* with resurrection of *Manta alfredi* (Krefft, 1868) (Chondrichthyes; Myiobatoidei; Mobulidae). *Zootaxa*. 2301: 1-28.

Misra, K. S. 1952. An aid to the identification of the fishes of India, Burma and Ceylon. 1. Elasmabranchii and Holocephali. *Rec. Indian Mus.* 49 (1): 89-137.

Misra, K. S. 1969. Elasmobranchii and Holocephali. In M. L. Roonwal, (Ed.) The fauna of India and the adjacent countries. Pisces, (Second Edition). Zoological Survey of India, Government of India Press, Faridabad, 1-276.

Moore, A. B. M., R. D. Ward and R. Peirce. 2012. Sharks of the Persian (Arabian) Gulf: a first annotated checklist (Chondrichthyes: Elasmobranchii). *Zootaxa*, No. 3167: 1-16

Moron, J., Bertrand, B. and Last, P. R. (1998) A check-list of sharks and rays of western Sri Lanka. *J. Mar. Biol. Ass. India*, 40: 142-157.

Narendran, T. C. 2001. Taxonomic entomology: Research and education in India. *Curr. Sci.* 81(5): 445-447.

NBAP. 2008. National Biodiversity Action Plan 2008. Govt. of India. Ministry of Environment and Forest. 78 pp.

Pavan-Kumar, A., P. Gireesh-Babu, P. P. Suresh Babu, A. K. Jaiswar, K. Pani Prasad, Aparna Chaudhari, S. G. Raje, S. K. Chakraborty, Gopal Krishna and W. S. Lakra. 2013. DNA barcoding of elasmobranchs from Indian Coast and its reliability in delineating geographically widespread specimens. Mitochondrial DNA, 1940-1736. 1-9. [Early online].

Prathapan, K. D., P. D. Rajan and J. Poorani (2009). Protectionism and natural history research in India. *Curr. Sci.*, 91:1006-1007.

Raje, S. G., Grace Mathew., K. K. Joshi, R. J. Nair, G. M. Ra, M. Srinath, S. Gomathy and Rudramurthy. 2002. Elasmobranch fisheries of India-An Appraisal. 71: 1-76

Raje, S. G., S. Sivakami, G. Mohan Raj, P. P. Manoj Kumar, A. A. Raju and K. K. Joshi 2007. An Atlas on the Elasmobranch fishery resources of India. 95: 1-253.

Smith, S. E., D. W. Au and C. Show. (1998). Intrinsic rebound potentials of 26 species of Pacific sharks. *Mar. Freshw. Res.* 41: 663-678.

Talwar, P. K. and R. K. Kacker. 1984.Commercial sea fishes of India. Zoological Survey of India, Calcutta. 997.

Vecchione, M., and B. B. Collette. 1996. The central role of systematics in marine biodiversity issues. *Oceanogr.*, 9(1): 44-49.

Venkataraman, K., M. C. J. Milton and K. P. Raghuram. 2003. Handbook on sharks of Indian waters. ZSI, Kolkata 1-113.

Vidthayanon, C. 2002. Elasmobranch Diversity and Status in Thailand. In, Fowler, S.L., Reed, T. M. and Dipper, F. A. (eds). Elasmobranch Biodiversity, Conservation and Management: Proceedings of the International Seminar and Workshop, Sabah, Malaysia, July 1997. IUCN SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. xv + 258 pp.

Vishwanath, W. and I. Linthoingambi. 2010. Emerging trends in taxonomy research and evolutionary systematics of fish fauna of North- East India. *Indian J. Anim. Sci.*, 80 (4) (Suppl. 1): 16-25.

Wafar, M., K. Venkataraman, B. Ingole, S. Ajmal Khan, and P. Loka Bharathi. 2011. State of Knowledge of Coastal and Marine Biodiversity of Indian Ocean Countries. *PLoS ON*E, 6(1): e14613.

White, W. T., P. R. Last, J. D. Stevens, G. K. Yearsley, Fahmi and Dharmadi. 2006. Economically important sharks and rays of Indonesia. *ACIAR. Monograph series*; no. 124. 338.

White, W. T., P. R. Last, G. J. P. Naylor, K. Jensen and J. N. Caira. 2010a. Clarification of *Aetobatus ocellatus* (Kuhl, 1823) as a valid species, and a comparison with *Aetobatus narinari* (Euphrasen, 1790) (Rajiformes: Myliobatidae). In Last, P. R., White, W. T. and Pogonoski, J. J., (Eds), Descriptions of New Sharks and Rays from Borneo pp. 141-164. *CSIRO Marine and Atmospheric Research* Paper 032.

White, W. T., P. R. Last and G. J. P. Naylor. 2010b. *Scoliodon macrorhynchos* (Bleeker, 1852), a second species of spadenose shark from the Western Pacific (Carcharhiniformes : Carcharhinidae). In Last, P.R., White, W.T. and Pogonoski, J.J., (Eds). Descriptions of New Sharks and Rays from Borneo, pp. 61-76. *CSIRO Marine and Atmospheric Research* Paper 032.

White, W.T., P. R. Last, G. J. P. Naylor and M. Harris. 2010c. Resurrection and redescription of the Borneo broadfin shark *Lamiopsis tephrodes* (Fowler, 1905) (Carcharhiniformes: Carcharhinidae). In Last, P. R., White, W. T. and Pogonoski, J. J., (Eds). Descriptions of New Sharks and Rays from Borneo, pp. 45-59. *CSIRO Marine and Atmospheric Research* Paper 032.

White, W. T. and P. R. Last. (2012). A review of the taxonomy of chondrichthyan fishes: a modern perspective. *J. Fish Biol.*, 80: 901-917.

Ecosystem Approaches to the Management and Conservation of Fisheries and Marine Biodiversity in the Asia Region

27-30 October 2013, Kochi, Kerala, India
Conclusions and Recommendations

Preamble

Mangroves for the Future (MFF) and the Ministry of Environment and Forests, Government of India, convened a Regional Fisheries Symposium at Kochi in the southern coastal State of Kerala, India between the 27-30 October 2013, in partnership with the Bay of Bengal Large Marine Ecosystem Project (BOBLME), the Central Marine Fisheries Research Institute (CMFRI) India, the Food and Agriculture Organization (FAO) of the United Nations, the South East Asian Fisheries Development Centre (SEAFDEC), and the United Nations Environment Program (UNEP).

The objective of the Symposium was to explore ecosystem-based approaches to management and conservation of fisheries and marine biodiversity in Asia, provide a forum for productive debate, and draw out knowledge and share practical solutions based on science and indigenous knowledge. Furthermore, the Symposium aimed to bridge the gap between the often conflicting priorities of the fisheries and environmental conservation sectors.

Experts, scientists, policy makers, Inter-Governmental Organizations and NGO representatives from 11 Asian countries; Bangladesh, Cambodia, China, India, Indonesia, Pakistan, Philippines, Seychelles, Sri Lanka, Thailand, and Viet Nam came together for scientific sharing and debate on the best ways to balance economic, social and environmental interests, to achieve sustainable fisheries for the Asia region.

Thirty seven scientific papers were presented covering five thematic areas: (i) Coastal Ecosystems and Fisheries – Towards and Ecosystem Approach to Fisheries Management; (ii) Spatial Planning, Marine Protected Areas and Fisheries Management; (iii) Artisanal Fisheries, Livelihood and Biodiversity; (iv) Exploring the Issues of Bycatch and Bycatch Management; and (v) By-catch, Sharks, Marine Turtles and other Endangered and Threatened species.

Discussions at the Symposium focused on the Ecosystem Approach to Fisheries Management (EAFM), the use of Marine Protected Areas (MPAs) and Fisheries Refugia (FR), as well as on the use of conventional fisheries management approaches and the reduction of bycatch. The Symposium also presented and discussed the recommendations from the recent Asia Pacific Fishery Commission Workshop on Managing Tropical Trawl Fisheries, held in Phuket, Thailand, 30 September- 4 October, 2013.

The symposium resulted in a number of conclusions and recommendations for practical action and future collaboration between countries, sub-regions, scientists, community practitioners, policy makers, and sectors to support national and regional policies for improved ecosystem based management of fisheries and marine biodiversity.

Conclusions and Recommendations

Recognizing that

- marine fisheries contribute substantially to the nutritional, social and economic benefits of the people in the Asian region and that millions of people in the region depend heavily on the health and productivity of critical coastal habitats and fisheries for their basic food, materials and livelihood needs;
- there is a growing interest on the application of ecosystem based fisheries management and some examples of good practices

on ecosystem based fisheries management that can be shared among the countries of South and Southeast Asia;

- there are growing concerns about the sustainability of fishery resources and the impacts of fishing practices on ecosystem services and marine biodiversity;
- unintended consequences of some fishing practices, including habitat destruction, incidental mortality of non-target species, are changing the function and structure of ecosystems;
- over-capacityi in fisheries often leads to overexploitation of fish stocks;
- there is growing consensus that fisheries management should adopt the Ecosystem Approach to Fisheries Management (EAFM) in order to address the twin objectives of fisheries sustainability and marine biodiversity conservation in coastal and offshore areas and that this should be a part of a holistic Integrated Coastal Management Approach;

The Symposium concluded that

- Fisheries Refugia (FR) offer a complementary management approach to traditional MPA management and involve the identification and designation of priority areas within which to integrate fisheries and habitat management objectives. The Fisheries Refugia approach is being tested in a number of countries in South East Asia and offer a good model for further learning and replication and or piloting across Asia and especially in South Asia,
- The Ecosystem Approach to Fisheries Management (EAFM) is a management planning process that offers a practical way to implement sustainable development principles for the management of fisheries and coastal habitats. EAFM has the potential to significantly enhance and evolve marine fisheries management in Asia and to contribute to the conservation of marine biodiversity. EAFM is complementary to a number of related approaches and management tools including, among others, Integrated Coastal Management (ICM), Coastal Zone Management (CZM), Sustainable Livelihood Approach (SLA), Wealth-Based Fisheries Management (WBFM), Ecosystem Approach to Fisheries (EAF), Large Marine Ecosystem (LME), Marine Spatial Planning (MSP),
- Overcapacity is a significant issue with respect to the continuing decline of fisheries in Asia that urgently needs to be addressed as part of a holistic solution to sustainable fisheries management. Fishing capacity should be urgently addressed and if required aligned with the harvestable potential (where such figures are available) or on the basis of a precautionary approach,
- Capture of juveniles of target species and incidental catch of non-target species are major issues that need to be addressed following suitable interventions,
- The use of marine spatial planning, including spatial and temporal closures, are recognized as effective components of ecosystems based management of coastal habitats and fisheries,
- Building effective institutions and mechanisms for the management of fisheries resources requires a close match between the spatial extent of the resource, the capacity and jurisdiction of the institutions as well as mechanisms to manage the resources. Defining appropriate operational management boundaries for ecosystem based fisheries management is important and will require matching fisheries management system boundaries with ecosystem boundaries. It will also take into account the joint unified operational management mechanisms.

The Symposium further recommended Sound Management Principles

1. The Ecosystem Approach to Fisheries (EAF) concept and related implementation framework Ecosystem Approach to Fisheries Management (EAFM), are consistently applied to address issues concerning the wider interactions between fisheries and the ecosystem as a whole,

2. MPAs and FR are promoted as important elements of the Ecosystem Approach to Fisheries Management (EAFM) and conservation of marine biodiversity. Establishment and strengthening of these measures need to address the tenure and livelihood concerns of all stakeholders,

3. Studies should be undertaken to define success of implementing the EAFM in order to monitor, evaluate and demonstrate the benefit of ecosystem based management approaches. In particular, establishing indicators and reference points as part of a framework for monitoring management performance should be prioritized,

4. Capacity development is promoted at all levels from the policy decision makers/managers, to grassroots practitioners of fisheries and biodiversity conservation to take into account that Ecosystem based approaches are relatively new but gaining ground in the Asia region. In particular, it is recommended that EAFM training should be promoted and incorporated as part of existing and new courses, both at regional and national levels through a network approach,

5. Traditional fisheries management measures including catch and effort quotas, gear design and restrictions should be based not just on sustainable use of the target resources but on their impacts on and implications for the whole ecosystem,

6. Unsustainable bycatch of juveniles should be reduced by introducing appropriate measures such as use of Bycatch Reduction Devices (BRDs) and modification of gear in a participatory process including all stakeholders,

Economic Justification

7. Total economic valuation of the ecosystem goods and services of critical habitats and associated fisheries should be applied in order to support sound development planning for sustainable fisheries as a part of sustainable coastal ecosystems management. In particular economic valuation and recognition of artisanal / small scale fisheries for their importance in the provision of food security (accessible and affordable protein) and livelihood services, in addition to other supporting services, should be considered more carefully in planning and policy decision making processes,

Enabling Policies and Safeguards

8. Application of ecosystem approaches must be based on effective cross-sectoral cooperation and

collaboration, which inter alia may require harmonization, coordination and mainstreaming of policies and programmes of government agencies. In some cases revision of some national laws, by-laws, decrees or ordinances may be needed to provide the required legal support. Formulation of management plans for important fisheries and other resources will be necessary. Similarly, governance frameworks to support adoption and implementation of ecosystem approaches may require strengthening,

9. Integrated Coastal Management (ICM) should be promoted as the underlying management framework required for the successful implementation of ecosystem based fisheries management in order that fisheries and non fishery users can co-exist with minimal conflict ICM strengthens coordination and cooperation between different local and national agencies working in the areas of fisheries, environment, tourism, shipping, ports etc. and the engagement of local government units and resource users on the ground. These institutional and policy arrangements and governance structures are to be in place for the effective adoption of ecosystem approach to fisheries management.

10. The policy and management decision making processes should be inclusive and participatory in order to achieve effective management of local fishery and coastal resources. The establishment of access rights systems, appropriate and enforceable rights to ecosystems resources is an essential component of the aforementioned processes that also include establishment of partnerships and co-management groups involving local communities/other civil society groups, private sector as well as the government. It is particularly important to empower small scale and artisanal fishers and fishing communities (e.g. through strengthening of their associations and representations) to enable them to engage and participate in the co-management process,

Research, Communication and Information Management

11. Data collection, processing and dissemination be strengthened and effective mechanisms be established to allow flow of information, especially among scientists, policy makers and local management decision makers, as well as community members and resource users. The use of indigenous/traditional knowledge in the process of sourcing information is important and should complement and be supported by scientific research,

Specific recommendations:

- Seek opportunity to advance the scientific basis for incorporating ecosystem considerations into management processes, including research in;
  - The structure and functioning of marine ecosystems, including, biological and physical factors affecting their stability and resilience;
  - Life cycle studies of commercial fish species including temporal and spatial distribution of critical stages;
  - By-catch and discard patterns in all fisheries to obtain better knowledge of the amount of fish actually taken;
  - Development of fishing technology and practices to improve gear selectivity and reduce adverse impacts of fishing practices on habitat and biological diversity;
  - Marine mammals and other endangered, threatened, and protected species (including sharks, marine turtles, snakes and birds) for their improved protection and conservation;
- Applied research and case studies of ecosystem management should be actively pursued. Knowledge gaps about ecosystem based fisheries management should be addressed by regional initiatives to support the development of national and transboundary near-shore fisheries management,
- Ensure that the existing guidelines on responsible fishing practices are adapted to meet the local conditions and disseminated to the actual user groups in appropriate local language.
- All regional countries are requested to increase their efforts to draft and finalize, as well as implement and review existing National Plans of Action (NPOA) for sharks, marine mammals and seabirds and other endangered, threatened and protected species,
- Strategic communication and awareness raising for all stakeholders in the 'value chain' (from fisher, to market, to consumer) is critical for ecosystems management and conservation of biodiversity to be effective. Harmful impacts of fishing gears on marine mammals, marine turtles and sea birds (and other vulnerable species) are important and emotive issues which require proper research and communication,

Regional Cooperation

12. Regional cooperation and information sharing to address issues of transboundary nature (e.g. conservation of biodiversity; management of shared fish resources; marine pollution prevention and ecosystem health) and share experiences regarding successful as well as unsuccessful application of the ecosystem approaches are improved.

13. The regional partnerships established during the Symposium are maintained for continued collaboration and sharing on ecosystem management approaches for fisheries and marine biodiversity conservation. In particular, the symposium noted that

- regional programmes and projects (such as MFF, BOBLME, SEAFDEC, FAO/ APFIC, UNEP and BOBP- IGO) have demonstrated potential for promoting regional good practices, information sharing and capacity development to support coastal and marine ecosystems management and should be continued,
- the many agencies, programmes and projects working in ecosystems based fisheries management and coastal conservation should collaborate to the extent possible to improve regional understanding of ecosystem based management practices in order to optimize results and benefits, and avoid duplication of work.

02 December 2013

MFF Secretariat

i The term **"overcapacity"** can be described in two ways. In input terms, "overcapacity" means there is more than the minimum fleet and effort required to produce a given TAC or given output (harvested catch) level. In output terms, overcapacity means that the maximum harvest level that a fisher could produce with given levels of inputs, such as fuel, amount of fishing gear, ice, bait, engine horsepower and vessel size would exceed the desired level of harvesting or TAC.

© FAO 2005-2013. Fisheries and Aquaculture topics. Assessing fishing capacity and overcapacity. Topics Fact Sheets. Text by **Rebecca Metzner**. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 27 May 2005. [Cited 20 November 2013]. http://www.fao.org/fishery/topic/14858/en

Instructions to Authors

Submission of manuscripts

Types of contribution

Research Papers should report the results of original research. The material should not have been previously published elsewhere, except in a preliminary form. Manuscript should not exceed 12.to 15 typed pages of A-4 size

Short Communications are less than four printed pages.There is no other difference between a Research Paper and a Short Communication.

Review articles on specific themes will be published on invitation by the Editor.

The Editorial Board reserves the privilege of returning to the author for revision manuscripts and illustrations which are not in the proper form given in this guide.

Editorial Policy

Articles submitted for publication are independently reviewed by at least two referees who are experts in the concerned area. However, manuscripts that do not meet the criteria for publication may be rejected by the Editor without being sent for review. Acceptance or rejection of a manuscript is at the sole discretion of the Editor and Associate Editors

It is mandatory on the part of the corresponding author to furnish the following certificate at the time of submission of the manuscript through the Head of Department/ Institute on official letter head. The certificate should have the names of all the authors and signature of the lead/ corresponding author.

This is to certify that the reported work in the paper entitled "……." submitted for publication is an original one and has not been submitted for publication elsewhere. I/ we further certify that proper citations to previously published work have been given and no data/ tables/ figures have been quoted verbatim from other publications without giving due acknowledgement and without permission of the author(s). The consent of all the authors of this paper has been obtained for submitting the paper to the journal of the Marine Biological Association of India.

Copyright

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all the authors and by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language without the written consent of the Publisher.

Papers for consideration should be submitted via e-mail to the Editor (e-mail: mail@mbai.org.in; mbai@rediffmail.com) or through the web portal of MBAI (www.mbai.org.in)

English language

Manuscripts should be written in English. Authors who are unsure of correct English usage should have their manuscript checked by someone proficient in the language. Manuscripts in which the English is difficult to understand may be returned to the author for revision before scientific review.

Format requirements for articles

General

1 Manuscripts should be typewritten, with numbered lines, with wide margins and double spacing throughout, i.e. also for abstracts, footnotes and references. Every page of the manuscript, including the title page, references, tables, etc., should be numbered in the upper right-hand corner. However, in the text no reference should be made to page numbers; if necessary, one may refer to sections. Avoid excessive usage of italics and bold letters to emphasize part of the text. Information/ data provided in tables should not be repeated in figures and vice versa. Verbose statements of tables and figures should be avoided. Instead, only the salient results should be highlighted.

2 Manuscripts in general should be organized in the following order:
Title (should be clear, descriptive and concise)
Name(s) of author(s)
Complete postal address (es) of affiliations
E-mail address of the corresponding author
Present address (es) of author(s) if applicable.
Abstract, Keywords (indexing terms), normally 4-6 items,
Running title.
Introduction
Material and methods
Results and discussion (Authors are encouraged to combine Results and discussion)
Acknowledgements and any additional information concerning research grants, etc
References
Tables
Figure captions
Figures

3. In typing the manuscript, titles and subtitles should not be run within the text. They should be typed as a separate line, without indentation. Use bold face, lower-case letter type for titles; use non-bold, italic letter type for sub-titles.

4 Species names and other Latin terms should be typed in italics.

5 SI units should be used.

6 It is important that the file be saved in MS Word, 12 point (Times New Roman). The text should be in single-column format. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. Do not embed "graphically designed" equations or tables, but prepare these using the word processor's facility. When preparing tables, if you are using a table grid, use only one grid for each individual table and not a grid for each row. If no grid is used, use tabs, not spaces, to align columns. Do not import the figures into the text file but, instead, indicate their approximate locations directly in the electronic text. See also the section on Preparation of electronic illustrations.

Abstracts

The abstract should be clear, descriptive and not longer than 400 words. It should provide a very brief introduction to the problem and a statement about the methods used in the study. This should generally be followed by a brief summary of results, including numerical data (means and standard errors, for example). The abstract should end with an indication of the significance of the results. An abstract is often presented separate from the article, so it must be able to stand alone.

Keywords

Immediately after the abstract, provide a maximum of 4¬6 keywords, avoiding general and plural terms and multiple concepts (avoid, for example, "and", "of"). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

Abbreviations

Define abbreviations that are not standard in this field at their first occurrence in the article: in the abstract but also in the main text after it. Ensure consistency of abbreviations throughout the article.

Tables

1. Authors should take notice of the limitations set by the size and lay-out of the journal. Large tables should be avoided. Reversing columns and rows will often reduce the dimensions of a table.
2. If many data are to be presented, an attempt should be made to divide them over two or more tables.
3. Tables should be numbered according to their sequence in the text. The text should include references to all tables.
4. Each table should be typewritten on a separate page of the manuscript. Tables should never be embedded in the text.
5. Each table should have a brief and self-explanatory title.
6. Column headings should be brief, but sufficiently explanatory. Standard abbreviations of units of measurement should be added between parentheses.
7. Vertical lines should not be used to separate columns. Leave some extra space between the columns instead.
8. Any explanation essential to the understanding of the table should be given as a footnote at the bottom of the table.

Formulae

Present simple formulae in the line of normal text where possible. In principle, variables are to be presented in italics. Use the solidus (/) instead of a horizontal line, e.g., X/Y. Powers of e are often more conveniently denoted by exp. Number consecutively any equations that have to be displayed separate from the text (if referred to explicitly in the text). Give the meaning of all symbols immediately after the equation in which they are first used.

Preparation of electronic illustrations

General

Make sure you use uniform lettering and sizing of your original artwork.

Save text in illustrations as "graphics" or enclose the font. Number the illustrations according to their sequence in the text.

Use a logical naming convention for your artwork files. Provide all illustrations as separate files. Provide captions to illustrations separately. Produce images near to the desired size of the printed version.

Formats

Regardless of the application used, when your electronic artwork is finalised, please "save as" or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/ halftone combinations given below):

EPS: Vector drawings. Embed the font or save the text as "graphics". TIFF: Colour or greyscale photographs (halftones): always use a minimum of 300 dpi.TIFF: Bitmapped line drawings: use a minimum of 1000 dpi.TIFF: Combinations bitmapped line/half-tone (colour or greyscale): a minimum of 500 dpi is required.

Please do not:

1. Embed graphics in your word processor (spreadsheet, presentation) document;
2. Supply files that are optimised for screen use (like GIF, BMP, PICT, WPG); the resolution is too low;
3. Supply files that are too low in resolution;
4. Submit graphics that are disproportionately large for the content.

Captions

Ensure that each illustration has a caption. Supply captions separately, not attached to the figure. A caption should comprise a brief title (not on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

Line drawings

The lettering and symbols, as well as other details, should have proportionate dimensions, so as not to become illegible or unclear after possible reduction; in general, the figures should be designed for a reduction factor of two to three. The degree of reduction will be determined by the Publisher. Illustrations will not be enlarged. Consider the page format of the journal when designing the illustrations. Do not use any type of shading on computer-generated illustrations.

Photographs (halftones)

Remove non-essential areas of a photograph. Do not mount photographs unless they form part of a composite figure (plate). Where necessary, insert a scale bar in the illustration (not below it), as opposed to giving a magnification factor in the caption.

Colour illustrations

Please make sure that artwork files are in an acceptable format (TIFF, EPS or MS Office files) and with the correct resolution. For colour reproduction in print, you will receive information regarding the costs after receipt of your accepted article. Please indicate your preference for colour in print.

Please note: Should your illustrations be printed in black and white, do not use colour in your drawings.

References

1. All publications cited in the text should be presented in a list of

references following the text of the manuscript. The manuscript should be carefully checked to ensure that the spelling of author's names and dates are exactly the same in the text as in the reference list.

2. In the text refer to the author's name (without initial) and year of publication, followed - if necessary - by a short reference to appropriate pages.
3. If reference is made in the text to a publication written by more than two authors the name of the first author should be used followed by "et al.". This indication, however, should never be used in the list of references. In this list, names of first author and all co-authors should be mentioned.
4. References cited together in the text should be arranged chronologically. The list of references should be arranged alphabetically by authors' names, and chronologically per author. If an author's name in the list is also mentioned with co-authors the following order should be used: publications of the single author, arranged according to publication dates; publications of the same author with one co-author ; publications of the author with more than one co-author. Publications by the same author(s) in the same year should be listed as 1994a, 1994b, etc.
5. Use the following system for arranging your references:

   a. For periodicals Alagaraja, K. 1962. Observations on the length-weight relationship of pearl oyster. *J. Mar. Biol. Ass. India,* 4: 198-205.

   b. For proceedings of symposia, special issues etc.

   Damodaran, N., J. Toll, M. Pendleton, C. Mulligan, D. Deforest, M. Kluck, M.S. Brancato and J. Felmy. 1999. Cost analysis of TBT self-polishing copolymer paints and tin-free alternatives for use on deep-sea vessels. In: A. Champ, T.J. Fox and A. J. Mearns (Eds.), *Proceedings of the International Symposium on the Treatment of Regulated discharges from shipyards and drydocks,* Vol. 4, *Marine Technology Society*, Washington D. C. 20036. p. 153-168.

   c. For books Vivekanandan, E. 2005. *Stock Assessment of Tropical Marine Fishes.* Indian Council of Agricultural Research, New Delhi, 115 pp.

   d. For multi-article books Callow, M. 1999. The status and future of biocides in marine biofouling prevention. In: M. Fingerman, R. Nagabhushanam and M. Thompson (Eds.) *Recent Advances in Marine Biotechnology,* Vol. 3, New Hampshire. Science Publishers, Inc. p. 109-126.
6. Titles of periodicals mentioned in the list of references should be abbreviated following ISO 4 standard. The ISSN word abbreviations, for example, can be found at http://www.issn.org/Istwa.html.
7. In the case of publications in any language other than English, the original title is to be retained. However, the titles of publications in non-Latin alphabets should be transliterated, and a notation such as "(in Russian)" or "(in Greek, with English abstract)" should be added.
8. Papers accepted for publication but not yet published should be referred to as "in press".
9. References concerning unpublished data and "personal communications" should not be cited in the reference list but may be mentioned in the text.

Nomenclature

1. Authors and editors are, by general agreement, obliged to accept the rules governing biological nomenclature, as laid down in the International Code of Botanical Nomenclature, the International Code of Nomenclature of Bacteria, and the International Code of Zoological Nomenclature.
2. All biota (invertebrates, fish, birds, mammals, etc.) should be identified by their scientific names when the English term is first used.
3. All biocides and other organic compounds must be identified by their Geneva names when first used in the text. Active ingredients of all formulations should be likewise identified.
4. For chemical nomenclature, the conventions of the International Union of Pure and Applied Chemistry and the official recommendations of the IUPAC IUB Combined Commission on Biochemical Nomenclature should be followed.

After acceptance

Proofs

One set of page proof in PDF format will be sent by e-mail to the corresponding author (if we do not have an e-mail address then paper proofs will be sent by post).

If you do not wish to use the PDF annotations function, you may list the corrections (including replies to the Query Form) and return to the Editor in an e-mail. Please list your corrections quoting line number. If, for any reason, this is not possible, then mark the corrections and any other comments (including replies to the Query Form) on a printout of your proof and return by post.

Please use this proof only for checking the typesetting, editing, completeness and correctness of the text, tables and figures. Significant changes to the article as accepted for publication will only be considered at this stage with permission from the Editor. We will do everything possible to get your article published quickly and accurately. Therefore, it is important to ensure that all of your corrections are sent back to us in one communication. Please check carefully before replying, as inclusion of any subsequent corrections cannot be guaranteed. Proof reading is solely your responsibility. Note that we may proceed with the publication of your article if no response is received.

DOI- Link

A digital object identifier (DOI) can be used to cite and link to electronic documents. A DOI is guaranteed never to change, so you can use it to link permanently to electronic documents. JMBAI articles are DOI linked through CrossRef from Vol 53(2). To find a document using a DOI

1. Copy the DOI of the document you want to open. The correct format for citing a DOI is as follows: doi:10.6024/jmbai.2011.53.2.01658-01
2. Open the following DOI site in your browser: http:/dx.doi.org
3. Enter the following DOI citation in the text box provided, and then click Go.

Reprints

The corresponding author, at no cost, will be provided with a PDF file of the article via e-mail.

Journal of Marine Biological Association of India has no page charges.

REGISTRATION OF NEWSPAPER (CENTRAL) RULES 1958

STATEMENT ABOUT OWNERSHIP AND OTHER PARTICULARS ABOUT NEWSPAPER

Form IV

(See Rule 8)

1. Place of publication	-	Kochi
2. Periodicity of its publication	-	Bi annual
3. Printer's Name & Address Nationality	-	M/s Anaswara Offset Pvt. ltd., Perandoor, Kochi - 682 018
Nationality	-	Indian
4. Publisher's Name	-	Dr. P.U Zacharia, for the Marine Biological Association of India
Nationality	-	Indian
Address	-	CMFRI Campus, P. B. No. 1604, Kochi - 682 018
5. Editor's Name	-	Dr. P. U Zacharia
Nationality	-	Indian
Address	-	CMFRI Campus, P. B. No. 1604, Kochi - 682 018

6. Names and address of individuals who own the newspaper and partners or shareholders holding more than one per cent of the total capital - Marine Biological Association of India, CMFRI Campus, P. B. No. 1604, Kochi - 682 018.

I, Dr. P.U. Zacharia , hereby declare that the particulars given above are true to the best of my knowledge and belief.

Sd/-.

P. U Zacharia

Kochi 682 018

Dated : 15.10.2014

MBAI

Marine Biological Association of India

Founded in 1958