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ASIA-PACIFIC FISHERY COMMISSION (APFIC)

APFIC/FAO Regional Expert Workshop

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Foreword

The challenge of effective fishery management is more critical than ever, now that the Asian region is passing from four decades of expansion and increased production to an era of overcapacity, overexploitation and unsustainable practice. Although there is great variety in fishing methods and in the status of capture fisheries resources in the region, many of the key coastal fisheries of the region are facing the aforementioned problems. Acknowledging this situation, the Fourth Regional Consultative Forum Meeting of the Asia-Pacific Fishery Commission (APFIC) identified the need for more effective management of the tropical trawl sector that balances the demand for fish for human consumption and for aquaculture feeds with the need to sustain ecosystem functions in the marine fishery and improve capture fishery quality.

Improving the management of tropical trawl fisheries in the APFIC region requires actions across a range of issues using an approach that is appropriate to the social, economic and governance contexts of the APFIC member countries. These complex considerations can best be addressed by applying an ecosystem approach to fisheries management. The Asia-Pacific Fishery Commission strongly highlighted these issues at its Thirty-second Session and agreed to use trawl fisheries as a model through which to directly address the management of trawling and indirectly to build capacity in fishery and ecosystem management approaches with the APFIC member countries in Asia.

The APFIC regional guidelines for the management of tropical trawl fisheries in Asia were developed through an APFIC expert workshop process that placed FAO global best practice in the Asian regional context. The guidelines cover spatial management, improved assessment of fisheries, innovative gear approaches and, importantly, how multigear, multispecies fisheries can be managed in way that yields catch from multiple trophic levels and segments of the fishery.

These guidelines are targeted primarily at fishery departments and those institutions that are tasked with fishery management at subnational levels. The guidelines are expected to provide concrete advice on options that are available to address typical issues facing tropical trawl fisheries in the region and perhaps elsewhere. A second purpose of the guidelines is to increase understanding of the issues of tropical trawl fisheries and the ways that they can be managed. It is intended that other stakeholders in the fishery and market chain will better understand how management processes can be supported and implemented. This improved understanding will enable stakeholders to engage more effectively with fishers and fishery managers in addressing their particular concerns about fishery management, resource use and sustainability.

These guidelines are a practical and usable product that can support the development of management plans for tropical trawl fisheries in Asia. They should also provide an effective basis for the greater engagement of relevant actors in strengthening and improving the management of the tropical trawl sector in the APFIC region.

Hiroyuki Konuma
Assistant Director-General and
Regional Representative for Asia and the Pacific

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Abbreviations

APFIC	Asia-Pacific Fishery Commission
AR	artificial reef
BOBLME	FAO/GEF Bay of Bengal Large Marine Ecosystem Project
BRD	bycatch reduction device
CCRF	FAO 1995 Code of Conduct for Responsible Fisheries
CITES	The Convention on International Trade in Endangered Species of Wild Fauna and Flora
CO_2	carbon dioxide
COFI	FAO Committee on Fisheries
CPUE	catch per unit effort
E EAFM	"Essential Ecosystem Approach to Fishery Management" training course
EAF/EAA	Ecosystem Approach to Fisheries/Ecosystem Approach to Aquaculture
EAFM	Ecosystem Approach to Fisheries Management
EM	electronic monitoring systems
ETPs	endangered, threatened or protected species
FAD	fish aggregating devices
FAO	Food and Agriculture Organization of the United Nations
FAO RAP	FAO Regional Office for Asia and Pacific
FMP	fishery management plan
GIS	geographic information system
GPS	global positioning system
GT	Gross Tonnes
ITQ	individual transferable quotas
IUU fishing	illegal, unreported and/or unregulated fishing
JTED	juvenile and trash fish exclusion device
kg	kilogram
km^2	square kilometre
M&E	monitoring and evaluation
MAC	management advisory committee
MCS	monitoring, control and surveillance
MEY	maximum economic yield
MLL	minimum legal length
MPA	marine protected area
MSY	maximum sustainable yield
NGO	non-governmental organization
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
PSA	productivity-susceptibility analysis
RA	risk assessment
RCFM	APFIC Regional Consultative Forum Meeting
REBYC II	FAO/SEAFDEC/GEF Strategies for Trawl Fisheries Bycatch Management Project
SEAFDEC	Southeast Asian Fisheries Development Center
TAC	total allowable catch
TED	turtle exclusion device
VMS	vessel monitoring system
VPS	vessel positioning system

Background to the regional guidelines

The Asia-Pacific Fishery Commission (APFIC) is an intergovernmental, regional, fisheries advisory and consultative body which works towards the improvement, understanding, awareness and cooperation in fisheries/aquaculture issues in the Asia-Pacific region. There are 21 member countries, principally from the Asia-Pacific region.

The Thirty-second Session of the Asia-Pacific Fishery Commission strongly highlighted the issues associated with trawl fisheries in the region and agreed to take trawl fisheries as a model through which to directly address the management of trawling and indirectly to build capacity in fishery and ecosystem management approaches.

The Fourth APFIC Regional Consultative Forum Meeting (4th RCFM) suggested that the Asia-Pacific region should develop a regional vision for more effective management of the trawl sector. This regional vision, would seek to balance the demand for fish for human consumption (e.g. fresh/frozen and surimi) and feeds for aquaculture, with the need to sustain ecosystem functions in the marine fishery and improve capture fishery quality. Addressing this challenge will require approaches relating to spatial management, better assessment of fisheries, innovative gear approaches and, importantly, how multigear, multispecies fisheries can be managed in a way that yields catch from multiple trophic levels and segments of the fishery.

APFIC has identified regional outcomes for the enhancement of the marine capture fisheries sector in the Asia-Pacific region, including ways to reduce bycatch and improve trawl management. These key outcomes were:

- A method for risk-based assessment of trawl fisheries developed and available.
- Best practice advice for trawl management available.
- Reduction of trawl bycatch.
- Reduction of juvenile catches prioritized over reduction of total effort.
- The composition (species) and locations of capture of the low value and trash fish component needs to be more clearly elaborated.
- Ecosystem assessment methodology developed and used for management.
- Ecosystem indicators developed and used to monitor fisheries performance.
- Private sector engaged with fishery management (capture and post-harvest) and driving responsible practice as a regular part of doing business.
- Co-management increasingly implemented as the principal management model for fisheries in the region, inclusive of large, medium and small-scale operators as well as women.

In addition, APFIC has noted that spatial and seasonal measures applied in fisheries should be assessed in terms of their fishery effects. The use of science-based approaches to the establishment of protected areas and artificial reefs was strongly encouraged. Science and local knowledge should be used to determine key habitats or areas that should be targeted for these types of management measure. Key outcomes relating to this, which were identified by the 4th RCFM were:

- Science-based management methods (which incorporate local knowledge) developed for Marine Protected Area (MPA) development, including evaluation of effectiveness for fisheries.
- Science-based refugia/habitat-based spatial measures (including artificial reefs) for fisheries developed.
- Seasonal or periodic fishing closures and other temporal measures developed based on scientific information and local knowledge.

- Key habitats (based on depth, spawning or nursery areas or sensitive habitats) are identified and integrated into fishery management plans.
- Artificial reef construction follows science-based planning and supports the separation of large and small scale-fishing operations.
- Fishery resources conservation areas are placed/aggregated so that they contribute to local stock recruitment and other fishery benefits.

To contribute to these outcomes, the Thirty-second Session of APFIC recommended the convening of an APFIC Expert Workshop on Trawl Fishery Management. The ad hoc expert working group was tasked to deliver a guideline for tropical trawl fishery management, which would be both relevant and practical to implement for use by the APFIC member countries.

Regional expert workshop process

A zero draft of the guidelines were prepared by the APFIC Secretariat and circulated to an ad-hoc working group and the regional experts prior to the expert workshop. Preliminary comments and feedback was incorporated into an updated draft ready for the expert workshop.

The expert workshop was convened in Phuket to modify, fill in any gaps, streamline and validate and finalize the draft guidelines. Twenty-eight regional experts and resource persons participated in the expert workshop. The workshop was conducted over 4 and a half days of intensive discussion in both plenary and working groups. The agenda of the workshop is presented in Appendix 5.

All participating regional experts made presentations of the different aspects of trawl fisheries in their home countries to provide context and orientation on the issues which were covered in the guidelines. This also served to break up the work of reviewing and amending the text of the guidelines.

Working group sessions served to provide specific edits to large tables which contain the bulk of the technical recommendations on management actions. The draft guidelines were discussed chapter by chapter in plenary session, incorporating feedback from working group sessions.

During the summary session at the end the workshop, the regional experts developed some recommended minimum standards for the management of tropical trawl fisheries, which had emerged from their deliberations. The regional experts endorsed the recommendations and agreed to their insertion in the final guideline document (see Table 11). The outputs of the plenary and group discussion and recommendations were documented and incorporated into a post-workshop draft, which was circulated to participants for final comment.

The final version of the guidelines will be presented for endorsement by the APFIC Member Countries at the 33rd Session of APFIC to be held in Hyderabad, India in June 2014.

Expert workshop participants

There were 28 participants in the expert workshop, drawn from regional and national fishery organizations, private sector and projects in the APFIC region. The regional experts were selected with a focus on their involvement in various aspects of trawl fisheries. A list of participants is presented in Appendix 6.

Acknowledgements

This expert workshop was made possible by regional cooperation and partnership. Support for participation in the workshop was provided by the FAO, the FAO/SEAFDEC/GEF Strategies for Trawl Fisheries Bycatch Management Project (REBYC II), the FAO/GEF Bay of Bengal Large Marine Ecosystem Project (BOBLME). Cooperation from the Thai Department of Fisheries, Southeast Asian Fisheries Development Center (SEAFDEC), Sustainable Fisheries Partnership (SFP), WorldFish Center and the Australian Fisheries Management Authority (AFMA) is gratefully acknowledged. Local arrangements and logistic support were generously supported by the Andaman Sea Fisheries Research and Development Center (AFRDEC) of the Thai Department of Fisheries.

Department of Fisheries, Thailand

Bay of Bengal Large Marine Ecosystem (BOBLME) Project

Strategies for Trawl Fisheries Bycatch Management (REBYC II) Project

Southeast Asian Fisheries Development Center (SEAFDEC)

Global Environment Facility

WorldFish Center

Australian Fisheries Management Authority (AFMA)

Sustainable Fisheries Partnership (SFP)

ASIA-PACIFIC FISHERY COMMISSION (APFIC)

Regional guidelines for the management of tropical trawl fisheries in Asia

SECTION 1: Background to the guidelines

These guidelines provide practical, simple, easy-to-read advice for fisheries managers of tropical trawl fisheries in Asia. Trawl fisheries are among the most productive fisheries in the world. In Asia, trawling is one of the most important fishing methods, with an estimated 80 000 trawl vessels operating in the region (Funge-Smith *et al.,* 2012). Trawl fishing has been one of the chief methods responsible for placing the Asia-Pacific region as the world's largest producer of fish, with more than 50 percent of the world's wild fish captured in the region (48.7 million tonnes). Of the top ten producers of capture fish in the world, five are in the Asia-Pacific region. China is by far the largest producer in the region with an annual production of 15.7 million tonnes, followed by Indonesia with 5.4 million tonnes and India with 4.7 million tonnes (Funge-Smith *et al.,* 2012).

The increases in capture fishery production that are being achieved in this region in recent decades can be attributed to increases in fishing effort, including gear modification and speed of trawling, an expansion of the geographical range of fishing activities, and the retention of most animals caught (including shorter-lived, small, fast-recruiting species). It is recognized that the trawl fisheries are mainly responsible for these trends throughout this region, and especially in tropical areas.

Trawl fisheries are characterized by a method that involves towing a net (or nets) behind a mobile vessel and catching the organisms that are in the path of the net (Figure 1). Trawl doors, sometimes called otter boards, are used to spread the net apart and open the mouth of the net (otter trawling).

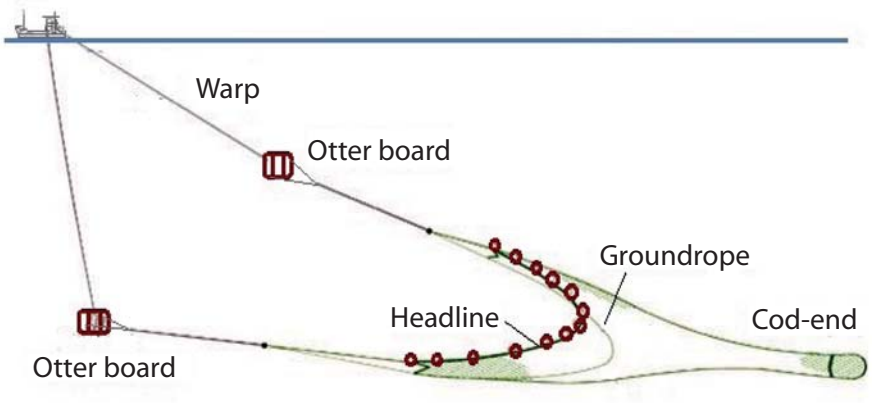

Figure 1 The gear used with the typical otter-trawl

Most often these nets are positioned on the sea floor (demersal trawling) but sometimes they are positioned above the sea floor in the water column (pelagic trawling). Fish and other organisms that enter the net then pass through the net, which is shaped roughly like a cone down to the rear (narrower) section of the net where the catch gathers. This part of the net is called the cod-end and it is here where animals may escape capture by passing through the meshes or be retained and finally landed onboard the fishing vessel.

Tropical trawl fisheries in the Asian region[1]

As in most parts of the world, industrial trawling in Asia began in the early part of the twentieth century when steamships and, later, diesel-powered vessels began to tow large nets (although there is some record of Japanese fishers towing beam trawls behind sailboats in Manila Bay prior to this).

[1] An excellent summary of this history is provided in Morgan and Staples, 2006, based on Butcher, 2004 (available at http://www.fao.org/docrep/010/ag122e/AG122E05.htm).

Scale of trawl fisheries: It was in the early 1970s that trawling became a dominant form of fishing in the region. At this time trawling in tropical Asian waters underwent a rapid expansion that led to massive increases in the total catches of shrimp and finfish. There are now an estimated 83 000 trawl vessels operating in the tropical parts of the APFIC region (Funge-Smith *et al.,* 2012). Indicative figures from some key countries that have trawl fisheries show that trawling accounts for 25 to 52 percent of their total marine catch[2], with a total annual tonnage in excess of 6.6 million tonnes[3]. Trawling can also produce high value products, for example China and four other Asian countries account for 55 percent of the world's total catch of shrimp (FAO, 2010, p. 124).

Trawl gear used: The main gears used in Asia's tropical trawl fisheries are the bottom otter trawl, with two major variants, namely the shrimp trawl and fish trawl. There are also modifications used to produce high opening nets that can target more of the water column. Pair trawls are used in some countries (e.g. Thailand) but banned in others (e.g. Malaysia) and these may be operated on the bottom or as mid-water or pelagic trawls. They are generally towed faster and are capable of catching pelagic and faster-swimming species. Beam trawls may be used in some fisheries but are relatively uncommon.

Typical depths and distances from shore: 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 and results in significant overlap and/or interaction with fisheries using other gears.

Typical species caught: Tropical trawl fisheries in Asia catch approximately 800 species of elasmobranchs, teleosts, crustaceans, molluscs and echinoderms, with at least 300 species contributing to the fishery. The vast numbers of species caught are mostly utilized and discarding is relatively uncommon.

Status of the region's tropical trawl fisheries

There is considerable diversity in the region's tropical trawl fisheries, however they can be broadly split into three types (Table 1). Each type has different economic, social and environmental issues associated with it and therefore the management responses will be quite different.

This diversity of context means that there are a number of management objectives for trawl fisheries that can be summarized as follows:

- Well-managed trawl fisheries that have addressed issues relating to impacts and sustainability of the trawl operations. These fisheries are typically operating profitably and within sustainable limits.
- Those trawl fisheries that have not been closely managed and have been increasingly fished to a point that the quality of the resources is declining. These have a reasonable chance of being restored to provide Maximum Economic Yield at a higher trophic index with the introduction of a management plan.
- Those that have lost top-end predators and have fewer long-lived demersal species. These could be better-managed to improve or sustain the existing services and profitability.
- Those that are so heavily modified that there have been significant changes to the composition of the stocks. There is little that can be achieved to improve these fisheries without major reform of the fishery and its dependent industries.

[2] From various sources: 52% Thailand (2009); 48% Malaysia (2012); >50% India (2010); 43% Viet Nam (1997); ~25% Indonesia (2008)

[3] Calculated from the total trawl catch of India, Thailand, Malaysia, Viet Nam, Indonesia; based on Funge-Smith *et al.*, 2012

Table 1 The three main categories of tropical trawl fisheries in the Asian region (including Australia)

Status of trawl fishery	Typical features
High ecosystem integrity	**Underfished/Fully-fished**
High diversity	Effective management
	Limits on effort
	Fishery operating close to maximum value for food fish
	Fishery operating at Maximum Economic Yield
Modified ecosystem	**Fully fished/Overfished**
Medium diversity	Some management in place
	Probably excess fishing capacity/fishing effort
	Ecosystem changed by fishing, loss of higher value species
	Producing a mixture of good-, medium- and low-quality fish for direct consumption, processing, surimi, and animal feeds
	Gear restrictions needed
Degraded ecosystem	**Overfished for extended period**
Highly modified	Little effective management
	Overcapacity
	Fishery not very profitable
	Subsidies to continue fishing
	Fished down
	Producing low-value species that are largely directed for surimi or processing for feeds
	Management needed to improve efficiency and reduce overfishing effects

The rapid increase in tropical trawl fishing effort in the Asian region since the 1970s has led to significant problems. This is because the increased landings that occurred as trawlers fished new grounds have led to the serial depletion of stocks. The history of industrialized trawling in Asia can therefore be summarized as one of unregulated, sequential expansion. Such serial depletion has also impacted significantly on traditional fishers, often resulting in violent clashes as the exploitation of demersal fish and shrimp stocks has been effectively transferred from small-scale fishers to the highly mechanized industrial trawl fleet. Attempts at regulating and controlling this industrial trawl development, where it has occurred, have been universally weak and ineffective because of non-compliance, limited enforcement and fishers' lack of awareness of regulations.

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

- complete bans on trawling (mostly at the subnational level);
- the introduction of fishery zonation and trawl exclusion areas in many countries in the region;
- efforts to improve the post-harvest utilization of low value catch (e.g. surimi); and
- subsidies to sustain production, despite declining catches and profitability.

In some examples, the introduction of trawl bans resulted in the rapid recovery of both shrimp and fish stocks (e.g. following a trawl ban, the density of demersal fish in the Straits of Malacca more than doubled from 1.2 tonnes/km^2 to 3 tonnes/km^2 between 1983 and 1985). This has led to onward benefits to small-scale fishers. However, zonation regulations are enforced with various degrees of success and it is a common complaint that trawlers break zoning regulations and fish in reserved areas and during closed seasons.

The need for management of the tropical trawl sector

Fisheries management aims to increase the social, environmental and economic benefits from harvesting natural fisheries resources. It attempts to reduce the negative impacts of the many complex issues that affect the sustainable development of fisheries.

The situation today in Asia is that there is a trawl sector throughout the region that catches enormous quantities and a great diversity of fish and shrimp to fulfil market demands, with very little discarding. Data that would allow the accurate partitioning of landings for various uses are widely unavailable. It is well known that a variety of markets rely heavily on the seafood produced by the trawl fisheries to provide a vital source of protein for human consumption in the region. There is a large and growing market for surimi, which is of particular importance since this requires cheap white fish, especially the juveniles of commercially valuable and important species such as threadfin bream, goatfish[4]). Large quantities of fish are also converted into aquaculture feeds and animal feeds for other agriculture sectors. The trawl sector, which is partly subsidized by governments, therefore provides very significant incomes and economic wellbeing for many communities throughout Asia. It provides large numbers of jobs directly in the sector, and an even larger number in related industries such as canneries, processing plants, transport, refrigeration, and supporting services.

However, these positive aspects of the trawl sector in tropical Asia are offset by concerns about the impact of poorly-managed trawl fisheries on fish populations, coastal ecosystems and coastal populations. Added to this, the expansion of trawl fisheries has reached a limit as there are no new, unexploited fishing grounds available. Although there are some possibilities for expansion into deeper waters, it is well known that these areas have lower diversity and quantities of fish than shallower fishing grounds. The outcome is almost certain: that trawlers would return to depleted nearshore areas.

As described above in its history, negative aspects also include overcapacity, excess fishing effort and, because trawls are poorly selective (usually by design), they can lead to the suboptimal harvest of juveniles of many species. They also can adversely affect populations of commercially and biologically important target fish and impact species which are endangered, threatened or protected species (ETPs), do damage to benthic habitats and disrupt normal ecosystem functions. The non-selective nature of trawling is also well known for causing significant conflicts with other fleet segments that target the same species, especially those employing artisanal fishing methods. As described above, such conflicts have occasionally had fatal consequences in the region where there are often insufficient human and financial resources available for adequate enforcement of regulations, leading to significant illegal, unreported and/or unregulated (IUU) fishing.

On top of these effects, there are broader impacts in the region as a result of climate change and consequential changes to weather patterns, and the spatial and temporal distributions of species and habitats.

This picture of the negative aspects identified above may not necessarily be shared by all stakeholders and even some governments whose policies advocate for increased production. However, it is evident that trawling in tropical Asian waters is an important, yet complex human activity that interacts across many geographic scales and socio-economic bands. The contribution of trawl fisheries to fish production, occupations and income generation is counterbalanced by concerns about the sustainability of catches and ecosystem impacts. As a consequence, these fisheries, more than any other in the region, require careful management underpinned by sound information and solid enforcement, to support a transition to sustainable trawl fisheries management and practices.

[4] For details see Funge-Smith, *et al.*, 2012

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, in parallel with this, to develop and implement strategies that will limit the region's trawling effort to levels that will ensure long-term, sustainable demersal resources for all fleet segments.

The Asia-Pacific Fishery Commission (APFIC) at its thirty-second session recognized the importance of the trawl sector and its impacts on aquatic resources and benthic habitats and requested simple, practical advice on trawl management. In particular, this request has stipulated that such advice should:

i. be consistent with local management measures and the capabilities of the relevant management authorities; and
ii. be applicable for fisheries that do not have high levels of science, assessment and surveillance.

SECTION 2: Purpose of these guidelines

In response to the Asia-Pacific Fishery Commission's request, the main purpose of these guidelines is to provide practical, simple, easy-to-read, advice to fishery managers of all levels on options for addressing the typical challenges raised by trawling in the tropical waters of Asia. In these guidelines, "fisheries managers" refers to those individuals and/or institutions that have responsibilities for fisheries management and although this is usually government employees, it may include fishers themselves as they seek to improve the sustainability of their fishery through formal management.

This document is a guide to inform the local fisheries managers and authorities (including Provincial Fisheries Offices, Local Government Units) who are empowered to regulate fisheries, about management interventions that are available for dealing with specific issues concerning tropical trawling in Asia. These guidelines are also meant to enable more effective dialogue with fishers to help them make decisions as part of a "bottom-up" approach to fisheries management.

A secondary purpose of these guidelines is to provide all fisheries stakeholders and the general public with information on how Asian trawl fisheries can be managed. These guidelines outline the sorts of best-practice measures than can be used by managers and fishers to ensure the sustainability of the fishing sector and the natural resources on which they depend.

This document is meant to be completely advisory in nature and so does not provide prescriptive, mandatory solutions to managers. However, it does provide managers with a suite of options that they can consider when faced with particular issues in their fishery. It also provides a framework for developing management plans that can be used to implement existing or new fisheries policies in a given country. Examples from various parts of Asia are included so as to illustrate the type of practical interventions that may work in different fisheries contexts. That is, the document highlights particular solutions that have worked, and also lessons learned where certain interventions have not. It is expected that these guidelines will assist fishery managers in the development of fishery improvement plans and facilitate the development of trawl Fishery Management Plans (FMPs).

These guidelines are meant to be brief and concise. They avoid the format of other, more generic guidelines (that are usually developed and negotiated through international processes) by being simpler, more direct and more applicable in the Asian regional context. Additional supporting material, (e.g. examples of management plans, explanation of how to use assessment tools) can be found in the trawl guidelines section of the Asia-Pacific Fishery Commission Web site.[5]

[5] http://www.apfic.org/training/apfic-trawl-management-guidelines.html

SECTION 3: Scope, target audience and principles

These guidelines cover the range of typical management issues, problems and potential solutions in Asia's tropical trawl fisheries. Of particular importance are such issues as they relate to developing countries in the region that have their own unique problems as they try to balance economic growth with sustained food production, human nutrition and environmental health. These guidelines are applicable to the various forms of trawling used in the region (demersal, pelagic/mid-water trawling, pair-trawling) but recognize that different management issues and measures may be relevant only for certain gears (e.g. pelagic trawl fisheries should not have many issues concerning benthic habitat damage).

The approach of these guidelines could also be applied to the management of pushnet fishing. This method operates close to shore in very shallow water and often involves using small mesh pushnets that are typically associated with a number of adverse fisheries impacts. In many countries this form of fishing is banned because of its impacts on vulnerable benthic habitats (especially seagrass beds), the catch of juveniles and the subsequent conflict this creates with other fishers.

Many of the problematic issues associated with trawling (throughout the world, not just in Asia or the tropics) relate to the low selectivity of trawl gears and these guidelines devote significant attention to such issues. However, the guidelines also devote significant attention to other issues, such as the need for seafood protein in the region, the demand for surimi products, the supply of low-value fish for aquaculture and agriculture, overcapacity, habitat impacts, ecosystem effects, IUU fishing, conflicts with other fishers.

The primary target audience for these guidelines are fishery managers (or those responsible for the development and implementation of management measures) throughout Asia who are charged with the very significant responsibility of managing and conserving tropical trawl fisheries. It is recognized that sometimes these managers are not necessarily highly trained or experienced, yet nevertheless they need concrete options to address typical problems of their fisheries. It is the intention for these guidelines to empower these managers to initiate more effective management of tropical trawl fisheries throughout Asia.

The guidelines are also intended to support fishers and fisher associations as they seek to develop rules for sustainable management of their fisheries as part of co-management arrangements. Fishers are a key group as it is well-recognized that fisher-engagement is central to the entire fisheries management process.

Throughout this document it is acknowledged that the involvement of fishers, fishing communities and other stakeholders is vital in many steps of fisheries management, from identifying and prioritizing issues, through the development, implementation and ownership of management measures, to the drafting and ongoing review of formal management plans. Although this "bottom-up" approach is vital for effective management, it is must be linked to effective government organization, administration, legislation, enforcement and monitoring.

Identifying appropriate stakeholders early in a fisheries management process is therefore vital and consideration should be given to conducting an initial scoping study of stakeholders. The starting point for management planning is therefore identification and characterization of the various stakeholder groups and individuals and establishing the appropriate level of their involvement in the fisheries management process (e.g. for secondary stakeholders communication of simple updates or basic information may be sufficient, whereas for primary stakeholders more formal consultation may be needed and they may also be far more engaged as members of committees).

A formal stakeholder scoping study provides such information and allows better planning of the stakeholder-engagement process covering the steps required to develop and implement the management plans that are described in these guidelines.

A secondary target audience for these guidelines is the general public and non-governmental organizations (NGOs) who may wish to use them as a 'how-to guide" to identify best practice management steps than can be used by governments and fishers to management the publicly-owned natural resources that are exploited.

Because of the range of target audiences, these guidelines have been prepared in a way that is meant to be simple-to-follow, practical and easy-to-read.

These guidelines can also be used by civil society to better understand how trawl fisheries are operated and managed. It will also assist understanding and dialogue between fishers and actors in the market chain, as well as other stakeholders in the marine environment.

The document itself is therefore written to be as brief and concise as possible and does not require the reader to cover extended, complex discussions of issues before getting to the key points.

In addition to the above over-riding principles of being concise, practical and easy-to-follow, several other general principles have been adopted in preparing these guidelines. The underlying concept is sustainable development that takes into account the "triple bottom line" (ecology, society and the economy) when developing a solution fisheries problems. Sustainable development of fisheries is implemented through the ecosystem approach to fisheries (EAF) management, which has become internationally accepted as a guide to planning and managing human activities in relation to the natural environment.[6]

The EAF takes account of the fact that fisheries operate in (and indeed rely on) the ecosystems in which they occur. EAF therefore seeks to manage fisheries holistically, incorporating impacts that the fishery (and various management measures) may have on interacting species and the broader ecosystem, of which human society is part.

Another important principle is the so-called precautionary principle, which encourages managers to take action on a potentially harmful issue, despite a lack of relevant scientific information – which is often the case in data-poor fisheries in the Asia-Pacific region. It also encourages managers to be more conservative with respect to management decisions, when there is more uncertainty. This often is very difficult to implement as there are competing interests between safely conserving the stocks (fishery manager's responsibility, interests of the artisanal fishery), versus catching fish and making money (interests of industrial fishers, traders and processors). This is most often seen in the trade-offs on decisions regarding management measure such as duration of a closed season/areas, optimum fishing capacity/effort, gear measures/mesh sizes.

There are also other overarching principles of responsible practice that are incorporated into these guidelines, including those that can be found in global guidance documents such as:

- FAO 1995 Code of Conduct for Responsible Fisheries (CCRF).
- FAO International Guidelines on Bycatch Management and Reduction of Discards, endorsed by the Committee on Fisheries (COFI) at its twenty-ninth session (February 2011).
- FAO Guidelines for the Ecosystem Approach to Fisheries.
- Draft text of the FAO 2013 Voluntary Guidelines for Securing Sustainable Small-scale Fisheries in the Context of Food Security and Poverty Eradication.

[6] For a simple overview of the ecosystem approach to fisheries (EAF) see Staples and Funge-Smith (2009).

Other concepts that were used in developing these guidelines include various "best-practice" management approaches such as:

- proactive management measures versus reactive;
- involving fishers in all aspects of management planning;
- the commitment to, and growing use of, co-management mechanisms;
- the trade-off between accuracy and the need to cover large areas with limited resources;
- the use of information from fishers to improve knowledge;
- the increasing availability of data poor assessment techniques such as risk assessment;
- the use of best-practice enforcement techniques;
- the potential of eco-labelling and eco-certification and involvement of the market chain; and
- the need to incorporate regular review and updating of management strategies.

SECTION 4: Identifying and prioritizing key management issues

Identifying issues

There are several techniques available to fisheries managers to identify, and then prioritize management issues in a fishery. Whichever tool is used, there are two over-arching principles that will always be necessary:

i. the need to engage fully, constantly and consistently with all stakeholders and fleet segments (more specifically those persons that have a technical, social and economic stake in the fishery); and
ii. the need to use individuals or institutions with specialized knowledge or local knowledge when appropriate.

Fishery decision-makers who manage fisheries have a very tough job. They typically receive advice, lobbying and even pressure from many stakeholders, interest groups and experts. This may come from the fishing industry being managed (in this case Asian tropical trawl fishers), other interacting fleet segments (such as inshore, artisanal fishers), environmental interests, conservation groups, dependent supporting industries such as canneries and processors, marketing groups, political groups, government departments, scientific experts, economists, inspectors, lawyers, the general public. Very often, each of these groups has its own vested interest.

Having received all this (often conflicting) information, fisheries managers are then expected to make decisions that will lead to the long-term sustainability of the fishery and other interacting fisheries, as well as the integrity of the ecosystems on which they depend – all considered within societal pressures that are characterized by an ever-increasing demand for, and reliance on seafood products.

This is not an easy task, especially when dealing with highly diverse, moving, varying and poorly understood oceanic and coastal fishery resources, as well as the fishers who pursue them. In developing countries, this challenge is greater because of limited scientific data, weak enforcement, limited compliance and low levels of funding for management.

The good news is that there are techniques available that can help fisheries managers deal with such complexities.

The first step is to identify the key management issues that are relevant for a fishery. Some stakeholders are very forthright in expressing their issues, some have formal mechanisms for doing so (as may be the case for scientific experts), some use the media (as may be the case for conservation or political groups) and others use more subtle lobbying techniques. For some other important stakeholders, more proactive methods may be needed to identify their issues. This is often the case, for example, when trying to identify the particular issues of artisanal fishers who may not be formed into groups or formal alliances, and who may not have ready access to various forms of modern communication, influence or organizational capabilities. Nevertheless, it is still very important and relevant to obtain information about management issues from such people because if ignored such issues can rapidly escalate into significant conflict and even violence. The best way to obtain information from these groups is therefore to seek out comments by personally, and regularly, visiting such groups and obtaining their comments on particular problems. Building trust and behaving ethically are important in developing these vital consultative relationships.

Examples of issues

The following paragraphs identify typical issues that are encountered in tropical trawl fisheries in Asia, and that would need to be considered in developing a management plan for these fisheries.

Conflict among fleet segments: When trawlers fish in the same areas as small-scale and/or artisanal fishers, there can be quite significant and sometimes violent, even fatal interactions among them. This is because trawling is quite a non-selective, mobile method, resulting in large volumes of catch and sometimes running over and damaging sedentary gears such as artisanal nets and pots. Local fishers often view the trawlers as taking "their" fish (including the juveniles of species they fish for as adults), damaging their gear, and impacting on benthic habitats and ecosystems on which their livelihoods and food security depends.

Overcapacity: With more than 83 000 trawlers working in tropical Asia, there are probably too many vessels for the size/value of the catch. This case is not confined to Asia and can be found in other parts of the world. Such a situation leads to excess fishing effort, which causes overfishing of stocks and significant hardship for individuals and communities relying on those stocks. In an ideal fishery, the number of fishing vessels should be sufficient to allow sustainable, profitable and fair access for all vessels.

Unprofitable trawl sector: Rising fuel prices and labour costs, stable or declining catches and too many fishing vessels (overcapacity), are driving many trawl fisheries in the region to unprofitability. This leads to hardship for operators, their communities and those that depend on processing and marketing of the fish and fishery products. A common approach in the past has been to reduce costs via government subsidies and the import of cheaper labour. Unfortunately, these are only short-term solutions that, in combination with open access fisheries, simply increase fishing pressure on already overexploited stocks.

Overfishing: Trawl fishing is one of the most efficient fishing methods of catching large quantities of fish. When trawling effort reaches the high level that occurs in Asia's tropical waters it can contribute greatly to the overfishing of stocks to unsustainable levels. Tropical trawl fishing is also a non-selective fishing method that may operate in fishing areas and at times where juvenile of commercial species occur. As a result, many species are caught at sizes and ages that are suboptimal and many individuals caught will not have had an opportunity to spawn and contribute to the next generation. When this happens, it is called "growth overfishing". A more extreme situation occurs when large numbers of spawners are taken, which can lead to long-term declines in the recruitment of stocks. This is called "recruitment overfishing". A further issue occurring in many tropical trawl fisheries in Asia is that many species caught by trawls are small fish that never grow to a large size. For such species, trawling can cause particularly significant growth- and recruitment- overfishing and represent a major threat to the sustained exploitation (and even existence) of the stocks. These small individuals are also usually of a lower value and may not even be directly used for human consumption. Ideally, all species should be harvested at optimal sizes to ensure continuous and sustained exploitation, and at maximum economic value to the fishery.

Bycatch: The bycatch of unwanted organisms is a common feature of any trawl fishery and is particularly problematic when such bycatch includes at-risk species and juveniles (leading to suboptimal harvesting of species and growth overfishing as mentioned above). Bycatch is also a major issue when it includes endangered, threatened or protected species (ETPs). Ideally, problematic bycatches should be reduced to a minimum. The interaction of trawl fishing with juvenile fish should be reduced so that the sustainable exploitation of those species is maximized. Moreover, and interactions with ETPs should be minimized so that the endangered status of those species is improved.

Habitat impacts: Demersal trawling involves towing nets, ground chains, ropes and otter-boards ("trawl doors") over the sea floor and this can negatively affect benthic habitats. This issue is most extreme in shallow coastal waters and around hard structures (submerged reefs, rocky outcrops). In some tropical benthic habitats such as mud flats and sand bottoms, recovery after trawling can be very quick, especially where there are favourable tides and currents. Even so, trawling effects on sensitive benthic habitats should be minimized, since many invertebrates, including worms, corals and sponges, and marine flora (such as seagrass), provide food and protection for other organisms and juvenile commercial species.

Effects on ecosystem function: By disrupting benthic habitats and removing large numbers of aquatic organisms, unmanaged trawling can have significant impacts on the natural functioning of marine ecosystems. This can lead to changes in the ecosystems and changes in the species interactions. This is undesirable, since the natural cycles and functioning of these same ecosystems are vital for providing the food and habitat of the fishery resources exploited by the trawl fishery, as well as other associated fisheries (e.g. artisanal or other gears).

IUU fishing: Many trawl fisheries are already subject to management measures to resolve the issues being discussed here. These measures include closed areas, seasonal restrictions, zoning measures, mesh sizes, gear restrictions. Despite these measures, there is often poor enforcement, understanding and compliance, particularly in the case of overcapacity or weak fishery controls. In most fisheries, there are some vessels that operate illegally, do not report properly and/or operate in an unregulated way (i.e. that engage in IUU fishing). This not only causes problems in terms of managing a fishery, but also leads to misleading information. This often leads to significant conflicts with fishers or fleet segments that are operating according to regulations. Ideally, all vessels in a fishery should be obeying all the regulatory and reporting requirements of that fishery.

Weak monitoring, control and surveillance (MCS): Adequate monitoring, control and surveillance should be a prominent feature of any fishery in order to reduce the incidence of IUU fishing, and also to ensure full compliance with fishery management plans and associated rules and regulations. A functional, close-to-real-time MCS system that is enabled through appropriate legal powers and political will, should be implemented to ensure adherence to the fishery management plan and the rules and regulations of any fishery.

Science and monitoring needs: Adequate scientific research and monitoring should be a characteristic of a fishery in order to provide the information that is a basic prerequisite to all management planning. Ideally fishery management plans should be strengthened by relevant scientific information of many forms. Critical information needs include data on the catch and economics of the fishery and the social and financial drivers that underpin the fishery's activities, markets and profitability. Data is also needed on species biology, harvest rates and the fishing gears used by all vessels in a fishery, both domestic and foreign. That is, all research should be focused on assisting the fishing industry and fisheries managers to achieve management goals. Once management measures are being implemented, adequate scientific monitoring is essential to determine their success or failure, and what may be done to improve them. However, experience has shown that obtaining this scientific data can be a very significant challenge for countries where there are few consistent data collection programmes, limited funding and lack of appropriate expertise.

Exploitation of low-value fish: The targeting of low-value fish has become a feature of many tropical trawl fisheries in Asia. This is partly because of the declining abundance of larger, higher-value species and the resulting development of production and market demand for aquaculture and agriculture feeds and fish surimi products. These associated industries, which are dependent on supplies of this low value fish, generate significant income and jobs for local communities. When such demand drives the capture of unsustainable quantities of fish at suboptimal sizes or in juvenile stages, it can contribute to the growth of overfishing, reduced economic returns from fisheries and threaten the sustainable exploitation of the resource.

Impacts on supporting industries: Any management interventions or initiatives that restrict the operation of the trawl sector may have necessary negative consequences on the surimi, canning, seafood processing, refrigerated transport, fish retailing, fishmeal and aquaculture industries. Although such impacts may not be directly related to fishery management, their economic and social interests will have a strong influence on the acceptability of management measures and the demand and markets for fish. This is an important consideration that should be integrated into any trawl fishery management plan, in order to maximize compliance with the new measures and minimize negative impacts on the fishery.

Ghost fishing and other unidentified mortalities: There is growing awareness that individuals being caught and killed in lost fishing gear (ghost fishing) can significantly impact some species. In addition, mobile trawl gear can interact with species that are not captured, but which may die later as a result of that interaction (this is called 'cryptic mortality'). An example of this is where animals that escape through meshes are wounded and then die without being landed. Gear loss in the trawl fleet should be minimized and other cryptic sources of mortality should be identified and minimized where possible.

Increased investment and subsidies: Governments often provide access to low-cost fuel or develop port infrastructure and port services, or provide low-cost loans and other types of subsidies to the fisheries sector. These incentives are intended to:

- promote the fishing industry to produce more fish for food security and job creation; and/or
- stabilize the industry by acting as a buffer against rising fuel prices, operation costs, risk of unemployment and market instability.

These subsidies can offset the real production costs and result in increased fishing effort, which gives a false impression that the fishery produces enough fish to pay its production costs and is operating at a real profit. This can lead to increased investment in boats, gear and infrastructure causing a cycle that leads to more and more fleet overcapacity (too many boats and not enough fish). Subsidies can undermine safety at sea because vessels have to fish longer and further from port as stocks decline, but their profits are too low to upgrade to newer and more efficient operations. Ideally subsidies should be used only as *temporary measures* to reduce fishing effort, as incentives for compliance with regulations, and to promote safety at sea and should always be linked to mechanisms for improved fisheries management.

It can be seen from the above examples that any process designed to identify management issues for a fishery will yield a far greater number and scope of issues than can be readily addressed, particularly in countries with relatively few resources available to do so.

In many cases the issues listed above are directly linked, with one issue causing another or one or more issues resulting from the same underlying problem. For example:

- Onshore infrastructure and investment in ports and processing drives the demand for fish production and leads to calls for incentives to expand the fishery.
- Fleet overcapacity exceeds the capacity to monitor the fishery and the race for fish undermines compliance with fishery regulations. This becomes worse as the fishery declines.
- It is clear that overcapacity in fishing vessels leads to declining fish stocks and this triggers calls for subsidies and increased interest in targeting low value fish.
- Overfishing and habitat and ecosystem impacts change the types of fish being caught and this leads to the development of processing industries capable of utilizing lower value products.

Deciding upon which issues are the most important and how to address them, are key processes in managing a fishery. In the following section we examine two of the simplest ways to achieve this.

Prioritizing issues

There are several techniques that can help fisheries managers to decide what management issues are the most important to address in a management plan. At first glance, techniques such as risk assessment tables and Productivity-susceptibility analyses seem complex and difficult to use, but they are actually simple tools that have been developed from the application of simple logic. They are very useful tools to use when trying to come to terms with multiple issues and can quickly clarify the future direction for a fishery's management strategy.

Risk assessment

The best way to decide on priorities when there are so many competing management issues in a fishery is to assess the importance of each in terms of the relative consequences if it occurs, compared to the likelihood of it occurring. This is called risk assessment and basically involves balancing the consequences of an issue if it occurs (whether minor, moderate, major, extreme) against the likelihood of it happening (again, whether it is highly likely to happen or unlikely).

If an issue has a high likelihood of occurring (or is actually happening at present) and the consequences of the issue for the sustainability of the fishery are also very severe, then the issue is a high priority and should be addressed urgently. Conversely, if an issue has few consequences, and little chance of happening, then it would be ranked as a low priority. Low priority issues are those that could be safely left alone in order to address more serious issues.

A simple table is usually used to do this exercise, which can be completed by all stakeholders in a fishery individually, with scores combined. A more effective approach is to do it collectively in an open workshop format, so that different stakeholders gain an understanding of the different issues and perspectives of others.

A very successful methodology to follow in this process is the one developed by Fletcher *et al.* (2002) to assess ecological risks associated with various fishing activities. Although this was developed for use in an Australian context, its logic and principles have been found to be applicable in most parts of the world (for more information and an excellent "how-to" guide, see the EAF toolbox[7]).

This process involves experts in particular areas and key fishery stakeholders coming together in a workshop format to consider the range of potential consequences of an issue and how likely those consequences are to occur. The estimated consequence of an event is multiplied by the likelihood of that event occurring to produce a relative score that estimates the level of risk.

The estimate of the ***consequence*** level for each issue is scored from 0–4 based on particular scoring criteria in Table 2, with 0 being negligible and 4 being a major impact and should be estimated at the appropriate scale and context for the issue in question. For example, for shrimp species, killing one shrimp is a major impact on the individual shrimp, but is negligible for the population. Similarly, when assessing possible ecosystem impacts of fishing, this should be done at the level of the whole ecosystem, not at the level of an individual patch of the ecosystem. In a workshop format, these scores come from the collective experience and knowledge of workshop participants.

[7] http://www.fao.org/fi/website/EAFNETRetrieveAction.do?dom=eaftool&xml=eaf_tool_4.xml&lang=en

Table 2 An example of a general consequence table for use in risk assessments related to fishing (based on Fletcher *et al.,* 2002)

Consequence level	Score	Descriptor
Negligible	**0**	Very insignificant impacts – unlikely to be even measurable at the scale of the stock/ecosystem/community against natural background variability
Minor	**1**	Possibly detectable but minimal impact on stock structure/function or dynamics
Moderate	**2**	Maximum appropriate/acceptable level of impact (e.g. full exploitation rate for a target species)
Severe	**3**	This level will result in wider and longer term impacts occurring (e.g. recruitment overfishing)
Major	**4**	Very serious impacts occurring with a long timeframe needed to restore to an acceptable level

Note: In a workshop setting, some participants may tend to dominate proceedings at the expense of the valid views and knowledge of others. This is especially those with strong personalities and, in cases where many nationalities are involved, those who are native speakers of the selected language for the workshop. Effective facilitation is **essential** to ensure that such effects are minimized and the views of all participants are considered.

The **likelihood** of an issue occurring is then scored from 1 to 4 by the workshop participants, with 1 being remote and 4 being likely (Table 3). This should be based on a judgment about the chance of the events, or chain of events, occurring that could result in a particular adverse consequence associated with the issue. As for the consequence scores, these judgments are also based on the collective experience and knowledge of workshop participants.

Table 3 An example of likelihood definitions (based on Fletcher *et al.,* 2002)

Likelihood level	Score	Descriptor
Likely	**4**	It is expected to occur (or is occurring)
Possible	**3**	May occur
Unlikely	**2**	Uncommon, but has been known to occur
Remote	**1**	Not known to have occurr,ed previously, but not impossible

From the consequence and likelihood scores, the overall risk value is easily calculated (i.e. risk = consequence × likelihood) and these are then linked to one of five colour-coded risk categories, the relationship for which is illustrated by a risk matrix (Table 4).

Table 4 An example of a risk matrix of consequence and likelihood (based on Fletcher *et al.,* 2002)

	Consequence				
Likelihood	**Negligible (0)**	**Minor (1)**	**Moderate (2)**	**Severe (3)**	**Major (4)**
Remote (1)	**0**	**1**	**2**	**3**	**4**
Unlikely (2)	**0**	**2**	**4**	**6**	**8**
Possible (3)	**0**	**3**	**6**	**9**	**12**
Likely (4)	**0**	**4**	**8**	**12**	**16**

Note: The numbers in the cells indicate the risk value, and the colours indicate risk categories.

Once these scores are identified for each issue, one can assess the category of risk from negligible (dark green) to extreme (bright red) and the related management response that is expected for each issue – from no response to significant management interventions (see Table 5).

Table 5 Relationship between risk value, risk category and management response (source: Fletcher *et al.,* 2002)

Risk category	Risk values	Likely management response
Negligible	0 – 2	No response required
Low	3 – 4	Response can be considered, but low priority
Moderate	6 – 9	Specific management action needed
High	12 – 16	Priority attention to management action

In applying the above logic to particular management issues, stakeholders, experts and fisheries managers are able to (quite quickly) identify particularly problematic issues that should be dealt with as a matter of priority (the ones whose scores appear in the bright red range), compared to relatively minor issues that can be safely ignored (those in dark green). In this very logical and transparent way, a reasonably accurate prioritization of management issues can occur and those high priority issues that need to be addressed in a management plan can be identified and resources to deal with them can be accordingly allocated. In effect, this initial risk assessment forms the start of the process to develop the fishery's management plan, which will contain the response to high priority issues identified. Such a plan will also outline operational objectives, the actual management responses that are designed to solve issues, indicators and performance measures of success, legislative requirements, data requirements, compliance requirements and mechanisms for ongoing review (see Sections 8 and 9 of these guidelines).

Figure 2 below shows the logic that can be used to assign a risk level to particular issues facing a fishery. The idea is to get stakeholders to prioritize each issue based on whether the issue can be expected to have a high or low impact and whether it is likely to occur or unlikely to occur (i.e. the frequency of the issue). This method can be applied in situations where decisions need to be made where the information may not be clearly assigned to the categories of risk used in the example above.

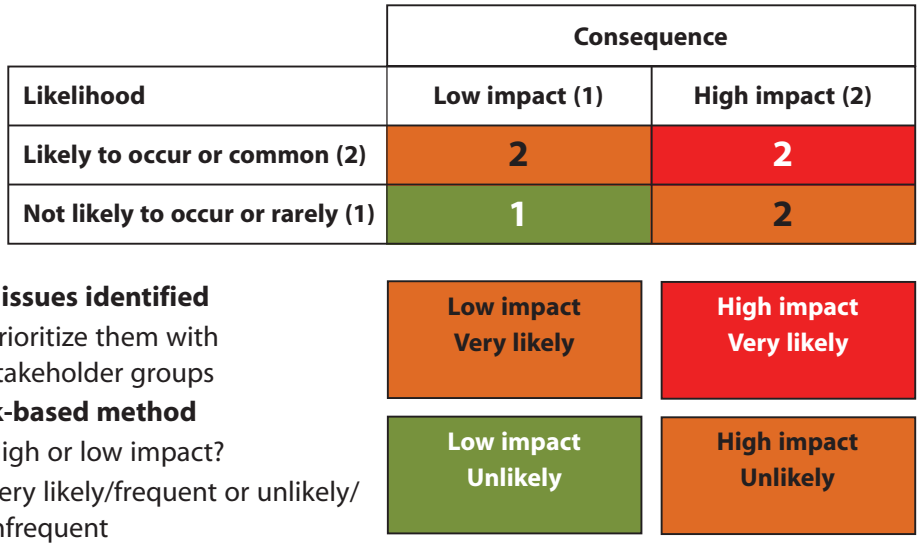

Figure 2 A simple risk assessment scheme

Appendix 1 provides an example of applying a risk assessment to various issues occurring in a trawl fishery.

Productivity-susceptibility analysis

Productivity-susceptibility analysis (PSA)[8] is a useful tool when trying to prioritize management issues that concern particular species in the fishery. This approach is more complex than the risk assessment tool described above, but it allows rapid screening of how different species may be affected by a fishing activity (i.e. how "at risk" they are). It relies on two basic facts: (i) that some species are more resilient to fishing activities than others (because of their biology and/or ecology); and (ii) some species are more likely to be impacted by an activity than others (because of where and when they occur compared to the activities of the fishery).

PSA is typically used for individual species, as a way of identifying which ones are most at risk or least vulnerable. But PSA can also be used for species groups that share common characteristics (e.g. small pelagic species, large demersal species). Although this approach may be less precise, it can still provide help in indicating the major issues to be addressed. The PSA technique can also be used effectively for assessing the likelihood of impacts of fishing activities on different habitats (e.g. the different consequences of trawling in shallow seagrass areas, on spawning grounds, on deep-water sandy bottoms away from the shore).

The PSA is based on the assumption that the risk posed to a species (or a group of species or habitat) because of fishing will depend on two characteristics:

1) the ***productivity*** of the species, which will determine the rate at which it can recover from fishing; and
2) the extent of the impact to the species caused by fishing, which will be determined by the ***susceptibility*** of the species to fishing.

For use with fish species, a productivity-susceptibility analysis examines seven attributes of productivity of a species and four attributes that measure its susceptibility (Table 6).

Table 6 The attributes used to measure productivity and susceptibility for each fish species

Productivity	Attribute
	Average age-at-maturity
	Average maximum age
	Fecundity
	Average maximum size
	Average size-at-maturity
	Reproductive strategy
	Trophic level

Susceptibility	Attribute
	Availability considers the overlap of fishing effort with a species' distribution
	Encounterability considers the likelihood that a species will encounter fishing gear that is deployed within the geographic range of that species (this is based on two attributes: adult habitat and bathymetry)
	Selectivity considers the potential of the gear to capture or retain the species
	Post capture mortality considers the condition and subsequent survival of a species that is captured and then released

[8] Full details of the PSA approach are described in Hobday *et al.* (2007 and 2011)

The above attributes for many species can be obtained from the published scientific literature, experts and other sources such as the FishBase[9] online database. In particular, the productivity attributes for each species (ages, fecundity size at maturity, etc.) are based on data from the literature and because they relate to the biology of a species, they are usually quite fixed and only change if new research updates existing information.

Determining the four aspects of susceptibility is not straightforward and uses the following considerations:

Availability considers the overlap of fishing effort with a species' distribution. For species without distribution maps, availability is scored using the species' broad geographic distribution (global, regional, local). Where more detailed distribution maps are available, availability is scored as the overlap between fishing effort and the portion of the species' range that lies within the broader geographical spread of the fishery. Overrides can occur where direct data from observer programmes are available.

Encounterability is the likelihood that a species will encounter fishing gear deployed within its range. Encounterability is scored using habitat information, modified by bathymetric information. Higher risk corresponds to the gear being deployed at the main depth range of the species. Overrides are based on mitigation measures and observer data.

For species that do encounter fishing gear, **selectivity** is a measure of the likelihood that the species will be caught by the gear. Factors affecting selectivity will be based on the fishing gear and the species' reaction to it, but body size in relation to gear size (e.g. mesh size) is an important attribute for this aspect. Overrides can be based on body shape, swimming speed and observer data.

For species that are caught by the gear, **post-capture mortality** measures the survival probability of the species. Obviously, for species that are retained, survival will be zero, but species that are discarded may or may not survive. This aspect is mainly scored using independent field observations or knowledge from the literature or from experts.

An example of various criteria and scores for productivity and susceptibility attributes is presented in Table 7. Obviously the criteria under each attribute should consider the biological traits of species occurring in the location of the actual fishery and this will be quite different for different tropical Asian trawl fisheries.

Overall susceptibility scores are a product of the four attribute scores outlined above. This means that susceptibility scores will be substantially reduced if any one of the four attributes is considered to be low risk. However, in keeping with the precautionary principle, the default assumption in the absence of supporting data for both productivity and susceptibility attributes is that all aspects are high risk and are scored as such.

Once each species is assigned a risk score based on their attributes for productivity and susceptibility, the results are plotted on a PSA plot (Figure 3). The x-axis contains attributes that influence the productivity of a species, or its ability to recover after being impacted by fishing. The y-axis contains attributes that influence the susceptibility of the species to impacts from fishing. The combination of susceptibility and productivity determines the relative risk to a species, i.e. species with high susceptibility and low productivity are at highest risk, whereas species with low susceptibility and high productivity are at lowest risk. The white contour lines divide regions of high (red), medium (orange/yellow), and low risk (green).

[9] http://www.fishbase.org

Table 7 An example of PSA criteria and scores for productivity and susceptibility attributes for species (adapted from Patrick *et al.,* 2009 and Hobday *et al*., 2007)

Productivity attributes	**Low productivity/ High risk**	**Medium productivity/ Medium risk**	**High productivity/ Low risk**
	Score 3	**Score 2**	**Score 1**
Average age at maturity (years)	>4	2 to 4	<2
Average maximum age (years)	>30	10 to 30	<10
Fecundity (eggs/spawning)	<1 000	1 000 to 10 000	>10 000
Average maximum size (cm)	>150	60 to 150	<60
Average size at maturity (cm)	>150	30 to 150	<30
Reproductive strategy	Live bearer, mouth brooder or significant parental investment	Demersal spawner "berried"	Broadcast spawner
Mean trophic level	>3.25	2.5–3.25	<2.5

Susceptibility attributes		**High susceptibility/ High risk**	**Medium susceptibility/ Medium risk**	**Low susceptibility/ Low risk**
		Score 3	**Score 2**	**Score 1**
Availability	1) Overlap of adult species range with fishery	>50% of stock occurs in the area fished	Between 25% and 50% of the stock occurs in the area fished	<25% of stock occurs in the area fished
	2) Distribution	Only in the country/ fishery	Limited range in the region	Throughout region/ global distribution
Encounterability	1) Habitat	Habitat preference of species make it highly likely to encounter trawl gear (e.g. demersal, muddy/sandy bottom)	Habitat preference of species make it moderately likely to encounter trawl gear (e.g. rocky bottom/reefs)	Depth or distribution of species make it unlikely to encounter trawl gear (e.g. epi-pelagic or meso-pelagic)
	2) Depth range	High overlap with trawl fishing gear (20 to 60 m depth)	Medium overlap with trawl fishing gear (10 to 20 m depth)	Low overlap with trawl fishing gear (0 to 10 m, >70 m depth)
Selectivity		Species >2 times mesh size or up to 4 m length	Species 1 to 2 times mesh size or 4 to 5 m length	Species <mesh size or >5 m length
Post capture mortality		Most dead or retained Trawl tow >3 hours	Alive after net hauled Trawl tow 0.5 to 3 hours	Released alive Trawl tow <0.5 hours

Note: Availability 2 is only used when there is no information for Availability 1; the most conservative score between Encounterability 1 and 2 is used.

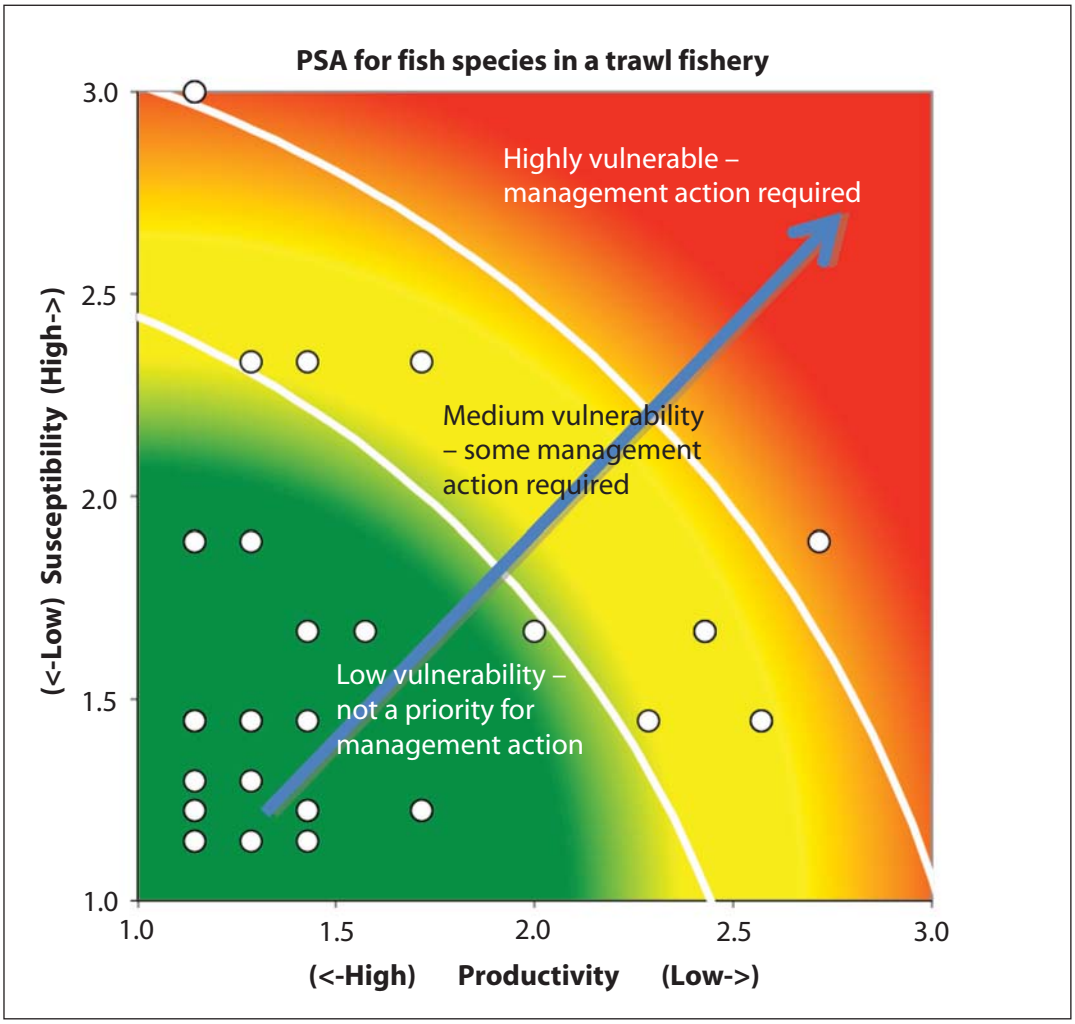

Figure 3 A typical PSA plot for a trawl fishery

The idea behind using PSA as a tool is to get scientific experts and stakeholders working together in assigning relative scores against various key attributes, then prioritize each issue based on whether the issue can be expected to have a high or low impact, and whether it is likely to occur or unlikely to occur (i.e. the frequency of the issue). In this way, information from PSAs is used to guide discussions on priorities for management such as which species (groups of species or even habitats) require attention as a matter of urgency and which do not. In such discussions, supported with the information generated by the PSA process, the group can often identify appropriate management measures to use to address the identified high priority issues (e.g. a closed area/season, or a gear modification to protect a vulnerable group). In some cases it will also guide more detailed research needs and investigations designed to develop other appropriate management actions.

Appendix 2 of these guidelines contains an example of a PSA for a demersal trawl fishery to demonstrate the process that can be used to assign values in terms of the relative risk to species based on their productivity and susceptibility.

Engaging fishery stakeholders – using expert and local knowledge for setting priorities

An important part of risk assessment and PSAs is the involvement of all fishery stakeholders. The semi-quantitative nature of PSAs and risk assessment largely comprises desktop-based research work, including a significant amount of searching scientific literature and mining databases. For such work, it is important to engage the right level of scientific expertise.

Often, critical information to assess likelihoods and consequences is simply not available in the scientific literature, but in the minds of experts who are able to provide expert opinion.

Equally, many issues lie outside of the scientific field (such as reasons for non-compliance, conflict issues; economic priorities). This means that a broad group of stakeholders must be consulted regarding the activities being assessed (fishers and their representatives, conservationists, artisanal fishers, tourism operators, etc.). The involvement of relevant stakeholders ensures:

- the contribution of expert judgment and fishery-specific technical and ecological knowledge;
- the contribution of local/inside knowledge or perspectives;
- ownership over the process and outcomes, which can lead to greater compliance with any measures introduced in response to the risk assessment;
- that the whole process is done in a transparent way; and
- opportunity for feedback.

The engagement with stakeholders is the starting point of the process of development and implementation of a management plan.

Since all these groups need to be effectively engaged when embarking on the process of prioritizing fisheries management issues, coordination is an important consideration. It is advisable to establish a steering committee at a very early stage. The steering committee would consist of the relevant industry representatives, scientists, conservationists, and other stakeholders who may be able to contribute information to the process.

This committee might eventually become institutionalized as a Management Advisory Committee (MAC) when the management plan is developed (see Section 9).

Following agreement on the final risk ratings, this group can then be used to consider management responses for high risk issues (and species) and begin to develop the management plan to resolve such issues.

It is also important to regularly review risk assessments of issues. The timing of reviews will vary considerably and may be in response to such things as:

- the desire by industry or other stakeholders to review issues (especially if they are unhappy with a management measure or believe it is not working);
- the need to assess the success (or failure) of various management interventions;
- the availability of new information about the fishery or its species;
- the occurrence of new issues that need to be incorporated into the fishery's management;
- periodic reviews that are required by the management plan, by governments, by other regulatory bodies; and
- (periodic) reviews required by third party organizations (e.g. trade partners, eco-labelling and recertification requirements).

SECTION 5: Management approaches to resolve identified issues

Once various management issues have been identified and prioritized, the next step is the most important, namely developing solutions to address the high priority issues. This is the most important part of the fisheries management process, and thus the most important section of these guidelines because here we describe solutions that can be used to resolve the various management issues. These solutions or measures are meant to be simple and practical and give a starting point to fisheries managers about how to manage their trawl sector to become more sustainable and reduce some of its worst impacts.

These measures have been developed in the knowledge that there are different levels of management sophistication among fisheries management agencies in the countries of Asia and each measure is allocated to an approximate level of management sophistication (see Table 8). This indicates whether the solution is typical of a simple fisheries management regime (Level 1), through to a more sophisticated regime that has more management, scientific and compliance resources available (Level 3).

Table 8 Examples of the typical characteristics of level 1-, 2- and 3-type management regimes

Levels of management regimes	Typical features
Level 1:	• No indicators or benchmarks in place • Mainly input controls (mesh size restrictions) • Artisanal zones that exclude trawling • Other spatial measures or zones • Seasonal closures • Typically low levels of enforcement/poor compliance • Limited data collection
Level 2:	• Some indicators and benchmarks for management are identified • Better implementation of the management measures than in level 1 • Some monitoring to inform the performance of measures • Better enforcement/greater compliance • Occasional review
Level 3:	• Resource assessments undertaken • Targets and trigger points set • Specific regulations in place to achieve these targets • Effective monitoring • Good data • Enforcement • Regular review

Details of the various solutions are contained in Tables 9 and 10. In Table 9, various high priority management issues are listed and potential solutions (or management measures) are listed against each, together with the sorts of things that are needed to implement the measure and an indicative cost to the various stakeholders involved.

It is clear from Table 9 that some management measures can address several issues simultaneously. The ability to address multiple issues through a single measure is highly attractive in terms of cost and enforcement.

In Table 10, the management measures are listed with the issues that they are able to address and the degree of effectiveness. In Table 10, certain overarching management measures are used as examples (closures, gear modifications, capacity reduction) to illustrate how just a few management measures (and in the case of closures, quite simple, less costly ones) can be used to address several management issues at the same time.

Table 9 Key management issues and possible measures

(i) Economic, social and human wellbeing issues

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
Conflict between different fishing sectors	Trawlers fishing in same areas as artisanal fishery – taking "their" fish, damaging their gear and boats	Reduced conflict between different fishing sectors	Reserve special, artisanal-only fishing zones, such as nearshore closures, that exclude trawling	1	Legal formalization of zones, political support, good compliance, MCS, judicial support Awareness programme (consultation, communication – highlighting benefits, e.g. of VMS, good enforcement, MCS, community monitoring) Introduction of VMS for offshore vessels	High
			Obstructions to deter illegal trawling	2	Significant construction and maintenance of subsurface obstructions (e.g. FADs, artificial reefs) by government and/or other fisheries[10] Communication of locations to range of stakeholders, including building community support	Medium to high
			Day/Night closures to trawling to avoid other fisheries	2	Legislation to establish closure times, good compliance, MCS, judicial support, community monitoring	Low
			Facilitate meetings between sectors experiencing conflict	1	Willingness and ability of sectors to attend meeting. Government available to chair meeting. Support from fishery association	High
			Flow of benefits back to community from trawl fishery e.g. employment on trawl boats, product going to communities	1	Public awareness of the benefits back to the community	Medium
			Awareness programme regarding the existing regulations	1	Participation from a wide range of stakeholders and political support (includes fishers, policy-makers, managers and community)	High

[10] This could increase conflict if not endorsed and managed by the government.

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
Overcapacity	Too many trawlers for the size of available fisheries resources	Optimum fleet capacity	Limit and freeze the number of licences	2	Implementation of rigorous licensing system. Non-compliant boats will not be allowed to fish. Enabling legislation related to safety compliance, inspection and national port state measures	High
			Government/Industry buy-backs – Compensation for loss of income through negotiated exit of vessels	2	Significant injection of funds from government and industry and political will. Enabling legislation to cap numbers. Registration and licensing system rigorously enforced, accounting, audit systems and penalties	Medium
			Conversion of existing trawlers to other fishing gears/practices/sector	2	To be effective the conversion has to be directed to a proven (known) underexploited fisheries resource (if any). Conversion could also be to another sector, e.g. tourism, transport	Low
	Excess fishing effort	Reduced number of trawl operations per unit of time and area	Limit on the number of licences	2	Implementation of rigorous licensing system. Non-compliant boats will not be allowed to fish Enabling legislation related to safety compliance, inspection and national port state measures	High
			Reduction of fuel and other capacity enhancing subsidies such as free port facilities, ice, tax exemptions etc. With subsidies only available for compliant vessels	3	Link subsidies to provision of information and compliance. License and registration system rigorously imposed to all fleet segments (including the artisanal fleet)	Medium
			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	1	Redistribute the large amounts in fuel subsidies and other capacity enhancing subsidies that governments are paying to reward good practices. Access to markets for compliant vessels Legislative backing to ensure that subsidies don't support inefficient and unsustainable fishing	Medium
			Spatial zoning for individual boats	2	Equitable identification of boat-specific fishing grounds, legislation to establish fishing zones, allocation process for individual boats, MCS	High
			Seasonal closures to limit effort	1	Identification of appropriate times for closures. Limit fishing effort during the open season	High

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
			Total allowable catches and individual transferable quotas	3	Sophisticated share establishment and trading scheme. Reliable stock assessments for all commercially important species to establish TACs and allocations Data sets to establish catch records Communication with fleet when TAC is met, MCS, enabling legislation	High
			Limits to days allowed to fish (boat days)	3	Sophisticated scheme to establish and allocate days/boat. Reliable stock assessments to establish total boat days allowed Enabling legislation, communication with fleet when total days are met	Medium
			Limited entry for new participants, 2 for 1 entry schemes	1	Good licensing scheme that is regularly monitored. Enabling legislation MCS to ensure limited entry is complied with. Industry support to encourage self-compliance	Medium
			Fishing on a rotational basis	2	Agreement among fishers and monitoring of vessels in port and at sea	High
Unprofitable trawl sector	Costs are too high compared to the value of the catch	Profitable trawl sector attracting ongoing investment	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	1	Significant injection of funds from government. Noting that governments are already paying large amounts in fuel subsidies and other capacity enhancing subsidies (e.g. landing site subsidy) Potential for temporal application of subsidy and caps to level of subsidy Financial and economic analysis/studies for the subsidy and situation of the trawl fishery Legislative backing to ensure that subsidies don't support inefficient and unsustainable fishing Rewards and access to markets for compliant vessels If some vessels are leaving the fishery there is no need to apply subsidy	Medium to low
			Increase value of the catch through better marketing, eco-labelling, acceptance of the fishery and its products (e.g. for fishmeal) as responsible	2	Some investment by industry, eco-labelling certification requiring sustainable practices (including compliance), marketing campaigns	Medium

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
			Fishing practices and gear modifications including boat, hull and engine that reduce operating costs (e.g. labour costs and fuel consumption)	2	Change to existing practices and gears (and investment in developing new gears) that use lighter, more fuel-efficient methods. No fuel subsidies that contradict	High to medium
			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	2	Change to existing practices and gears (and investment into developing new gears) that reduce damage of catch in the cod-end and on deck. This must be linked to market incentives	Medium
			Long-term recovery of fishery leads to increased CPUE, improved productivity and profitability	3	Good management planning that is well implemented and allowed to run for several years	High
Impacts of trawl management measures on supporting industries (traders, processors, transport, etc.)	Support industries may suffer if trawl catches and overall sector is reduced	Support industries able to adjust to changes in trawl sector management	Management changes to trawl sector are implemented gradually, allowing support industries time to adjust	1	Gradual implementation of changes to the trawl fishery that is consistent with the support industries' abilities to adjust Provision of information on changes and alternative ventures and enterprise development	High

(ii) Fishing & fishery issues

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
Bycatch of juvenile fish	Juveniles caught before spawning	Species harvested after spawning	Space/time closures to protect juveniles	2	Identification of locations and times of particular importance as nursery areas. Legal formalization of closures. MCS to ensure compliance. Industry involvement in developing closures to increase buy-in, and encourage compliance	Medium
			Permanent closures to trawling in nearshore nursery areas	1	Legislation to establish locations and times for closure. MCS to ensure compliance	Medium
			Minimum Legal Lengths (MLLs) set at size of sexual maturity	2	Identification of size at sexual maturity for key harvested species. Legislation setting sizes. Fishing gear that selects MLLs. MCS to ensure compliance. Consistency across users (e.g. other fisheries should have the same restrictions)	Medium
			Gear modifications (mesh size, panels, grids) to exclude undersize fish	2	Identification of appropriate modifications to protect the maximum number of juveniles of key species. Enabling legislation, MCS to ensure compliance, education and extension of new gears. Industry involvement in developing new gears	Medium
			Reduce mortality of juvenile fish through introduction of bycatch reduction devices (BRDs) in nets	2	Researching, developing and implementing appropriate BRDs such as grids (e.g. juvenile turtle exclusion devices). Enabling legislation to require the use of new gear types. MCS to ensure compliance. Education and extension of new gears. Industry involvement in developing new gears	Low
	Species harvested at a suboptimal size for maximum value (growth overfishing)	Species harvested at an optimal size for maximum value	Space and/or time closures to reduce trawling where/when juveniles occur	2	Legal formalization of established locations and times of closures. Ongoing monitoring to identify problematic locations/times. MCS to ensure compliance	Medium
			Permanent closures to trawling in nearshore nursery areas	1	Legislation to establish locations and times for closure. MCS to ensure compliance	High
			Minimum legal lengths (MLLs) set at a size close to the optimal	2	Identification of optimal size for maximum value (value/recruit) for key harvested species. Legislation for setting sizes. Fishing gear that selects MLLs. MCS to ensure compliance. Consistency across users (e.g. other fisheries should have the same restrictions)	Medium

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
Bycatch of juvenile fish *(continued)*			Gear modifications (mesh size, panels, grids) to exclude undersize fish	2	Identification of appropriate modifications to protect the maximum number of juveniles of key species Enabling legislation, MCS to ensure compliance, education and extension of new gears Industry involvement in developing new gears	Medium
			Reduce mortality of juvenile fish through introduction of BRDs in nets	2	Researching, developing and implementing appropriate BRDs such as grids (e.g. juvenile trash fish exclusion devices) Enabling legislation to require the use of new gear types. MCS to ensure compliance Education and extension of new gears. Industry involvement in developing new gears	Low
Overfishing	Excessive trawl effort leads to depletion of stocks	Trawl fishing effort is commensurate with the sustainability of stocks	Capacity reduction measures	2	Includes reducing the numbers of trawlers through limiting numbers of licences, buy-back schemes, etc. Implementation of rigorous licencing system. Enabling legislation	High
			Space/time closures to protect vulnerable stocks	2	Identification of locations and times of particular importance to recruitment and spawning of vulnerable small species. Legislation to establish closures. MCS to ensure compliance. Industry involvement in developing closures to increase buy-in and encourage compliance	Medium
			Permanent closures to trawling in critical areas for vulnerable stocks	1	Identification of locations and times of particular importance to vulnerable small species. Legislation to establish locations and times for closure. MCS to ensure compliance	High
	Trawling taking too many individuals (spawners and juveniles) of vulnerable small species	Stocks of small species caught by trawling are sustained	Space/time closures to protect vulnerable small species	2	Identification of locations and times of particular importance to recruitment and spawning of vulnerable small species. Legislation to establish closures. MCS to ensure compliance. Industry involvement in developing closures to increase buy-in, and encourage compliance	Medium
			Permanent closures to trawling in critical areas for vulnerable small species	1	Identification of locations and times of particular importance to vulnerable small species. Legislation to establish locations and times for closure. MCS to ensure compliance	High
			Gear modifications (mesh size, panels, grids) to exclude vulnerable small species	2	Identification of appropriate modifications to protect vulnerable small species. Enabling legislation, MCS to ensure compliance, education and extension of new gears. Industry involvement in developing new gears	Medium

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
Overfishing *(continued)*	Low-value fish being exploited at suboptimal sizes to feed aquaculture, animals and humans (incl. surimi)	Species harvested at optimal sizes for ongoing, sustainable exploitation and realizing improved economic benefits	Space and/or time closures to reduce trawling where suboptimal sized and low-value fish occur	1	Programmatic approach required. This can include short-term financial assistance. Research and M&E to identify problematic locations/times. Legal formalization/recognition of established locations and times of closures. High levels of MCS to ensure compliance. To be effective all measures require communication and consultation with stakeholders Significant research and development required to identify and promote alternative feeds for aquaculture, land animals and humans (to mitigate the driver)	Medium
			Appropriate mesh sizes/gear changes where suboptimal sized and low-value fish occur	2	Research, monitoring and evaluation of biological and economic factors to identify acceptable mesh sizes and gears. Formal regulation of mesh size/gears. High levels of MCS to ensure compliance. To be effective all measures require communication and consultation with stakeholders	Medium
Bycatch of endangered, threatened or protected species (ETPs)	Catching ETPs in trawl nets	Interaction of trawl sector with ETPs is minimized so those species' endangered status is improved	Space and/or time closures to reduce trawling where/when ETPs occur	2	Legislation to establish locations and times of closures Ongoing monitoring to identify problematic locations/times	Medium
			Reduce mortality through introduction of BRDs in nets	2	Researching, developing and implementing appropriate BRDs such as grids (e.g. turtle exclusion devices) Enabling legislation to require the use of new gear types MCS to ensure compliance. Education and extension of new gears Industry involvement in developing new gears	Medium
			Reduce mortality through better on-deck discarding practices (e.g. recovering techniques for turtles)	2	Researching, developing and implementing appropriate on deck recovering practices Education programme, ongoing communication with fishers about the importance of handling ETPs properly	Medium

(iii) Ecosystem, habitats and ecological issues

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
Habitat impacts	Trawling may change or disrupt benthic habitats	Minimal negative effect of demersal trawls on benthic habitats	Spatial closures to remove trawling from sensitive areas (e.g. key habitats)	1	Maps of benthic habitat types, legislation to establish closures, MCS support Consideration of existing closures Generate compliance through awareness and consultation	High
			Obstructions to deter illegal trawling	1	Significant construction and maintenance of subsurface FADs, reefs, etc. by government and/or other fisheries Communication of locations	Medium
			Modified trawl gear that minimizes benthic impacts	2	Research & development and implementation of appropriate trawl gear modifications (e.g. lighter ground chains, bobbins, modified otter boards, sweeps) Enabling legislation to require the use of new gear types. MCS to ensure compliance Education and extension of new gears. Industry involvement in developing new gears	Medium
Effects on ecosystem function	Excessive and uncontrolled trawling disrupts normal ecosystem function and food webs	Minimal disruption of natural ecosystems and food webs	Spatial closures to protect entire sensitive ecosystems containing representative habitat types and resources	2	Identification and mapping of ecosystems, prioritization of ecosystems for protection based on representativeness, extent and natural value, legislation to establish closures, MCS support Raising awareness and generating compliance	High
			Balanced harvesting throughout the ecosystem	3	Research and identification of all ecosystem components and their respective sustainable harvests, markets for currently unsold components, modified gear and/or quotas to enable species-specific harvesting	Medium

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
Carbon footprint by trawlers	High CO_2 emission	Reduction in carbon footprint	Fuel efficiency norms established	3	Development and implementation of fuel efficiency requirements. Studies needed to evaluate fuel efficiency norms as well as carbon footprint	Medium
			Guidelines on best practices to reduce fuel consumption and carbon footprint	3	Preparation of appropriate guidelines and their eventual implementation. The success of this is related to reduction of operational cost No fuel subsidies This scenario is valid for voluntary reduction Market forces to reduce carbon footprint must be taken into consideration	Medium
			Technologies to reduce fuel consumption	3	Research and development of alternative technologies	Medium
			Use of alternative energy sources (solar, wind, etc.)	3	Research and development of alternative energy sources	Medium

(iv) Issues related to governance, institutions and the ability to implement measures

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
IUU fishing & MCS	Trawlers operating illegally, not reporting or unregulated	Legal trawling	Establish and enforce fishing zones for trawling	2	Regulation to establish fishing zones. Consultation on location of fishing zones. Communication between sectors and with community about fishing zones. Education about zones. Sufficient compliance boats and trained officers to police trawlers at sea. Community enforcement	High
			Electronic monitoring (including VMS)	3	Significant investment into the programme. Support by Industry Ability to install VMS on boats (power supply, etc.). Trained staff to monitor vessels, technicians to repair faults and review footage Legislation to protect data collected	High
			Communication between agencies responsible for issuing boat licences, skipper licences and gear registration	2	Willingness to communicate and share data. Established ongoing working relationships between agencies	Medium
			Communication and collaboration between neighbouring countries	2	Willingness to communicate. Established working relationships Political will for countries to work together	Medium
		Regular and accurate reporting of trawl activity	Onboard logbooks	2	Work with industry to design a logbook system with appropriate collection, data entry and analysis for MCS. Legislation to require logbook reporting. Capacity to enforce requirement to fill out logbooks correctly. Political will to enforce reporting requirements Education on why it is important to report. Investigate option of electronic logbooks/incentives	Medium
			Education programme on importance of regular and accurate reporting	2	Resources to develop education programme. Willingness to participate in training. Expert resources to deliver training programme. Ongoing discussion about importance of accurate and regular logbook reporting	Medium
			Observer programmes	2	Significant investment in the programme. Support from Industry Legislative power to place observers on boats. Training of observers Education of industry. Capacity for boats to take observers. Data collection points and resources to analyze data. Scientific resources to analyze data for use in assessments etc. Investigate option of crew-member observer programmes to reduce costs and strain on boats to carry observers	High

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
IUU fishing & MCS *(continued)*	Improved compliance Enforcement of regulations		At sea surveillance by Officers	2	Sufficient compliance boats and trained officers to police trawlers at sea. Education on consequences of non-compliance with regulation Political will to fine and/or punish fishers who are non-compliant	High
			Dockside monitoring	1	Enabling legislation. Regular inspection of landings at port. Resources to undertake dockside monitoring. Reporting by officers. Investigate option for requiring skippers to pre-report landing location and catches onboard	Medium
			Reduction of transboundary IUU fishing	2	Vessel registration; vessel monitoring system (VMS); established system of communication with neighbouring country/province	
Science and monitoring needs	Adequate scientific research and monitoring to provide information for management planning, M&E	Management Plans are underpinned by adequate scientific information on species and harvest rates with industry participation	Onboard logbooks	2	Design and implementation of a logbook system with appropriate collection, data entry and analysis for scientific needs. Compliance to ensure logbooks being filled out correctly. Education of industry Introduce application of electronic logbook using smart phones/ tablets, easy transfer of data to statistics system	Medium
			Portside monitoring	1	Portside monitoring should answer performance indicators of fisheries management. Regular inspection and measuring of landings at port including biological aspects. Reporting by scientific staff. Data from port state measures inspection feeds into fisheries management data Introduce application of electronic catch monitoring using smart phones/tablets, easy transfer of data to statistics system. Will require strong buy-in and participation of the boat owners and local management authorities	High
			Observer programmes	2	Significant investment into the programme. Support by industry Legislative power to place observers on boats. Training of observers Education of industry. Capacity for boats to take observers. Data collection points and resources to analyze data. This can work in very lucrative fisheries	Low
			Electronic monitoring (including VMS) to enhance safety at sea and assist in reduction of IUU	3	Significant investment into the programme. Support by industry Trained staff to monitor vessels, technicians to repair faults and review footage. Legislation to protect data collected. Integration of catch records with VMS	High
			At sea MCS inspection	2	Significant investment in the programme. Support by Industry. Data from MCS inspection feeds to scientific information and fisheries management	Medium to low

General issue	Specific issue	Desired outcome	Possible measure	Level	To be effective this will require	Likelihood of success
Science and monitoring needs *(continued)*			Biological research into key species to determine optimal exploitation sizes, locations and times	3	Significant investment and training for scientific personnel. Forum to discuss the science among stakeholders. Industry involvement in research communication and education. Regional sharing of data (network/forum) information on biological, economic and financial analysis benefits the industry	High
			Regular programmed stock monitoring with research vessels	2	Programme of work and budget allocated. Training for scientific personnel cruise planning, data management/sharing with scientists and industry results of the data analysis passed on to industry	Medium to high
			Fishing technology research to identify appropriate gears	3	Significant investment and training for scientific personnel	High
			Dialogue with Industry and other stakeholders	1	Forum (e.g. trawl management committee) to discuss the science (research results) among stakeholders. Transmission of the scientific findings into easy and understandable format. Proper identification of industry representatives	High

Table 10 Examples of management measures that have the potential to address several management issues simultaneously

(i) Spatial and temporal measures

Overarching measure	Specific measure	Issue addressed	Desired outcome	Level	To be effective this will require	Likelihood of success
Space/time closures	Reserve special, artisanal-only ishing zones, fsuch as nearshore closures that exclude trawling	Conflict between different fishing sectors: trawlers fishing in same areas as artisanal fishery and taking "their" fish, damaging their gear and boats	Reduced conflict between different fishing sectors	1	Legal formalization of zones, good compliance, MCS, judicial support. Awareness programme (consultation, communication – highlighting benefits of, e.g. VMS, good enforcement, MCS, political support, community monitoring). Introduction of VMS for offshore vessels and clear and simply vessel marking system for all	High
	Obstructions to deter illegal trawling			2	Significant construction and maintenance of subsurface obstructions, FADs, ARs, etc. by government and/or other fisheries. Communication of locations to range of stakeholders, including building community support	High
	Day/Night closures to trawling to avoid other fisheries			1	Legislation to establish closure times, good compliance, MCS, judicial support, artisanal monitoring. Awareness programme with fishers, policy-makers, managers and community regarding the existing regulations	High
	Spatial zones for individual boats to avoid shifting effort	Excess fishing effort	Reduced number of trawl operations per unit of time and area	2	Equitable identification of boat-specific fishing grounds, legislation to establish fishing zones, allocation process for individual boats, MCS	High
	Seasonal closures to limit effort			1	Identification of appropriate times for closures. Support/access to supplemental livelihoods. Awareness raising and communication. Research to determine most suitable season, duration and location	High
	Space/time closures to protect juveniles	**Growth overfishing:** Species harvested at suboptimal sizes	Species harvested at optimal sizes for ongoing sustainable exploitation and improved economic benefits	1	Identification of locations and times of particular importance to recruitment and spawning of key species. Legislation to establish closures. MCS to ensure compliance. Industry involvement in developing closures to increase buy-in, and encourage compliance	Medium
	Closures to trawling in nearshore			1	Identification of locations and times of particular importance to recruitment of key species. Legislation to establish locations and times for closure. MCS to ensure compliance	High

Overarching measure	Specific measure	Issue addressed	Desired outcome	Level	To be effective this will require	Likelihood of success
Space/time closures *(continued)*	Space and/or time closures to reduce trawling where/when juveniles occur	**Bycatch:** Bycatch of juveniles leading to growth overfishing	Reduction of juvenile fish in bycatch	1	Identification of locations and times of particular importance as nursery areas. Legislation to establish locations and times of closures Ongoing monitoring to identify problematic locations/times MCS to ensure compliance	Medium
	Space and/or time closures to reduce trawling where/when ETPs occur	**Bycatch:** Interactions with ETPs	Interaction of Trawl sector with ETPs is minimized so those species' endangered status is improved	1	Legislation to establish locations and times of closures. Ongoing monitoring to identify problematic locations/times. Generating compliance through communication	High
	Spatial closures to remove trawling from sensitive areas (e.g. key habitats)	**Habitat impacts:** Trawling disrupting benthic habitats	Minimal disruptive effect of demersal trawls on benthic habitats	1	Maps of benthic habitat types, legislation to establish closures, MCS support. Consideration of existing closures	High
	Spatial closures to protect sensitive ecosystems containing representative habitat types and resources	**Effects on ecosystem function:** Trawling disrupts normal ecosystem function and food webs (e.g. removing prey species of pelagic species)	Maintained natural ecosystems and food webs	1	Research, identification and detailed mapping of ecosystems, prioritization of ecosystems for protection based on representativeness, extent and natural value, legislation to establish closures, MCS support	High
	Establish and enforce fishing zones for trawling	**IUU fishing:** Trawlers operating illegally, not reporting or unregulated	Trawling occurring in a regulated, legal way, with adequate reporting	2	Regulation to establish fishing zones. Consultation on location of fishing zones Communication between sectors and with community about fishing zones Education about zones. Sufficient compliance boats and trained officers to carry out MCS effectively. VMS with colour coding/marking of boats Promotion of community enforcement	High

(ii) Modifications to gears and fishing practices

Overarching measure	Specific measure	Issue addressed	Desired outcome	Level	To be effective this will require	Likelihood of success
Modifications to fishing gears and fishing practices	Conversion of existing trawlers to other fishing gears and practices	**Overcapacity:** Too many trawlers for the size of available fisheries resources	Optimum fleet capacity	2	Has to be directed to a proven (known) underexploited fisheries resource (if any). Conversion could also be to other sector e.g. tourism, transport.Training and education with stakeholders, including communities, on changes	?
	Fishing practices and gear modifications that reduce operating costs (e.g. labour costs and fuel consumption)	**Unprofitable trawl sector:** Costs are too high compared to the value of the catch	Profitable trawl sector attracting ongoing investment	2	Change to existing practices and gears (and investment in developing new gears) that use lighter, more fuel-efficient methods. No fuel subsidies that undermine sustainability objectives. Investigate redirection of subsidies and other incentives for use of improved gear designs (e.g. social security, fuel subsidy, ice). Conduct participatory research with industry to gain trust and ensure gear modifications are practical for fishing operations in that particular region. Ensure gear modifications are safe for use on vessels, and for crews (e.g. metal BRDs might be dangerous in rough weather) **Possible options:** • Use of BRDs/TEDs • Better onboard handling practices • Deck tanks (hoppers) • Improved gear design to reduce weight of ground rope, restrict bobbins (rubber discs), modify otter boards to reduce weight, mesh geometry in trawl net, restricting head rope length and opening height, lighter net materials to reduce drag	High to medium
	Increase the value of the catch by improving its quality through gear modifications (e.g. increased mesh size leading to reduced damage of catch in cod-ends) and on-deck handling practices			2	Changes to existing practices and gears (and investment into developing new gears) that reduce damage of catch in the cod-end and on deck. Participatory research, education and ongoing consultation regarding gear modifications. This must be linked to market incentives **Possible options:** • Restrictions on towing times, may be difficult to monitor – education and awareness of benefits are needed • Prohibit the use of materials that obstruct cod-end meshes • Regulations related to approved cod-end specifications (e.g. twine diameter, material type, double twine)	Medium

Overarching measure	Specific measure	Issue addressed	Desired outcome	Level	To be effective this will require	Likelihood of success
Modifications to fishing gears and fishing practices *(continued)*					• BRDs/TEDs • Deck tanks and improved onboard handling practices • Minimum mesh size appropriate to region and type of trawl	
	Exclude undersize fish through gear modifications (mesh size, panels, grids)	**Bycatch of juvenile fish:** species harvested at a sub-optimal size for maximum value (growth overfishing)	Species harvested at optimal size for maximum value	2	Identification of appropriate modifications to protect the maximum number of juveniles of key species • Industry involvement in developing new gears (participatory research) • Must be linked to market incentives for larger product Introduce: • Enabling legislation • MCS to ensure compliance • Education and extension of new gears **Possible options:** • Prohibit the use of materials that obstruct cod-end meshes • Regulations related to approved cod-end specifications (e.g. twine diameter, material type, double twine) • BRDs/TEDs • Deck tanks and improved onboard handling practices • Minimum mesh size appropriate to region and type of trawl • Investigate subsidies and other incentives for use of improved gear designs (e.g. subsidies for social security, fuel, ice)	Medium
	Reduce mortality of juvenile fish through introduction of bycatch reduction devices (BRDs) in nets			2	Research, develop and introduce appropriate BRDs • e.g. grids and panels (e.g. juvenile TEDs) • Ensure research is participatory to gain trust and ensure gear modification is appropriate • Industry involvement in developing new gears Introduce: • Enabling legislation to require the use of new gear types • MCS to ensure compliance • Education and extension of new gears Redirect subsidies and other incentives for use of improved gear designs (e.g. subsidies for social security, fuel, ice)	Medium

Overarching measure	Specific measure	Issue addressed	Desired outcome	Level	To be effective this will require	Likelihood of success
Modifications to fishing gears and fishing practices *(continued)*	Exclude undersize immature fish through gear modifications (mesh size, panels, grids)	**Bycatch of juvenile fish:** Juveniles caught before spawning	Species harvested after spawning	1	Identify appropriate modifications to protect the maximum number of juveniles of key species • Industry involvement in developing new gears • Ensure research is participatory to gain trust and ensure gear modification is appropriate Introduce: • Enabling legislation • MCS to ensure compliance, education and extension of new gears • Link to spatial and temporal closures to protect juveniles Redirect subsidies and other incentives for use of improved gear designs (e.g. subsidies for social security, fuel, ice)	**Medium**
	Reduce mortality of ETPs through introduction of BRDs in nets	**Bycatch of ETPs:** Catching ETPs in trawl nets	Interaction of trawl sector with ETPs is minimized so those species' endangered status is improved	2	Research, develop and introduce appropriate BRDs: • e.g. grids (TEDs) • Involve industry in developing new gears • Use participatory research to allow for modifications for operational reasons • Communication with fishers about benefits of using gears such as TEDs, e.g. reduced sponge/rubble catch/reduced catch of large objects that damage catch and nets Introduce: • Enabling legislation to require the use of new gear types • MCS to ensure compliance • Education and extension of new gears	**High**
	Reduce mortality through better on-deck discarding practices (e.g. recovering techniques for turtles)			1	Investment in developing and implementing appropriate on-deck recovery practices. Make sure recommended handling practices are safe and practical. Education programme, ongoing communication with fishers about the importance of handling ETPs properly	**Medium**
	Modified trawl gear that minimizes benthic impacts	**Habitat impacts:** Trawling may change or disrupt benthic habitats	Minimal negative effect of demersal trawls on benthic habitats	2	Participatory research & development and implementation of appropriate trawl gear modifications • e.g. lighter ground chains, bobbins, modified otter boards, sweeps, restricting head rope length and opening height etc. • Involve industry in developing new gears	**Medium**

Overarching measure	Specific measure	Issue addressed	Desired outcome	Level	To be effective this will require	Likelihood of success
Modifications to fishing gears and fishing practices *(continued)*					Introduce: • Enabling legislation to require the use of new gear types • MCS to ensure compliance • Education and extension of new gears	
	Fishing technology research to identify appropriate gears	**Science and monitoring:** Adequate scientific research and monitoring to provide information for management planning, monitoring and evaluation	Management plans are underpinned by adequate scientific information on species and harvest rates	3	Significant investment and training for scientific personnel. Participatory research to gain trust and ensure gear modification is practical for fishing operations in that particular region	**High**
	Appropriate mesh sizes/gear changes where suboptimal sized and low-value fish occur	**Exploitation of low-value fish:** Low-value fish being exploited at suboptimal sizes to feed aquaculture, animals and humans (incl. surimi)	Species harvested at optimal sizes for ongoing, sustainable exploitation and realizing improved economic benefits	1	High levels of MCS to ensure compliance. Significant research and development required to identify and promote alternative feeds for aquaculture, land animals and humans (mitigate the driver) Participatory research, monitoring and evaluation to identify problematic locations/times	**Medium**
	Technology to reduce fuel consumption	**Carbon footprint:** High CO_2 emission	Reduction in carbon footprint	3	Participatory research and development of alternative technologies Incentives for adopting low carbon technologies Investigate improved cod-end specifications to reduce drag and fuel consumption. Improved trawl geometry for more efficient and lighter trawls Reduce catch of unwanted bycatch, e.g. sponge and rubble through use of grid-like BRDs	**Medium**
			Use of alternative energy sources (solar, wind etc.)	3	Participatory research and development of alternative energy sources. Incentives for adopting low carbon technologies	**Medium**

(iii) Dealing with overcapacity

Overarching measure	Specific measure	Issue addressed	Desired outcome	Level	To be effective this will require	Likelihood of success
Capacity reduction – reducing the fleet size	Limit and freeze the number of licences	**Overcapacity:** Too many trawlers for the size/value of the available fisheries resource	Optimum fleet capacity	2	Implementation of rigorous licensing system. Non-compliant boats will not be allowed to fish. Enabling legislation related to safety compliance, inspection and national port state measures	**High**
	Government/Industry buy-backs – Compensation for loss of income through negotiated exit of vessels			2	Significant injection of funds from government and industry and political will. Enabling legislation to cap numbers. Registration and licensing system rigorously enforced, accounting, audit systems and penalties	**High**
	Conversion of existing trawlers to other fishing gears/practices and other resources			2	To be effective the conversion has to be directed to a proven (known) underexploited fisheries resource (if any). Conversion could also be to other sector, e.g. tourism, transport	**Very High**
	Limit effort creep through control of fishing efficiency – e.g. horsepower, head rope length, boat size			2	Good records of factors such as horsepower and head rope length Controls will be effective in cases where number of vessels cannot be reduced	**Medium**
	Encourage efficiency improvements as alternatives to fleet reduction			2	Establishment of trading regimes (e.g. tradable input controls) An estimate of the current level that will be set as the cap on the total allowable input (e.g. fleet horsepower, total head rope length) and basis of establishment	**Medium**
	Limit on the number of licences	**Overcapacity:** Excess fishing effort	Optimum fishing effort	2	Implementation of rigorous licensing system. Non-compliant boats will not be allowed to fish. Enabling legislation related to safety compliance, inspection and national port state measures	**High**
	Reduction of fuel and other capacity enhancing subsidies such as free port facilities, ice, tax exemptions etc. With subsidies only available for compliant vessels			3	Link subsidies to provision of information and compliance – License and registration system rigorously imposed to all fleet segments (including the artisanal fleet)	**Medium**

Overarching measure	Specific measure	Issue addressed	Desired outcome	Level	To be effective this will require	Likelihood of success
Capacity reduction – reducing the fleet size *(continued)*	Government subsidies (incentive) 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			1	Noting that governments are already paying large amounts in fuel subsidies and other capacity enhancing subsidies, redistribute the subsidies to reward good practices. Access to markets for compliant vessels Legislative backing to ensure that subsidies don't support inefficient and unsustainable fishing	**High**
	Manage foreign labour			2	Fishermen and crew ID cards, appropriate immigration controls and enforcement. Ensure crews are paid adequate local wages	**Low**
	Total allowable catches (TAC) and individual transferable quotas (ITQ)			3	Sophisticated share establishment and trading scheme. Reliable stock assessments for all commercially important species to establish TACs and allocations. Data sets to establish catch records. Communication with fleet when TAC is met, MCS, enabling legislation	**Medium**
	Limits to days allowed to fish (boat days)			3	Sophisticated scheme to establish and allocate days/boat. Reliable stock assessments to establish total boat days allowed. Enabling legislation, communication with fleet when total days are met. MCS	**High**
	Limited entry for new participants, 2 for 1 entry schemes			1	Good licensing scheme that is regularly monitored. Enabling legislation. MCS to ensure limited entry is complied with. Industry support to encourage self-compliance	**High**
	Fishing on rotational basis			2	Agreement among fishers and monitoring of vessels in port and at sea	

Implementing the measures, gaining stakeholder acceptance

In working through the above tables, it is important to note that when managing a fishery, and more particularly when developing a formal management plan, several factors need to be borne in mind, especially when dealing with the multispecies tropical trawl fisheries of Asia.

- In highly regulated fisheries, typically in developed countries, compliance with regulations is often supported by significant monitoring, control and surveillance arrangements. This is possible when the fishery has a relatively small number of vessels, or there is considerable investment in the MCS system by the fishery or government.
- In developing countries, particularly those where there is a large number of vessels, enforcement of regulations is much more problematic. The sheer scale and geographical spread of the fishing fleet means that the costs of patrolling and monitoring at sea or in port rapidly is at a level where fisheries agencies are simply incapable of using direct enforcement (and the application of penalties) as a means to control fishing behaviour. The tendency is therefore is to adopt more generic approaches involving management measures that can be applied to the whole fleet (or particular fleet segments, e.g. trawl vessels over 12 m), rather than to individual vessels. Examples include using zoning or spatial and seasonal closures, rather than individual transferable quotas (ITQs) or at-sea, gear inspections.

Another of the most important factors to consider when identifying management measures to implement is to ensure that there is "buy-in" or ownership by fishers of the measures. This was mentioned in Section 4 of these guidelines where the prioritization of issues was discussed (using risk assessment and PSA tools) and involved meetings of fishery stakeholders and experts.

By engaging with fishers (through structures such as steering committees and management advisory committees) in the prioritization processes, as well as in subsequent processes such as drafting, implementing and reviewing management plans (see Sections 6 and 7), fishers become effectively and fully engaged in the management of their fishery, have significant ownership over its management and are therefore less likely to have problems in terms of compliance once management measures are introduced. This approach maximizes the likelihood that appropriate and effective management measures for the fishery are selected, implemented and complied with.

In both developed and developing countries, a highly unpopular regulation will result in fishers seeking ways to circumvent the control, thereby undermining the management objective. When selecting measures that are reliant on significant buy-in from the fishery to ensure adequate compliance, the following should therefore be considered:

i) Measures ideally should be applicable to the entire fishery or fleet segment, such that individuals or small groups are not seen as unfairly benefitting or gaining an advantage at the expense of others.
ii) Measures involving time closures (which are often quite well-accepted because of their equal impact on all fishers) could be applied during seasons or periods when fishers would prefer not to be at sea (e.g. during dangerous periods such as the typhoon or monsoon season, during festivals or holiday seasons, during times of routine shore-based maintenance).
iii) Measures ideally should have the potential to increase economic efficiency in the medium term rather than the long term – for vulnerable smaller-scale fishers, short-term losses of income may be unacceptable.
iv) Where incentives are used, they should be temporary offsets for short-term economic losses while the fishery recovers (and should also be strongly linked to improved compliance with regulations).
v) Measures should also try to reduce conflict or increase social cohesion.

In many cases, trade-offs may be required that will involve using several measures that are, individually, less rigorous but, when used in combination, provide sound outcomes. However, when considering any management measure or intervention, one also needs to be aware of the economic and/or social implications of **inaction** – that is, if doing nothing will lead to a worsening of an issue or the decline of the economic/social/environmental situation, then introducing change should proceed as a matter of urgency.

Finally, in considering a management measure, or group of measures, to deal with particular issues in a particular fishery, one needs to be aware of, and document the following: the sorts of outcomes that one expects will be achieved following its implementation; where, when and why it could apply in that fishery; its strengths and weaknesses; and its simplicity, ease of implementation and cost.

Bearing all this in mind, some general recommendations are provided in Table 11, as a guide for the sort of management options that a management plan should include as a minimum standard in the tropical trawl fisheries of Asia.

Table 11 Minimum standards for tropical trawl fisheries in Asia

General recommendation	Actions to be taken
Initiate a process for managing trawl fisheries	Countries with a significant trawl sector should: • 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 institutional capacity development • Establish consultative processes that engage with fishers, the fishing industry and other stakeholders for ALL steps in the above processes
Strengthen monitoring, control and surveillance	• Clear, individual markings for all trawlers that are visible from a distance • Get effective MCS working (e.g. Satellite-based VMS on all larger vessels, surveillance) • Promote a fishers' volunteer watch/reporting scheme, and integrate into existing MCS arrangements
Manage fishing effort and fishing vessel overcapacity	• 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
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 • Ensure regulations are in place that provide an effective minimum of 40 mm mesh size in the cod-end, recognizing that larger mesh sizes than this are preferable • Promote gear designs that ensure correct selectivity in the cod-end • Develop and implement gear 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
Reduce the impact of trawl through spatial, habitat and temporal measures	• Minimum 3 nm trawl exclusion zone (noting that some countries currently have exclusion zones of 8 to 10 nm) • No trawling in critical habitats (e.g. seagrass, corals), nursery grounds or in waters shallower than 10 m • All trawl fisheries to have an annual seasonal closure of at least 1 to 3 months to coincide with peak spawning and nursery times

SECTION 6: Developing management plans

So far these guidelines have been building up to the most important task for a fisheries manager, namely how to develop a management plan for his/her fishery. The following flow chart shows the process we have been following throughout these guidelines and where the all-important management plan fits in. The chart illustrates an "adaptive management" approach where feedback loops enable the continual adjustment of the plan, its objectives and measures as a consequence of changing and developing circumstances.

As suggested earlier, the first step in developing a management plan for a fishery is to establish and assemble a steering committee. This should be comprised of:

i) government staff (including the relevant fisheries manager who would lead and chair the committee);
ii) key industry stakeholders; and
iii) representatives from other stakeholder groups who have an interest in the fishery, its operations and/or interactions (e.g. processors, scientists, economists, environmentalists, tourism operators).

This committee's function is to draft the management plan through a series of meetings, drafting sessions and constant iterative feedback. The best way to illustrate how to develop such a document is to work through its various elements and below in Table 12 we provide an example of the sorts of elements that one should consider.

Table 12 Elements to be considered in a management plan

Item	Indicative content of management plan
Title	"The management plan for the [*fishery name*] trawl fishery"
Vision	This should be a short, clear, high-level policy goal for the fishery.
Glossary	Provide definitions for key terms used in the management plan to ensure that readers interpret the plan correctly.
Background	**Description of the fishery:** Describe the geographical area of the fishery including a map, any jurisdictional (local, provincial, national, regional) boundaries, the general ecosystem/ habitats that the fishery operates in, any seasonality associated with the fishery's operation, the gears used and the species targeted.
	History of fishing and management: Provide a brief description of the past development of the fishery in terms of fleets, fishing effort, the gear used, the people and communities involved, etc. Provide a summary of previous management plans (if any) for the fishery and, in subsequent versions, any amendments to previous versions.
	Current status of the fishery's resources: Summarize the status of the various stocks exploited by the fishery – whether they are estimated to be overfished, fully fished, underfished, or whether the status is undetermined.
	Socio-economic benefits of the fishery, including post-harvest: Outline the value of the fishery in terms of its landings and where the catch is sold (i.e. locally or exported). Describe how the catch is handled, processed, marketed and utilized.
	Stakeholders: Describe the main stakeholders involved in the fishery (e.g. the fishers involved, associated or dependent industries, conservationists, adjacent fisheries, artisanal fisheries, recreational fishers) and their interests. Detail other uses and users of the ecosystem, especially activities that could, or are, causing significant impacts or conflicts. Outline current arrangements for coordination and consultation processes with stakeholder groups.

Table 12 Elements to be considered in a management plan (*continued)*

Item	Indicative content of management plan
	Any special environmental considerations for the fishery: Details of critical habitats, any particularly sensitive areas and endangered species interactions.
	Institutional aspects: Describe the current legislative background of the fishery, existing jurisdictional arrangements, roles and responsibilities. Detail the decision-making process, including recognized stakeholders and government departments, the nature of any rights granted in the fishery, details of those holding the rights and their responsibilities. Describe current, scientific research and MCS arrangements. Outline the current consultation process that has led to the need to develop this plan and how the current development of the plan is to proceed.
Major issues for management	Describe the various management issues that the plan needs to address.
	These are the issues that have been identified and prioritized using the risk assessment and stakeholder consultation processes suggested in Section 4 of these guidelines. As discussed in that section, these may include conflict between fleet segments, overcapacity, an unprofitable trawl sector, growth overfishing, various bycatch issues, habitat impacts, ecosystem impacts, IUU fishing, the exploitation of low-value fish, impacts of management on supporting and tangential industries, ghost fishing and other unidentified mortalities.
Management goals	Agree (two or three priorities) goals that represent the outcome you want from addressing the issues.
Management objectives	Describe the specific objectives of the plan. These need to address the high priority issues identified above. They also need to be able to be addressed by management measures.
Indicators and benchmarks (Performance measures)	Here describe the benchmarks and performance measures to be used to assess the success of the plan's management measures in meeting its objectives.
	For each objective, and associated measure(s), there should be: 1) The indicator(s) that need to be monitored 2) A clear description of current benchmarks 3) How to measure the achievement (or failure) of the management plan in meeting the objective. There is a need to be realistic when developing these: avoid locking in timeframes that may be difficult to achieve.
	Table 13 provides a series of examples of indicators and their methods for measurement of their success (or failure) in delivering desired management outcomes.
Management measures	These are the key ingredients of the Plan (i.e. the actual business end of the whole exercise) because this section describes each of the management measures that will be implemented to achieve the objectives listed above. This should therefore be the largest part of the Management Plan and will be an assemblage of measures along the lines of those listed in the Tables 8 and 9 in Section 5 of these guidelines
	For each measure, specify: 1) the components of the measure; 2) the time frame(s) by which it will be implemented; 3) the agency, group and/or individual(s) responsible for its implementation; 4) the information required to monitor these indicator(s).
	As described in Section 5, examples of measures might be the nature, extent and timing of spatial closures to trawling to achieve objectives concerning artisanal conflicts, bycatch issues, etc.; the design of gear modifications designed to reduce discarding or interactions with ETP species; the design of a capacity reduction scheme; and/or a fishing effort limitation programme, etc.

Table 12 Elements to be considered in a management plan (*continued)*

Item	Indicative content of management plan
Implementation arrangements	This section of the management plan will describe the steps involved in putting the plan into place. It will cover elements such as:
	Legal basis and financing: Legislative requirements, basis in law, official recognition, resourcing and funding needs and sources.
	Committees: Structure of the steering committees, advisory committees, consultative committees and their various roles and responsibilities; the membership descriptions of these committees (e.g. four commercial fishers, one environmental representative, one management representative, one scientist, one economist, etc.) and the roles and responsibilities of each member; the process for appointment of members; the responsibilities of the various agencies, governments and institutions involved. Training and education requirements and how to deliver them.
	Information and monitoring: Data collection and MCS requirements and responsibilities (i.e. the information outlined in Sections 6 and 7 of these guidelines).
	Review and update: Frequency, nature and format of ongoing and periodic reviews, feedback loops, audits and updates of the plan.
	Communication of the plan: This section would also include a description of any communication strategy concerning the plan and/or the management of the fishery, including details of outreach mechanisms, roles and responsibilities of individuals with respect to media liaison, and the associated resourcing requirements.

Examples of management plans

Some generic worked examples of draft management plans are provided in Appendix 4 to illustrate how one can start to construct such plans. These examples of plans examine a multispecies trawl fishery for low-value species and a typical shrimp trawl fishery.

Table 13 Example of indicators that can be used to measure progress towards management outcomes (performance)

General issue	Specific issue	Desired outcome	Indicators and measuring success
Conflict between fleet segments	Trawlers fishing in same areas as artisanal fishery – taking "their" fish, damaging their gear and boats	Reduced conflict between different fishing sectors	• Designation of nearshore trawl exclusion zones to at least 3 nm with effective enforcement • Stakeholder feedback; numbers of official complaints; regular reporting from artisanal fisher organizations/representatives • Productivity/profitability of artisanal sectors sustained or increased • Trawl sector also sustains profitability • Sustained increase of CPUE of both artisanal and trawl segments • Artisanal sector increases value per kg of fish (indicating greater diversity/quality of catch)
Overcapacity	Too many trawlers for the size of available fisheries resources	Optimum fleet capacity	• Cap on the entry of new trawlers to fishery implemented • Reduction in numbers of trawlers • Reduction in trawl effort (total trawler power/days fished) • Productivity/profitability of trawl fishery sustained or increased • Catch value increased (quality improved); operating costs reduced • Increased CPUE
	Excess fishing effort	Optimum fishing effort	• Cap on new trawler entry to fishery enforced • Reduction in number of trawlers • Reduction in trawl effort (total trawler power/days fished) • Effective zoning/access system developed and enforced • Subsidies applied only to compliant vessels • Increased CPUE
Unprofitable trawl sector	Costs are too high compared to the value of the catch	Profitable trawl sector attracting ongoing investment	• Productivity/profitability of trawl fishery sustained or increased • Catch value increased (quality improved); operating costs reduced • Increased CPUE • Investment in onshore marketing and processing/trading of responsible trawl fishery products is sustained or increased
Impacts on dependent industries (traders, processors, transport, etc.)	If trawl sector reduced, dependent industries may suffer	Support industries able to adjust to changes in trawl sector management	• Monitoring of production from dependent food industries, not significantly affected by trawl management adjustments • Increased use of alternatives and processing waste streams compensate for reduction of supply for fishmeal/feeds

Table 13 Example of indicators that can be used to measure progress towards management outcomes (performance) *(continued)*

General issue	Specific issue	Desired outcome	Indicators and measuring success
Bycatch of juvenile fish	Juveniles caught before spawning	Species harvested after spawning	• Designation of nearshore trawl exclusion zones to at least 3 nm • Zones/areas/seasonal closures to protect known juvenile/spawning stocks • Increased mesh size of trawl cod-end to at least 40 mm • Increased selectivity of gear (e.g. use of JTED or similar device) • % juveniles in catch reduced • Increased size composition of catch
	Species harvested at a suboptimal size for maximum value (growth overfishing)	Species harvested at an optimal size for maximum value	• Designation of nearshore trawl exclusion zones to at least 3 nm • Zones/areas/seasonal closures to protect known juvenile/spawning stocks • Increased mesh size of trawl cod-end to at least 40 mm • Increased selectivity of gear (e.g. use of JTED or similar device) • % juveniles in catch reduced (sampling of MLL) • Increased size composition of catch
Overfishing	Excessive trawl effort leads to depletion of stocks	Trawl fishing effort is commensurate with the sustainability of stocks	• Overcapacity is reduced from 30 to 50%; number of trawling licenses reduced • Spatial and time closures in place to protect vulnerable stocks • Permanent closures to trawling in place in critical areas for vulnerable stocks
	Trawling taking too many individuals (spawners and juveniles) of vulnerable small species	Stocks of small species caught by trawling are sustained	• Space/time closures to protect vulnerable small species • Permanent closures to trawling in place in critical areas for vulnerable small species • Compliance with regulations on gears to exclude vulnerable small species
	Low-value fish being exploited at suboptimal sizes to feed aquaculture, animals and humans (incl. surimi)	Species harvested at optimal sizes for ongoing, sustainable exploitation and realizing improved economic benefits	• Designation of nearshore trawl exclusion zones to at least 3 nm • Zones/areas/seasonal closures to protect known juvenile stocks • Increased mesh size of trawl cod-end to at least 40 mm • Increased selectivity of gear (e.g. use of JTED or similar device) • % juveniles in catch reduced (sampling of MLL) • Increased size composition of catch
Bycatch of endangered, threatened or protected species (ETPs)	Catching ETPs in trawl nets	Interaction of trawl sector with ETPs is minimized so those species' endangered status is improved	• Designation of zones/areas/seasonal closures to protect known critical habitats and migration routes for ETPs • Increased selectivity of gear (e.g. use of TED or similar device) • Evidence of use of recovery tanks/practices • Reduction in presence of turtle shell/shark products in local markets

Table 13 Example of indicators that can be used to measure progress towards management outcomes (performance) *(continued)*

General issue	Specific issue	Desired outcome	Indicators and measuring success
Habitat impacts	Trawling disrupting benthic habitats	Minimal disruptive effect of demersal trawls on benthic habitats	• Established trawl exclusion zones to protect sensitive/critical habitats • Increased area of trawl obstructions/subsurface FADs/artificial reefs etc. • Evidence of trawl gear modification to reduce benthic contact.
Effects on ecosystem function	Trawling disrupts normal ecosystem function and food webs	Minimal disruption of natural ecosystems and food webs	• Trophic level in catch composition increased (or increase in quantity of high trophic level indicator species) • Established trawl exclusion zones to improve ecosystem biodiversity • % juveniles in catch reduced • Increased size composition of catch • Establishment of long-term protected areas, with fishery specific objectives
Carbon footprint by trawlers	High CO_2 emission	Reduction in carbon footprint	• Reduced fuel use per kg of production • Optimized trawling times to minimize fuel consumption
IUU fishing	Trawlers operating illegally, not reporting or unregulated	Legal trawling	• Reports from MCS system (including VMS/VPS information) indicate reduced/no encroachment (improved compliance) • Reports from fishers organizations • Establishment of reliable information from trawler catch documentation scheme • Port/gear inspections indicate improved compliance
		Regular and accurate reporting of trawl activity	• Trawl logbook or e-reporting system in place • Catch reporting system in place • Port monitoring system in place
		Improved compliance/ enforcement of regulations	• Enabling legislation is in place to enforce MCS measures • Establishment of an enforceable and resourced MCS system • Wheelhouse/vessels marking system in place • VPS/VMS system in place • Number of penalties/infringement cases • MCS reports as part of the management plan
Science and monitoring	Adequate scientific research and monitoring to provide information for management planning, monitoring and evaluation	Management plans are underpinned by adequate scientific information on species and harvest rates with industry participation	• Portside monitoring system established • Catch reporting/catch documentation system in place • Evidence of integration of science and MCS systems • Evidence and regular review of a science programme capable of providing the science needs (indicated in this table) of management • Science-based performance indicators (drawn from the science-based indicators above in this table) are regularly monitored and report as part of the ongoing review of management plans

SECTION 7: Implementation

By the end of Section 6 of these guidelines, the fisheries manager (and his/her steering committee), have prepared a draft management plan for the fishery. This next section describes the steps involved in implementing this management plan (which also forms a part of the plan itself).

Develop an implementation plan

Once the fisheries management plan is drafted, it is often appropriate to develop an implementation plan that sets out the various steps involved in how to get the plan in place. This plan should identify the timing, locations, mechanisms, processes and people (and their responsibilities) for implementing the various steps.

Broad stakeholder consultation

Once a complete fishery management plan has been drafted by the steering committee, it needs to be released to a broader audience. Usually, this is done initially by distributing the draft to all stakeholders in the fishery. The fisheries manager and members of the steering committee usually communicate the contents of the management plan with the aid of physical presentations, which help to explain the various elements of the management plan to the fishers who are affected the most. Feedback and commentary from the participants in the fishery about the management plan's various elements should be welcomed because often very significant issues can be raised that can improve the plan and its implementation.

Next, the resultant draft plan should be circulated to other stakeholders that are external to the fishery (e.g. members of adjacent fisheries, artisanal fishers, conservationists). And as was the case above, this should be augmented, if practical, with physical presentations and discussion sessions. This will allow these groups an opportunity to provide their comments and feedback on the draft management plan and allow the committee and manager to incorporate any issues/improvements, if appropriate.

At this stage it is appropriate to put the draft management plan out for one final level of consultation – to the general public. In this situation, the management plan would be posted on a Web site or in a newspaper and public submissions invited. Alternatively, a public consultation could be convened.

As mentioned in Section 3 of these guidelines, to identify the various component groups and individual stakeholders that should be involved during the development of a fisheries management plan, it is often desirable to consider running a stakeholder scoping study early in the management process. Such a stand-alone project should seek to identify the particular groups that need to be engaged and the extent of that engagement – i.e. from being simply notified about developments, through to complete and formal involvement in prioritization groups, steering committees and management advisory committees.

Approvals

Once all these various consultations have occurred and consequent changes to the fisheries management plan have been incorporated, the plan is close to completion and should be forwarded to the formal adoption stage. This will usually require the drafting of enabling legislation, and the formal approval, sign-off (and often a public "launch") by the appropriate government official (i.e. usually a Minister) – at which point the fisheries management plan and its various elements become active and legally binding. Different countries have different mechanisms to achieve this. For example, in the Philippines, Council Approvals and Fisheries Administrative Orders are used. In India,

there is the Marine Fisheries Regulation Act and in Viet Nam, the Fishery Act allows the issuance of a decree, after which the fisheries management plan is then considered a legal document.

NOTE: When establishing the enabling legislation for a fisheries management plan, it is very important not to include the specific management regulations of the plan (such as size limits, timing of closures, TACs, prohibited gears, gear modifications). The enabling legislation must give management plans legal authority, but also allow the updating of the measures they contain. This is because the regulations and measures in the management plan need to be periodically updated, but to change the legislation may take years.

Ongoing review and measuring performance

Once the fisheries management plan is developed, it is important that it does not become a "paper plan" with no further input. It is good practice to adopt an "adaptive management" approach for any fishery management plan, where the plan's outcomes are continually assessed and its measures modified as a consequence.

To ensure that the fisheries management plan remains actively monitored and if necessary updated, it is important to establish or designate an oversight body. Sometimes, the steering committee that drafted the plan and brought the fisheries management plan to implementation, could (normally) become an ongoing management advisory committee (MAC) for the fishery. The responsibilities of the MAC or oversight body would include:

- the regular assessment of the operation of the fisheries management plan; and
- adaptation of the fisheries management plan to address new outcomes and information through time.

This important committee should meet regularly to discuss the changes taking place in the various fisheries under the fisheries management plan, and how the various measures in the fisheries management plan are progressing – against their dates of implementation and their performance criteria. This allows the opportunity for adjustments to occur in resourcing, timelines, etc. if necessary.

At the start, such meetings may be needed every three months or so as the need for reviews and feedback is often greatest at this stage. However, this will become less frequent as the fisheries settle into routine operations and adherence to the fisheries management plan, its various measures and reporting requirements. The ongoing implementation of the fisheries management plan also requires work, and for further updates to this plan, the MAC will need to:

- consider the objectives, performance measures;
- take into account any lessons learned or new information;
- review the data collected under the fisheries management plan; and
- make recommendations on how the fisheries management plan is to be operationalized from year to year.

SECTION 8: Monitoring, control and surveillance

Fisheries compliance is a specialized area of fisheries management. The role of fisheries compliance officers and inspectors is to make sure that when fisheries managers and decision-makers make laws, **these regulations are observed and offenders are prosecuted**.

The FAO Code of Conduct for Responsible Fisheries[11] encourages States to establish, within their respective competences and capacities, effective mechanisms for fisheries monitoring, surveillance, control and enforcement to ensure compliance with their conservation and management measures. Monitoring, control and surveillance (MCS) activities are therefore an essential component of all fisheries management programmes. Its major purpose is to ensure that fisheries management plans are given the best chance of working and of achieving their goals.

The various components of MCS can be defined as:

Monitoring: includes the collection, measurement and analysis of information about fishing activities, including but not limited to catches, species compositions, fishing effort, discards, and areas/times of operations. This information is the primary data that fisheries managers use to arrive at management decisions. It is also the basic data that fisheries scientists use to study fisheries. If this information is unavailable, inaccurate or incomplete, managers will be handicapped when developing and implementing management plans and their associated measures.

Control: involves the specification of the terms and conditions under which resources can be harvested (i.e. controls on fishing behaviour of the fishers). These specifications are contained in national fisheries legislation, international agreements, and other arrangements such as conventions and treaties that might apply to a region. Legislation provides the foundation for all MCS activities.

Surveillance: involves checking and supervising fishing and fishing-related activities to ensure compliance with legislation. This includes the terms and conditions of access, and the management measures and stipulates who can fish what, when, where and how. Surveillance ensures that the laws to protect fisheries resources are enforced, and that IUU fishing is minimized or, preferably, eliminated.

MCS tools

There are many potential elements to a MCS programme that should be considered when monitoring the implementation and compliance with management measures, these are summarized in Table 14.

Table 14 A summary of the tools and approaches that can be used to support monitoring, control and surveillance (MCS) in fishery management

MCS tool	Purpose, specific need, benefits
Effective supporting legislation	Ensures that all compliance activities are supported by the strength of law
An effective and live vessel registration and licensing system for all vessels, irrespective of the size or purpose	A computerized system to track ownership, port of registry, and authorizations to fish that is updated in real time
	Registration systems require long-term commitment and should not be confused with baseline or one-off surveys

[11] FAO CCRF articles 7.1.7, 7.7.3 and 8.1.4

Table 14 A summary of the tools and approaches that can be used to support monitoring, control and surveillance (MCS) in fishery management *(continued)*

MCS tool	Purpose, specific need, benefits
Stakeholder involvement in management planning	Ensures that industry is fully aware of, and has joint ownership of, compliance requirements. This requires setting up stakeholder dialogues and eventually joint government and stakeholder committees
	Ideally these are established within the legal framework of the fisheries law. In this way rights and responsibilities can be legally assigned and individuals' liabilities protected
Properly identifying vessels and operators	A starting point for good MCS is the effective identification of vessels. All vessels should have clear and painted in large easily identifiable characters license numbers on the wheelhouse tops and on the vessel sides along with the vessel's registered name. The port of registry should be clearly painted on the stern. For the FAO standards regarding the marking and identification of vessels see: ftp://ftp.fao.org/docrep/fao/008/t8240t/t8240t01.pdf
	It is important that all vessels be recorded, registered, marked and captured in an inventory in the MCS system
	If all vessels are not registered, this gives non-compliant vessels owners an excuse not to register their vessels
	Similarly, no fishing vessels should be constructed or modified (new, more powerful engines, lengthening and broadening hulls, etc.) without pre-authorization from the fisheries administration
Licensing skippers and crews	All skippers and crews should have a license to fish and their names and national identities, dates of birth and qualifications kept in a database
	Any skipper or crew that does not have a license should not be allowed to board a vessel with the purpose of engaging in fishing
Monitoring and validating landings by weight, species, fishing area	This is a reasonably low-cost MCS element and usually involves the planned or spot inspection of fishing vessels, fishing gear and catches at the port of landing, under the purpose of ensuring compliance with gear, species and size restrictions as mandated in legislation and/or regulations
Pre-departure inspections	These inspections are to ensure logbooks and reporting requirements are all in place before a fishing trip, but they can also be used to ensure all safety elements are onboard and operational
	These also serve as an opportunity to educate skippers and crews about fisheries management issues, data reporting systems and to provide feedback
Data collection systems including onboard observers, logbooks filled out by skippers and crews, and port inspections done by compliance officers	These elements provide the basic data needed for MCS (as well as scientific) investigations. Where practical, all vessels should maintain a fishing logbook that ideally should be standardized nationally
	This requirement will usually apply only to vessels of a certain length that have a dry space to fill in the logbook and with navigation equipment such as GPS or other equipment to plot and or record the position of fishing
Surveillance and monitoring the operations of fishing vessels and fleets at sea on either a routine or an ad hoc basis	These activities require significant resources including patrol boats and even aerial patrols
	These also serve as an opportunity to educate skippers and crews about fisheries management issues, data reporting systems and to provide feedback

Table 14 A summary of the tools and approaches that can be used to support monitoring, control and surveillance (MCS) in fishery management *(continued)*

MCS tool	Purpose, specific need, benefits
Gathering information about the operations of fishing vessels at sea	This can be achieved in a rudimentary way through the use of onboard logbooks that are completed by skippers and crews
	Real-time use of vessel monitoring systems (VMS) and electronic monitoring systems (EM) that use onboard cameras, GPS and sensors to determine the locations, operations and catches of vessels are providing better ways to do this
	Better data and especially data on bycatch and discards, comes from independent onboard observers
	Observers present an opportunity to educate skippers and crews about fisheries management issues, data reporting systems and to provide feedback
Auditing of information	A desk-top activity that can lead to the identification of IUU fishing via the examination of "paper-trails" about landings, sales of fish, and the movements of crews and vessels
	Document audits are included in port state measures. Compliance officers should be trained in carrying out audits and inspection including the collection, safe storage and transport of forensic evidence to be used in the prosecution of offenders
Integrated reporting and aggregation of MCS information among various jurisdictions and agencies	This approach seeks to harmonize national and regional data, standards and compliance requirements and can lead to very powerful cross-jurisdictional MCS. Regional cooperation is an important part of this and fisheries and MCS compliance officers are encouraged to support and actively engage with relevant regional networks[12]
	Also included in this should be collaboration with other sea-going agencies such as navies, coastguards and marine police
Vessels encouraged or required to carry VHF and/or HF radios or other authorized communications devices	A requirement for safe navigation but also important for communications between the fishing vessels and MCS authorities
Using onshore coast-watchers and other voluntary assistance	A useful way to monitor fishing vessels in particular areas (e.g. as they leave/return to port or in particular fishing grounds that are visible from shore)
The use of other fishing vessels and fisher groups as MCS platforms	A good low-cost alternative (e.g. used in parts of Malaysia, Timor-Leste, Indonesia) as artisanal fishers are empowered to report on illegal activities that they see as they go about their normal fishing operations
	One approach involves supplying hand-held GPS transmitters or small VHF radios to artisanal fishers who will report sightings of IUU to MCS patrol units
Smartphone applications that can support MCS which use GPS	This application links location geo-information with other functions such as camera, video and audio to provide a suite of information and outcomes. They can be loaded onto online maps and can be used to track IUU activity

[12] e.g. the Regional Plan of Action for IUU (RPOA-IUU) (available at http://www.rpoa.sec.kkp.go.id).

Spatial components of MCS

There are three main spatial components of MCS operations: operations that occur on land, at sea and from the air. Exactly what mix is used in a given situation will depend on the fishing activity under investigation, but often more importantly, will depend on the resources available.

Land-based MCS operations include the establishment and location of the MCS base or headquarters from which all activities are co-ordinated. This location is also where all desktop auditing work is done including the monitoring of paper trails, fish sales, transshipments, etc., and where all monitoring of remote tools is done (e.g. patrol vessels, VMS data, electronic monitoring information, Internet-based data streams from boats). Other crucial land-based MCS activities include port inspections and dockside monitoring, collection of logbooks, interviews of fishers, meetings, etc.

At sea MCS activities include the operations of patrol vessels in state waters and, if available, in high seas. This involves quite resource-intensive work requiring appropriately sound, fast, sea-going vessels that are equipped with radar, sonar, GPS and the latest communications equipment.

Airborne MCS activities include the use of aerial patrols (if a jurisdiction has access to fixed-wing aircraft or helicopters), satellites and drones. These are very expensive, particularly where there are large sea areas or archipelagos to patrol and hundreds or thousands of vessels. It would be more practical and cost-effective to link IUU monitoring to airborne surveillance conducted within the framework of maritime security and request cooperation from the relevant services.

In recent years, high-technology developments in MCS have involved the use of vessel monitoring systems (VMS) – which are now quite commonplace – but these systems are rapidly being overtaken with developments in other electronic monitoring (EM) systems that use consolidated on-deck video cameras, GPS tracking, and winch and engine sensors to monitor the location, activities, catches and bycatches of vessels. Real-time electronic reporting of catches is the next generation of MCS tools that will begin to become as commonplace as VMS within a few years.

The implementation of appropriate and efficient monitoring, control and surveillance requires enabling legislation, political will, adequate funding and cooperation and coordination between different government departments and ministries. In order to convince fisheries ministers and policy-makers of the economic and financial benefits that MCS can bring, fisheries managers are encouraged to undertake cost and benefit studies and calculations and to integrate these into their national plans of action for combatting IUU.

SECTION 9: Information, science and assessment

Effective fisheries management is based on an understanding of the fishery being managed. As fisheries become more complex, they require higher degrees of data and information to track the state of the fishery resources and the activities and impacts of fishers and their operations. Although fisheries managers who are responsible for facilitating the development of a fishery management plan do not need to be fisheries scientists, they do require some basic understanding of fisheries science and assessment. This is necessary to enable them to work with fishery scientists to ensure that management interventions are underpinned by good information.

To facilitate the understanding and coordination between these groups, there is a need for specialized individuals who have the task to:

i) make the results from science and research more accessible and useful to managers, fishers organizations and decision-makers; and
ii) help scientists to better understand the needs of and questions from managers and fishers representatives.

As discussed in Section 4, decision-makers who manage fisheries receive advice from many stakeholders, interest groups and experts. But the most influential information upon which decisions are made usually comes from rigorous, objective science. Decision-makers who require answers to complex, difficult questions about fisheries and marine ecosystems usually require the "best available scientific information", and because scientific research ultimately provides this scientific information it is one of the most important factors in framing fisheries management policies.

But, as with fisheries management, fisheries science is a very complex field that is basically is about trying to determine natural truths about highly mobile animals and the ecosystems in which they thrive that are mostly invisible to passive observation. For much of its history, therefore, fisheries science has worked on developing better techniques to study such diverse and difficult-to-study organisms. Fortunately, however, our tools has advanced greatly in recent decades and have enhanced our ability to study these systems and so provide better answers for fisheries managers to use.

But as was the case for management issues concerning a fishery, the questions that are asked of fisheries science are usually far greater in number and scope than can be readily answered – especially in developing country contexts where the financial resources and expertise are not readily available. In the latter situation, it is especially important that any scientific programmes that are being considered should be focussed directly on particular and precise management needs. That is, one must start with identifying a particular management objective, then determining the relevant management measure that will achieve the objective, and THEN design the scientific programme that will inform and monitor the management measure's success or failure.

There is a considerable amount of fishery science that is currently undertaken in many countries that does not contribute to management decision-making or improved understanding of the state of resources. The re-orientation of fishery research programmes to address the questions and needs of management can be considered an urgent priority in many countries.

Deciding which scientific questions are the most important to answer, and how to answer them, are therefore key processes in shaping fisheries research and, ultimately, fisheries management. The latter process (how to answer high priority questions) is usually best done by professional scientists because they are trained to be objective, impartial and to base their interpretations on rigorous analyses of available evidence. It is also well-accepted, however, that the best group(s) to lead the former process

(the prioritization of which scientific questions should be answered) should be the end-users of the research results, i.e. the decision-makers, fisheries managers and the stakeholders themselves. This is because these groups are in the best position to decide which areas of inquiry would contribute to decisions that would lead to the greatest improvement in the particular "stakes" in which they have a "holding".

In order to achieve this prioritization process for fisheries research issues, a good way to proceed is to adopt a similar methodology as that suggested in Section 4 to prioritize management issues using risk assessments. That is, by adapting that process for research and scientific programmes, fisheries managers can work with scientists and stakeholders to determine the severity of the consequences for a fishery by NOT doing a particular piece of research, versus the likelihood of those consequences occurring.

For some basic pieces of fisheries science, it is well-accepted that certain information-gathering processes should occur regularly for all fisheries – as a matter of course. These are programmes that contribute to indicators of stock status and are usually the benchmarks one uses to see how one's fishery is progressing and may include such indicators as catch per unit effort, the mean size at capture of species, the biomass of the juvenile and spawning stock.

The most basic data collection programmes involve the gathering of catch and effort information and basic catch composition. For other pieces of research, the priority depends to a large extent on the objectives and needs of the management plan for the fishery and the particular high priority management issues that need to be addressed.

For example, if bycatch of some species is a major issue (as it is in most trawl fisheries) then some sort of fishery-dependent observer programme may be needed from time to time that will quantify problematic issues. Similarly, some specific research projects may be needed to develop modifications to fishing gears that reduce such problematic bycatch.

Another example may be where there is a strong need for certain biological information about a species to address a particular management issue, in which case, targeted research about an animal's growth, fecundity or movements may be appropriate (using otoliths, reproductive studies or tagging programmes, respectively).

Appendix 3 contains details of the basic types of scientific information that may be needed by a fisheries manager and Table 15 summarizes their uses.

Table 15 Summary of basic types of scientific information that may be needed by a fisheries manager

Category of data	Information gathered	Methods	Used to
Catch and effort	• Total catches • Value of catches • Fishing effort • Bycatch data	• Port landings data • Industry-based logbooks • Independent observers (including bycatch data) • Electronic systems	• Estimate relative abundance of stocks • Determine status of stocks harvested • Determine relative productivity of the fishery • Understand bycatch interactions • Inform decisions about space/time closures
Length and age composition	• Length distributions of species • Age compositions of species	• Length measurements of samples from markets or fishers • Ages of samples of fish (otoliths)	• Assess the health of the stocks • Inform decisions about species size limits
Biological investigations	• Growth • Age • Diets • Movements • Spatial and temporal distributions • Reproductive biology (fecundity, age/size of maturity, location, timing and frequency of spawning)	• Genetic work • Otolith studies • Gonadal examinations • Gut content analyses • Tagging studies	• Inform decisions about species size limits • Assess the health of the stocks • Inform decisions about space/time closures
Habitat and ecosystem monitoring	• Size, location and extent of habitats • Size, location and extent of ecosystems	• Aerial photography • Swath mapping • Sidescan sonar • Underwater videos • Jump cameras • Dual frequency sonars • Geographic information systems (GIS)	• Establish habitat impact of fishing • Inform decisions about space/time closures
High technology	• Catch and effort data • Location and timing information • Bycatch data	• Vessel monitoring systems (VMS) • Electronic monitoring (EM) (onboard camera technology, engine and winch sensors)	• Inform decisions about space/time closures • Inform decisions about species size limits • Assess the health of the stocks • Understand bycatch interactions
Fishing technology	• Bycatch reduction devices • Selectivity work • Trawl gear development	• Field experiments • Flume tanks • Gear engineering	• Reduce bycatch and discards • Improve selectivity • Reduce habitat impacts • Reducing carbon footprint
Population dynamics	• Scenario reporting • Simulations and estimated consequences of management	• Modelling of all/part of the above data sets	• Evaluate the management strategy • Estimate the consequences of various management measures • Assess stock • Set the TAC

SECTION 10: Capacity development

Implementing a fisheries management plan using these guidelines requires significant resources of money and, more importantly, the specialist human resources needed to manage a fishery.

Training

The skills and expertise required of fisheries managers, scientists, compliance officers, skippers and crews in managing a fishery according to a strong management plan are quite significant and can only come from proper training and educational processes.

Fortunately there is no shortage of relevant courses available throughout the world, although unfortunately these courses are not readily available in developing countries, meaning that specialist trainers and educators often need to be brought in. However, if this is the case, it is often advisable to ensure that such courses and programmes are tailor-made for the specific fishery and people involved – so that time (and money) is not wasted on training people in elements that, although useful in a wealthy, data-rich fisheries jurisdiction, may not be very relevant in a less affluent, data-poor region.

There are several international initiatives in the area of such training for developing countries. Of particular relevance for fisheries managers are:

- "Essential Ecosystem Approach to Fishery Management" (E EAFM). This is a regional course specifically designed for the training of fishery managers, fishery officers and other stakeholders in EAFM in the Asian region.[13]
- "EAFnet" which has been developed to facilitate access to the information and resources that are available at FAO on the application of the Ecosystem Approach to Fisheries (EAF).[14]

It is also important that fisheries managers have appropriate training in people skills such as conflict resolution, communication techniques and how to chair and run meetings and committees.

Table 16 provides a list of the sorts of skills needed for fisheries managers.

[13] An open-source, regional training course developed by FAO/BOBLME/NOAA/US-CTI/APFIC (2013) (available at http://www.apfic.org/training/eafmtraining.html).
[14] Developed by FAO, this is available at http://www.fao.org/fishery/eaf-net/en

Table 16 Skills and capacity development needs for fishery managers

Category:	Skills:
General	Principles of natural resource management
	Leadership
	Team management
	Project management
	Proposal writing
	Facilitating and chairing meetings
	Time management
Consultation	Stakeholder engagement
	Conflict resolution
	Negotiation
	Participatory engagement
	Effective relationship building
Scoping	Economic evaluation or identification of issues
	Basic scientific understanding – MSY and MEY
Prioritization	Risk assessment
	Productivity-susceptibility analysis
Science	Fisheries biology
	Fisheries development
	Resource assessment
	Fishing gear knowledge
Developing fisheries management plans	Plan drafting
	Legislation drafting
	Negotiation and consultation
	Influencing skills
Implementation	Presentation skills
	Communication skills – both up and down
	Industry liaison
	Political briefing
	Media training
	Developing and tracking performance indicators
	Community engagement skills
Monitoring, control and surveillance	Understanding the basics of MCS
	Enforcement/compliance
	Risk based approach to directing compliance operations
Training fishers	Areas of training useful for fishers: • Stock assessment • Using fisheries information • The importance of ETPs and ecosystems • Leadership • The importance of data in fisheries management • Co-management • Communication

SECTION 11: Funding

Developing the financial capacity to fund the fisheries management process and its many components (management measures, compliance, research, administrative functions, etc.) is a major challenge when establishing a fishery management plan and there are numerous ways to obtain such funding. Of course there are often temporary funding sources available that can assist in establishing a management regime in a fishery (through the various aid and granting organizations) but there are also ways to obtain ongoing funding (once those start-up grants are completed) from the fishery itself and/or the government. Levy schemes (where a charge is placed on each kilogram of fish sold), fees-for-service arrangements, charges on quota transfers, tariffs on competing imports, are all ways that have been used to fund the management of fisheries on an ongoing basis.

Developing the case for more effective management to unlock budget allocations

One of the most significant sources of funding for fisheries management usually comes from governments (who are charged with the responsibility of managing the natural resources that are exploited by fishers – but owned by the public). To obtain adequate funding from government (local or national) budgets it is necessary to demonstrate:

- the value of the fishing sector to the local or national economy;
- the importance to livelihoods of local populations;
- why effective management of the fishery is in the local or national interest; and
- how the information collection/monitoring and consultation processes are necessary to enable effective management.

This information can be developed by carrying out economic surveys of the true value of a fishing industry (e.g. the value of the landed catch, value of processing sector, exports, number of people employed in the various parts of the market chain) and also by estimating:

- the financial value of the various ecosystem services that are being impacted by the fishery;
- the lost value of undersized catch, loss of resource rents and costs of mismanagement (or lack of action);
- the costs to maintain or rehabilitate ecosystem services which have been adversely impacted;
- the value of direct and indirect government subsidies to the fishery; and
- the cost of monitoring.

By factoring in the true social and economic benefits of the fishery (in terms of flow-on benefits), the economic argument for managing the fishery can be made clearer to those responsible for allocating funds for management.

Effective communication is the key and this will often mean arranging briefings for appropriate treasury officials, politicians and the media so that the true value of the sector is known and appreciated.

Improving management does not always require additional funding. It may be more effective to seek the redirection of existing funding. An example could be the re-allocation of funds currently used for fuel subsidies to more appropriate uses such as rewards for boats that comply with regulations.

No matter what the funding base available, it is important to properly integrate the fishery management system in terms of human and financial capacity within the local system of government. In many cases, this considerably restricts what can be achieved, unless there is strong support from the fishery stakeholders.

It is also simply not true that "more money means better management". Money certainly helps (of course), but it is often the case in fisheries management that it is possible to achieve excellent outcomes by working **smarter** – not necessarily **richer**. This of course, brings us back to the concepts introduced in Section 4 of these guidelines where a risk based approach to management allows one to direct limited resources to the highest priority components.

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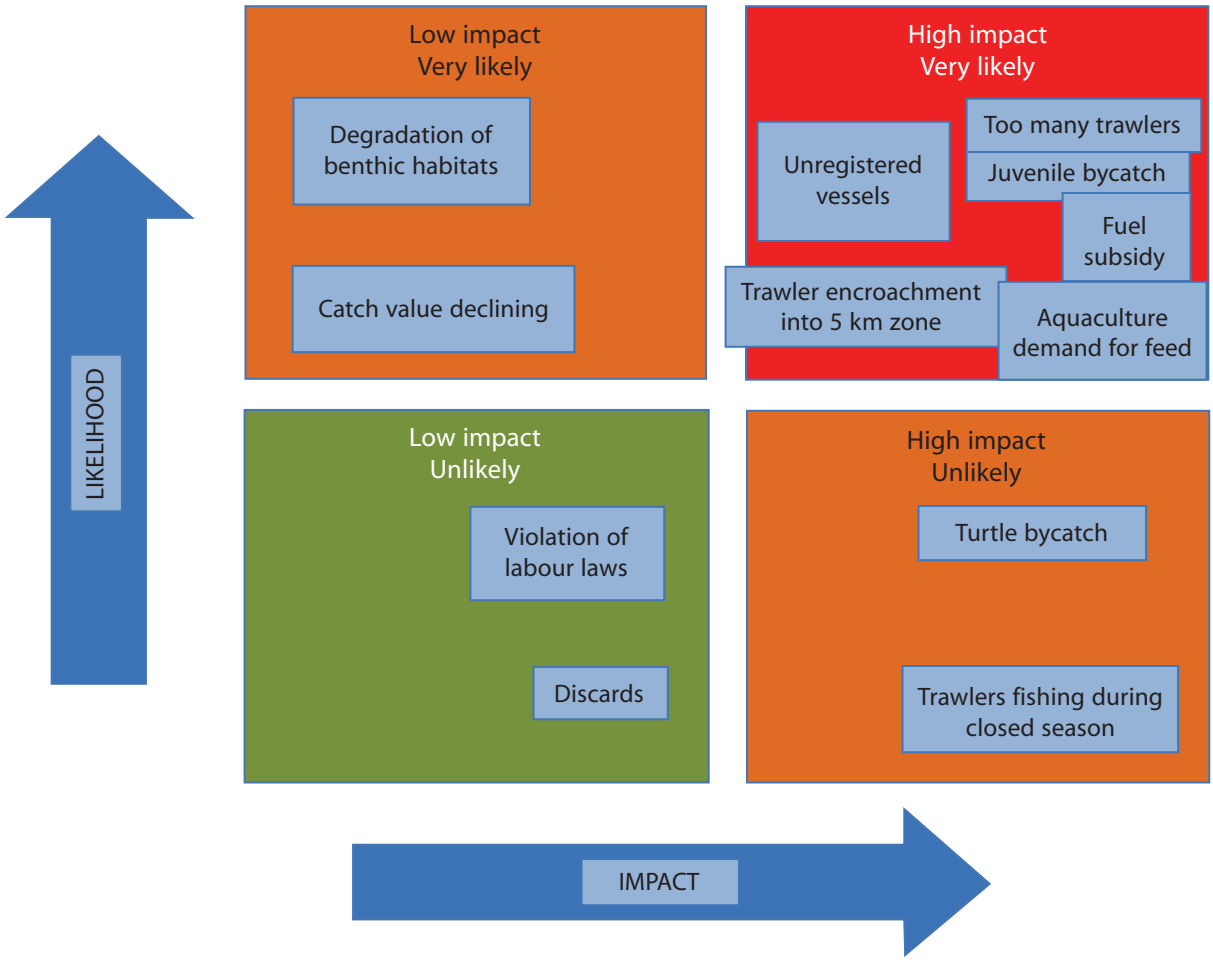
Appendix 1: Example of applying a risk assessment to typical issues occurring in a tropical trawl fishery

Identified fishery issue	**Likelihood** Likely to occur or common (2) Not likely to occur or rarely (1)	**Consequence** Low impact (1) High impact (2)	**Risk score**
Turtle bycatch	1	2	2
Catch value declining, low profitability	2	1	2
Discarding	1	1	1
Violation of labour laws prevents access to high value market	1	1	1
Aquaculture demand for feeds drives demand	2	2	4
Degradation of benthic habitats	2	1	2
Unregistered vessels undermine measures	2	2	4
Trawlers fishing during closed season leads to conflicts	1	2	2
Conflicts from trawler encroachment into 5 km reserved zone	2	2	4
Too many trawlers drives overfishing	2	2	4
Bycatch of juvenile fish impacts recruitment, lowers value	2	2	4
Fuel subsidy allows heavy effort	2	2	4



Appendix 2: Example of productivity-susceptibility analysis (PSA) for a trawl fishery

Tables showing the criteria and cut-offs for productivity and susceptibility which could be used or adapted for a tropical trawl fishery (adapted from Patrick *et al*., 2009 and Hobday, 2007)

Productivity attributes	Low productivity/ High risk	Medium productivity/ Medium risk	High productivity/ Low risk
	Score 3	Score 2	Score 1
Average age at maturity (years)	>4	2–4	<2
Average maximum age (years)	>30	10 to 30	<10
Fecundity (eggs/spawning)	<1 000	1 000 to 10 000	>10 000
Average maximum size (cm)	>150	60 to 150	<60
Average size at maturity (cm)	>150	30 to 150	<30
Reproductive strategy	Live bearer, mouth brooder or significant parental investment	Demersal spawner "Berried"	Broadcast spawner
Mean trophic level	>3.25	2.5–3.25	<2.5

Susceptibility attributes		High susceptibility/ High risk	Medium susceptibility/ Medium risk	Low susceptibility/ Low risk
		Score 3	Score 2	Score 1
Availability	(1) Overlap of adult species range with fishery	>50% of stock occurs in the area fished	25% and 50% of the stock occurs in the area fished	<25% of stock occurs in the area fished
	(2) Distribution	Only in the country/ fishery	Limited range in the region	Throughout the region/ global
Encounterability	(1) Habitat	Habitat preference of species make it highly likely to encounter trawl gear (e.g. demersal, muddy/sandy bottom)	Habitat preference of species make it moderately likely to encounter trawl gear (e.g. rocky bottom/reefs)	Depth or distribution of species make it unlikely to encounter trawl gear (e.g. epi-pelagic or meso-pelagic)
	(2) Depth range	High overlap with trawl fishing gear (20 to 60 m depth)	Medium overlap with trawl fishing gear (10 to 20 m depth)	Low overlap with trawl fishing gear (0 to 10 m, >70 m depth)
Selectivity		Species >2 times mesh size or up to 4 m length	Species 1 or 2 >mesh size or 4 or 5 m length	Species <mesh size or >5 m length
Post capture mortality		Most dead or retained Trawl tow >3 hours	Alive after net hauled Trawl tow 0.5 to 3 hours	Released alive Trawl tow <0.5 hours

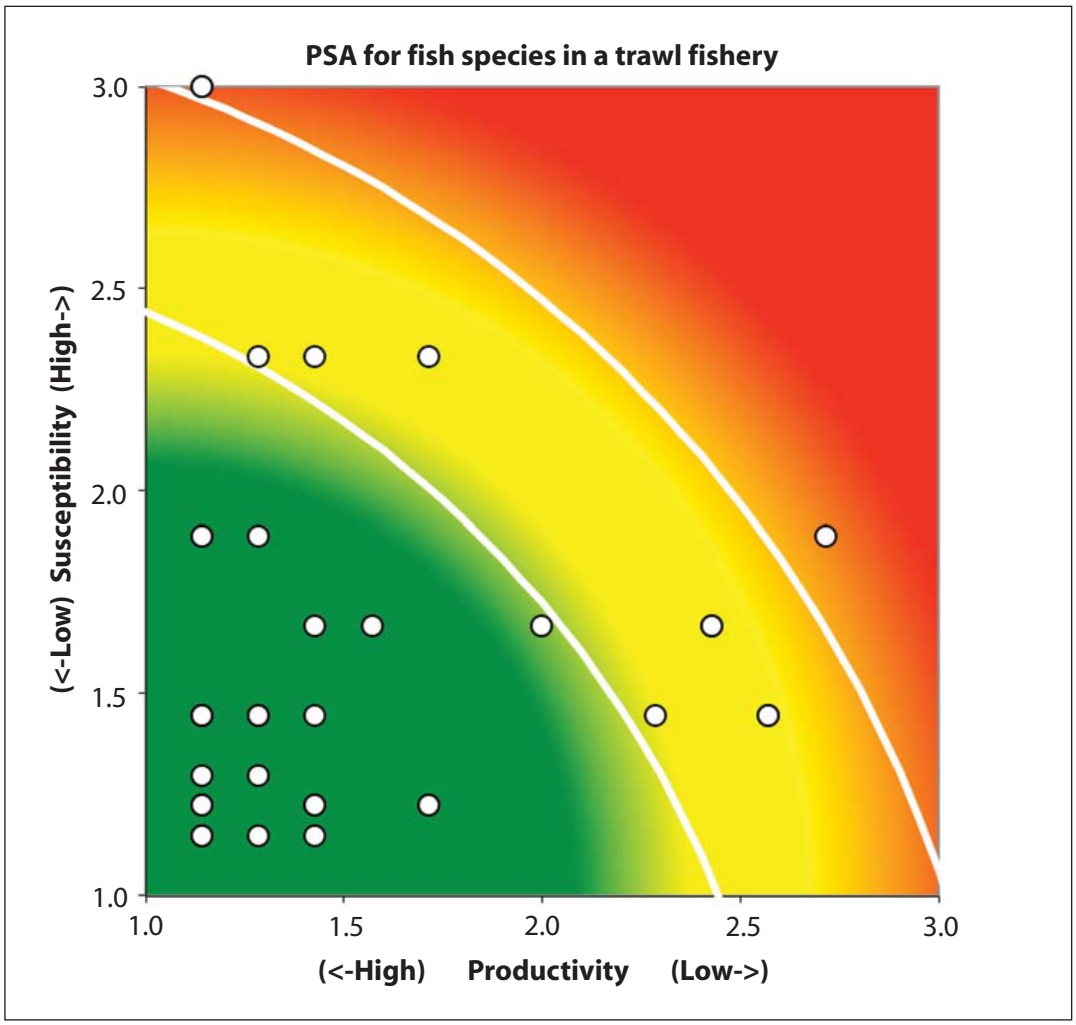
Notes:
Availability (2) is only used when there is no information for Availability (1).
The most conservative score between Encounterability (1) and (2) is used.

An example of a PSA table for 32 species in a demersal tropical trawl fishery

	PRODUCTIVITY ATTRIBUTES								SUSCEPTIBILITY ATTRIBUTES					OVERALL RISK VALUES	
FISH NAME	Average age at maturity	Maximum age	Fecundity	Average maximum size	Average size at maturity	Reproductive strategy	Trophic level	Productivity score (additive)	Availability	Encounterability	Selectivity	Post-capture mortality	Susceptibility (multiplicative)	2D Overall risk value (P&S) (multiplicative)	2D P&S Overall risk category (multiplicative)
Sea turtle	3	3	2	3	3	2	3	2.71	2	2	3	3	1.89	3.307	High
Snapper	1	1	1	1	1	2	2	1.29	3	3	3	3	3.00	3.264	High
Sea catfish	1	1	1	1	1	1	2	1.14	3	3	3	3	3.00	3.210	High
Shark (1)	2	3	3	2	2	3	3	2.57	1	2	3	3	1.44	2.949	Med
Guitarfish	2	2	3	2	2	3	3	2.43	1	3	3	3	1.67	2.945	Med
Threadfin (1)	1	2	1	2	2	1	3	1.71	2	3	3	3	2.33	2.895	Med
Croaker	1	2	1	1	1	1	3	1.43	2	3	3	3	2.33	2.736	Med
Shark (2)	1	2	3	2	2	3	3	2.29	1	2	3	3	1.44	2.704	Med
Stingray	2	2	3	1	2	2	2	2.00	1	3	3	3	1.67	2.603	Low
Croaker	1	1	1	2	2	1	3	1.57	1	3	3	3	1.67	2.291	Low
Spiny lobster	1	2	1	1	1	1	2	1.29	2	2	3	3	1.89	2.285	Low
Swimming crab	1	1	1	1	1	1	2	1.14	2	2	3	3	1.89	2.208	Low
Trevally	1	1	1	1	1	1	2	1.14	2	2	3	3	1.89	2.208	Low
Threadfin (2)	1	1	1	1	2	1	3	1.43	1	3	3	3	1.67	2.195	Low
Barracuda	1	2	1	2	2	1	3	1.71	1	1	3	3	1.22	2.105	Low
Grouper	1	2	1	2	2	1	3	1.71	1	1	3	3	1.22	2.105	Low
Puffer fish	1	2	2	1	1	1	2	1.43	1	2	3	3	1.44	2.032	Low
Sea bass	1	1	1	1	2	1	2	1.29	1	2	3	3	1.44	1.934	Low
Sole	1	1	1	1	2	1	2	1.29	1	2	3	3	1.44	1.934	Low
Sea snail	2	2	1	1	1	2	1	1.43	1	1	3	3	1.22	1.880	Low
Threadfin (3)	1	2	1	1	1	1	3	1.43	1	1	3	3	1.22	1.880	Low
Lizardfish	1	1	1	1	1	1	2	1.14	1	2	3	3	1.44	1.842	Low
Pompano	1	1	1	1	1	1	2	1.14	1	2	3	3	1.44	1.842	Low
Mullet	1	1	1	1	1	1	2	1.14	1	2	3	3	1.44	1.842	Low
Triggerfish	1	2	1	1	1	2	2	1.43	1	2	1	3	1.15	1.833	Low
Cuttlefish	1	1	1	1	1	1	3	1.29	1	2	2	3	1.30	1.826	Low
Squid	1	1	1	1	1	1	2	1.14	1	2	2	3	1.30	1.728	Low
Large head hairtail	1	1	1	1	1	1	3	1.29	1	1	2	3	1.15	1.724	Low
Grunt	1	1	1	1	1	1	2	1.14	1	1	3	3	1.22	1.673	Low
Horse mackerel	1	1	1	1	1	1	2	1.14	1	1	3	3	1.22	1.673	Low
Shrimp (1)	1	1	1	1	1	1	2	1.14	2	1	1	3	1.15	1.620	Low
Shrimp (2)	1	1	1	1	1	1	2	1.14	2	1	1	3	1.15	1.620	Low

After doing this exercise, one can use this information to create a graph illustrating the relative risks associated for the various species based on their productivity and susceptibility.

The graphical representation of species in a demersal trawl fishery on a PSA plot is shown below.



Appendix 3: Basic types of scientific information that may be needed by a fisheries manager

Catch and fishing effort data

These data come from the fishery and are often the only data available. Records of total catches are usually available long before any other information about a fishery and its component stocks because the information about the catch and its value is important for economic reasons. However, total catches alone tells us little about the state of the fishery, since the same total catch could be taken from an underfished as well as an overfished stock. To have a real understanding of the fishery, some measure of fishing effort is usually required. Although it is not always easy to collect a meaningful index of fishing effort, sometimes crude estimates will suffice. By collecting information on catch and the effort that was required to catch it, some estimates of relative abundance of stocks can be possible and are often quite informative for assessing the status of stocks harvested and the relative productivity of the fishery.

There are various ways to collect information on catch and effort. The crudest examine landings data at port (which often lack effort information). Better data come from industry-based logbooks when they are filled out onboard vessels during normal fishing operations. Of course such information relies heavily on the accuracy and precision with which skippers and crews record it, but if done properly logbooks can be a very useful and accurate means to monitor a fishery and the stocks caught.

Another way to collect these data involves the use of independent observers on vessels whose job is to record information on catches and effort, as well as (usually) bycatch and discards. Such programmes are often quite expensive because they require the employment of an additional person on a vessel and can be quite impractical in small-scale fisheries that involve small boats. Nevertheless these programmes are generally accepted as the most accurate way to record information on bycatch and discards in a fishery. Because of the expense involved in such programmes, however, it is common to have observers only on a representative sample of trips and vessels.

Length and age composition data

Other useful types of data provided from fishing are length compositions of samples of catches and, but not always, age data (obtained by ageing samples of individuals which, for finfish, can be done using otoliths). If a good statistical system is used to sample the catches, then the characteristics of the population exploited (for example, in terms of its age composition) can be estimated and used in assessing the health of the stocks, and formulating management measures such as species size limits. However, thousands of measurements are needed to determine the age structure/profile of the different species in the fishery.

Collecting samples to derive such data can be expensive, especially in developing countries. But more and more use is being made of fishers in this regard. In numerous cases, individual fishing vessels are used as sampling platforms and they provide bags of frozen or iced bycatch or other species to scientists. Such practices carry a double benefit inasmuch as the samples are provided for science, but also the engagement of fishers in that science can contribute to their feeling of ownership over the whole management process.

Biological investigations

Because fisheries involve the exploitation of natural populations, it is useful to know as much about the biology and ecology of the species harvested as possible. Information about the growth, age, diets,

movements, spatial and temporal distributions, reproductive biology (in terms of fecundity, age/size of maturity, location, timing and frequency of spawning) are all characteristics of a species that are very important to know when developing measures to manage a fishery. Such characteristics are also useful when doing the productivity-susceptibility analyses discussed in Section 4 and, as noted in that section, can often be determined from the scientific literature. Occasionally, however, targeted research may be necessary to determine certain key characteristics if they are unknown but vital to inform a high priority management measure. Such studies may employ a variety of methods including genetic work, otolith studies, gonadal examinations, gut content analyses and tagging studies (it is worth noting that there have been remarkable advances in recent years in tagging technology with very sophisticated, long-lasting, satellite and acoustic tagging methods now used widely throughout the world).

Habitat and ecosystem monitoring

Because all marine resources exploited by fisheries ultimately rely on the ecosystems that they inhabit, it is often desirable to have adequate understanding of the composition and extent of those ecosystems, in terms of the species present, how they interact and their typical habitats. Such information can inform ecosystem models and assist the fisheries manager in estimating the impacts of various fishery activities and subsequent management measures on the species within the ecosystem. Better understanding also sheds light on how the different species interact with the system and the inter-species interactions within the same ecosystem.

Basic information on habitats is also useful for setting boundaries around stocks and fisheries and therefore can assist in identifying areas of particular importance that may prove to be candidates for special protection via management measures involving spatial closures. Techniques for studying and mapping marine habitats and ecosystems have advanced significantly in recent years, with, for example, swath mapping, sidescan sonar, underwater videos, jump cameras, and dual frequency sonars all being used more routinely in a variety of geographic information systems (GIS).

Developments in information technology

The advances that have occurred in recent years as a result of more powerful computing abilities, telecommunications, satellite usage through GPS, the Internet, etc. have greatly improved the tools available to fisheries scientists and therefore have greatly enhanced the quality of the information and analytical tools available to fisheries managers for improved decision-making. Vessel monitoring systems (VMS) are being used quite routinely throughout the world to track vessels and determine what they are doing. This has been especially useful in trawl fisheries where the speed of vessels can identify when trawlers are trawling or moving between fishing areas and so greatly improve estimates of fishing effort. Such systems are also extremely valuable for monitoring, control and surveillance operations as individual vessels can be tracked in real time. Some of the latest technological developments in fisheries monitoring involves electronic monitoring (EM), where onboard camera technology as well as engine and winch sensors can often replace observers on vessels and, at a reduced cost, provide high quality information on catches, discards, sizes of fish and fishing effort, and/or greatly improve the quality of information from onboard logbooks.

Fishing technology

Since humans began fishing (at least 90 000 years ago), fishing technology has developed with the objective of trying to catch the greatest quantities of fish possible, of an ever-increasing variety. It has only been during the last few decades that fishing technologists have begun to focus on goals that seek to make fishing gears and practices more sustainable. This occurred initially in response to concerns over the bycatch of photogenic species (such as dolphins in tuna purse-seines) but quickly broadened to address the discarding of not-so-photogenic species (such as juvenile fish killed by

trawling). To mitigate these issues, technologists and fishers developed various innovative gear-based and operational solutions such as various types of separator grids and panels, square mesh panels, fish eyes, square mesh cod-ends, turtle exclusion devices. An incremental framework has been followed to achieve these successes involving:

(i) the identification of problems using observer programmes;
(ii) developing technological solutions to these problems;
(iii) experimentally testing them;
(iv) implementing them throughout the fishery; and
(v) gaining acceptance of the solutions from key interest groups.

Most recently, public concern has broadened once again from bycatch issues to impacts of fishing (and in particular mobile methods such as trawling) on entire ecosystems. For example, there is now heightened concern over habitat damage caused by such methods and cascading impacts on all species in the system, not just those caught, retained or discarded. Although identifying and quantifying such issues are difficult, finding solutions to identified problems is an even greater challenge, particularly for fishing technologists. The simplest solutions to such problems involve management strategies such as closures. A less extreme alternative involves the development of new technologies that reduce the impacts of fishing on ecosystems, in a similar way as that mentioned above to reduce bycatch problems. Innovations such as altering ground chains, foot ropes, sweeps and trawl doors are being examined as ways to mitigate the environmental damage done by trawling, and at the same time also reduce the drag of the gear and therefore fuel costs. Although such research is still in its infancy, the recent history of fishing technology is characterized by meeting such challenges successfully, giving one confidence that solutions to such issues will eventually be developed. Integral to the success of such work, however, is a corresponding improvement in the adoption of new methods by fishers. History has taught us that this is best achieved by involving fishers in all aspects of the work.

Fish population dynamics

To put all this information to use, sophisticated population dynamics modelling is usually done to enable the fisheries scientist to answer the questions posed by fisheries managers. These models try to estimate the operation of the fishery in relation to the biology and ecology of the species exploited and come up with predictions about what may happen to the exploited populations and the fishery under various management interventions. Such models have become more and more sophisticated in recent years, especially with the increased computing power now available.

But it is always useful to remember when working with models (and with all forms of fisheries information), that the more accurate the data that one collects about a stock, a population or a fishery, the better the models and predictions will be and, therefore, the better the fisheries management will be.

Appendix 4: Some examples of management plans

<table>
<tr><th>Item</th><th>Indicative content of management plan</th></tr>
<tr><td>Title</td><td>Management plan for a coastal multispecies trawl fishery</td></tr>
<tr><td>Vision</td><td>Higher biomass; profitable fishery; healthy ecosystem</td></tr>
<tr><td>Background</td><td>
Description of the fishery:

Annual production: 220 000 tonnes.

Target species: All species, squid sp. demersal and large pelagic, croakers, grunts.

Approximately 40% of catch is trash fish (range 30% to 60%).

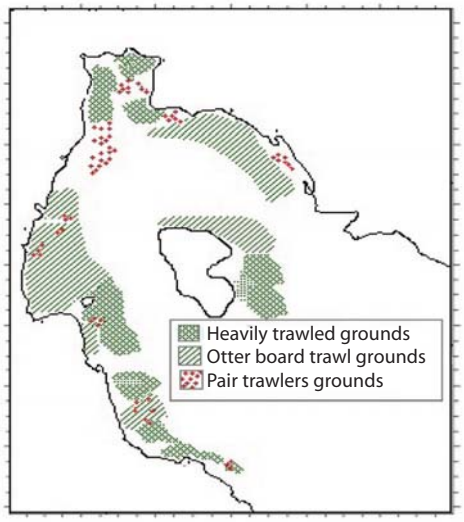
Poor quality.

No of vessels: 1 096.

Ownership pattern: Private.

Length: 16 to 24 m.

Gear: Otter board trawl & pair trawl.



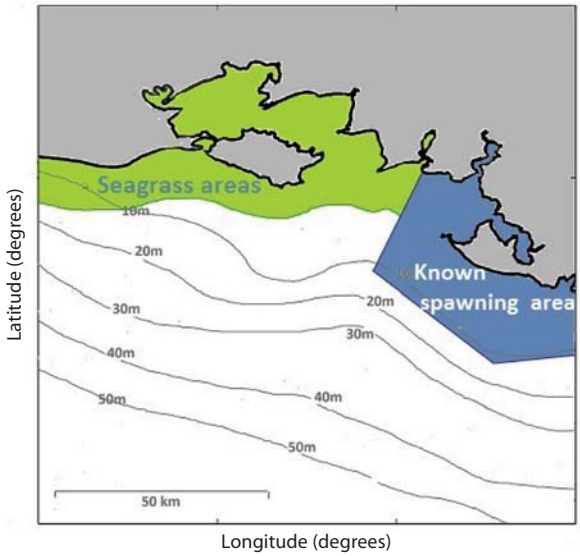
<table>
<tr><td><10 GT</td><td>10 to 29 GT</td><td>>50 GT</td></tr>
<tr><td>2</td><td>518</td><td>576</td></tr>
</table>
CPUE: Variable 15 to 60 kg/hr; average ~30 kg/hr
Typical depth of fishing: 20 to 50 metres
Large vessels trip length 1 or 2 weeks with some transfers between boats
Smaller vessels 1 or 2 days

History of fishing and management:
Fishery expanded rapidly in the 1970s and catches peaked in the early 1980s. Fishing down the food chain has occurred with current catches increasingly consisting of small, low value/trash fish and juveniles of more valuable species.

Existing management arrangements
Licensing: A license and registration system is in place, however 10% of vessels are not licensed (or are licensed for another gear).
Mesh size: There is no regulation on mesh size. Spatial closures are in place for three months each year. Inshore: 3 nm – permanent closure. There is a current freeze on boat numbers.
Landings: monitored at the port by provincial government; sampling for research
Protected areas (sanctuary and marine parks)
3 km from shore trawler exclusion zone
500 metres around the offshore platforms
3 month closure to trawling in selected areas
New closed season of inshore areas for 2 months
VMS under trial.
</td></tr>
</table>

Item	Indicative content of management plan		
	Current status of the fishery's resources: Single species stock assessments for few species – shows declining stock abundance Decline of catch and CPUE ETP species in trawls (but not in great numbers) – sea horse, turtle, dugong, dolphins.		
	Socio-economic benefits of the fishery, including post-harvest: Profitable fishery based on several market chains involving both human and animal feed 60% of the landings now used for fish meal + surimi.		
	Stakeholders: Industry – private industry (harvest, processing and exporters); state owned enterprises; Local – local communities; local government. National – national fisheries agency; enforcement agencies (on board inspections); national research institute. Non-government – NGOs (environmental). Academia-science and research. Other sectors – aquaculture.		
	Any special environmental considerations for the fishery: Species at risk – Sharks, rays.		
	Institutional aspects: Existing Legislation: Ten provinces have 3 nm exclusion zone (others have 3 km), freeze on number of vessel licenses; decree on the closed season Incomplete MCS and no logbooks.		
Major issues for management	Overcapacity Large catches of small low value/trash fish; large catch of juvenile fish Conflict with artisanal gears (gill nets, fixed gear) Impact on critical habitats Low profitability Poor governance, weak MCS Catching ETP.		
Management goals	1) Rebuild fish stocks 2) Protect sensitive/representative areas 3) Improve profit per boat.		
Management objectives	**Objective**	**Indicator**	**Benchmark**
	Reduce overcapacity	No. of trawlers over 20 metres/50 GT	<1 500 trawlers by 2020
	Increase CPUE	CPUE (research vessel)	Increase current CPUE of <30 kg/hr to 100 kg/h by 2020
	Increase size of capture/reduce juvenile catch	10 indicator species	For 10 indicator species: 25% increase in MLL (larger sizes of threadfins, lizardfish, goatfish etc.)
	Reduce conflict with artisanal gears	No. of reported conflicts	Reduce the number of reported conflicts by 50% by 2020
	Better governance (Strengthen MCS)	Number of cases where action taken Management arrangements MCS arrangements	Current arrangements
	Reduce number of ETP & at-risk species	ETP captures	Current level

Item	Indicative content of management plan		
	Increase profitability	Percentage of small vessels showing profit	Increased percentage of small vessels showing profit
Management measures	1. Cap and reduce licenses and vessels 2. Industry buyback of unprofitable vessels 3. Extend artisanal zone to 6 nm 4. Increase mesh size (Note: Specify 40 mm in the rules and regulations) 5. Reduce HP & head rope 6. Fit turtle excluder devices 7. Increased VMS monitoring and reporting 8. Extend no trawling closed areas to 3 nm from shore 9. Establish a management unit in the Fisheries Department and form a Steering Committee (Management Advisory Committee) of key stakeholders 10. Establish A MCS task force of all relevant agencies		
Implementation arrangements	**Actions to be taken**	Provincial governments required to extend zones legally to 6 nm Better MCS and controls for inner and outer Gulf There is need to have an overarching management for the fishery in which provincial management plan are a part of and agreed by all parties Collaboration and cooperation between provincial Governments to have coherence in the plan. Needs for steering committee, wide stakeholder consultations and recordings of meetings and processes Education related to rules, limits for all persons.	
	Data and information needs	Monitor the indicators listed above	
	Financing	Build the development and implementation of the plan into the fishery department's budgetary cycle Investigate the willingness of industry to contribute to better management for their benefit.	
	Communication	Establish a communication plan that identifies the target audience and key messages for each.	
	Review of the plan	Review the indicators against benchmarks annually and undertake a major review of the plan every five years.	

Item	Indicative content of management plan
Title	**Management plan for the [name] shrimp trawl fishery**
Vision	*Sustainable shrimp trawling with minimum environmental impacts to generate foreign exchange income for the benefit of the country.*
Background	**Description of the fishery:** – 120 vessels, 100 to 350 GT, 35 to 45 metres overall length – Main gear of the trawl fishery is double rigged otter board trawl with a mesh size of 30 mm operated from larger commercial vessels – Operates in shallow coastal areas targeting shrimp (economic high value) – Each trip extends for a month or more with a large crew  – The fishery operates close to critical/sensitive habitats (seagrass, mangroves – nursery areas). – Operating predominantly during night-time, but also some day-time fishing – Some discarding occurs (~80%) – Interacts with fish trawl (113 vessels) – The shrimp is exported to foreign markets and carrier boats are used in specific areas to transport the catch – All vessels are fitted with VMS.
	History of fishing and management: Started in late 1960s/early 1970s as a beam trawl fishery in shallow coastal waters, rapidly increasing number of fishing vessels. Trawling was introduced from Japan, promoted (and owned) by government. The resource was formerly for local use, but driven by export potential, the fishery expanded to deeper offshore waters. Catch peaked in late 1970s, after that declined. There is competition between and among fishery sectors, and competition with aquaculture sector for spawners and same markets for shrimp.
	Existing management arrangements Mandatory use of TEDs in shrimp trawls, but not required in fish trawls.
	Current status of the fishery's resources: To the best of available knowledge, the resource status is still relatively healthy. Highly productive stock, fast turnover. There is some concern that fishing removes too many spawners. There is also concern of overcapacity.
	Socio-economic benefits of the fishery, including post-harvest: Main benefits of the fisheries are from export earnings. Foreign markets Japan and USA for larger sizes, local markets for smaller sizes. On board processing occurs, also processing factories on shore. Sold as "head on" if high quality is high, "headless" if lower quality. Total value difficult to estimate.

<table>
<tr><th>Item</th><th colspan="3">Indicative content of management plan</th></tr>
<tr><td></td><td colspan="3">Stakeholders:
Industry – private industry (harvest, processing and exporters); fisheries/shrimp associations; state owned enterprises; Local – local communities; local government. National – National fisheries agency; enforcement agencies (onboard inspections); national research institute. Non-government – NGOs (environmental). Academia – science and research. Other sectors – aquaculture (utilize bycatch as feed).</td></tr>
<tr><td></td><td colspan="3">Any special environmental considerations for the fishery:
Interaction with turtles in some areas. CITES and Red List concerns
Degradation of coral reefs and seagrass habitats by trawling.</td></tr>
<tr><td></td><td colspan="3">Institutional aspects:
Fishery is under national government management but there is no specific management unit within fisheries department. No formal institutional arrangements for management councils or management advisory councils. Research done by department's research branch and universities. Legal basis is the national fisheries law and some environment/ wildlife acts.</td></tr>
<tr><td>Major issues for management</td><td colspan="3">The following are high priority issues based on a risk assessment/issue prioritization exercise.
No management arrangements
Overcapacity
Discards
IUU fishing
Habitat impact by gear
Low profitability
Weak MCS
Other issues that were considered as lower priority included: Conflict among sectors; ghost fishing; ecosystem impact; growth overfishing; bycatch of turtles, and lack of information.</td></tr>
<tr><td>Management goals</td><td colspan="3">1) Healthy shrimp resources and associated species and habitats
2) Equitable distribution of sustained foreign income earnings.</td></tr>
<tr><td rowspan="8">Management objectives</td><td>Objective</td><td>Indicator</td><td>Benchmark</td></tr>
<tr><td>Fishing capacity in balance with productivity of the stock</td><td>No. of licenses
No. of vessels</td><td>No. of licenses and vessels capped at present level for 3 years and then reduced by 30% by 2025</td></tr>
<tr><td>Minimized discards</td><td>Quantity of discards</td><td>Amount of discards reduced by 505 by 2020</td></tr>
<tr><td>Stop IUU fishing by foreign vessels</td><td>No. of foreign vessels reported</td><td>Reduce no. of foreign fishing vessel reporting by 50% by 2020</td></tr>
<tr><td>Maintain and improve habitat status</td><td>Area of mangrove and seagrass</td><td>Increase area of mangrove and seagrass by 30% by 2025</td></tr>
<tr><td>Increase profitability of shrimp trawling</td><td>Profit per vessel</td><td>Increase the profitability of vessels by 20% by 2020</td></tr>
<tr><td>Effective management arrangements</td><td>Management unit
Management advisory committee</td><td>Current arrangements</td></tr>
<tr><td>Strengthened MCS arrangements</td><td>Coordinated MCS group
No. of arrests</td><td>Current arrangements</td></tr>
</table>

Item	Indicative content of management plan	
Management measures	1. Cap and reduce licenses and vessels 2. Limit duration of operation and boat days 3. Two for one entry scheme 4. Head rope limit (head rope total for fishery) 5. Mandatory net panels and BRDs 6. Increased VMS monitoring and reporting 7. Permanent closure of nursery areas 8. Establish a management unit in the fisheries department and form a steering committee (management advisory committee) of key stakeholders 9. Establish A MCS task force of all relevant agencies.	
Implementation arrangements	**Actions to be taken**	Plan to be implemented by fishery department (including the relevant fisheries manager who would lead and chair the committee), key industry stakeholders, and representatives from other stakeholder groups who have an interest in the fishery, its operations and/or interactions. The committee's function is, through a series of meetings, drafting sessions and constant iterative feedback, to refine the management plan by working through its various elements.
	Data and information needs	Monitor the indicators listed above.
	Financing	Build the development and implementation of the plan into the fishery department's budgetary cycle Investigate the willingness of Industry to contribute to better management for their benefit.
	Communication	Establish a communication plan that identifies the target audience and key messages for each.
	Review of the plan	Review the indicators against benchmarks annually and undertake a major review of the plan every 5 years.

Appendix 5: Agenda of the regional expert workshop

APFIC/FAO Regional Expert Workshop on Tropical Trawl Fishery Management
Phuket, Thailand, 30 September–4 October 2013

Day 1	**30 September 2013**
08.00–08.30	**Registration**
08.30–09.00	**Opening** *Department of Fisheries, Thailand* Welcome by Mr. Vili Fuavao, Deputy Regional Representative, FAO Regional Office for Asia and the Pacific *APFIC Secretariat*
09.00–09.30	**Background to the expert workshop – *why we need trawl management guidance*** *Simon Funge-Smith, Secretary, Asia-Pacific Fishery Commission*
09.30–10.00	**Morning tea/coffee**
10.00–10.15	**Introduction to the expert workshop process** *Simon Funge-Smith, Secretary, Asia-Pacific Fishery Commission*
10.15–10.30	**Structure of the guidance document** *Presentation by Steve Kennelly, APFIC consultant*
SESSIONS 1 & 2	**Background and purpose**
10.30–11.30	**Short presentation of draft content** *Discussion of text* **Recommendations for amendment**
SESSION 3	**Scope, target audience, and general principles**
11.30–12.00	**Short presentation of draft content** *Discussion of text* **Recommendations for amendment**
12.00–13.30	**Lunch**
SESSION 4	**Identifying and prioritizing key management issues and measures**
13.30–14.00	**Short presentation of draft content** [Steve Kennelly] *Use of the three level approach*
14.00–15.30	**Case studies of key issues and management solutions for various countries** *Theme: Trawl fisheries management issues, solutions and how to prioritize them.* *Brief presentations of specific case examples (10 minutes each)*
15.00–15.30	**Afternoon tea/coffee**
SESSION 4	**Identifying and prioritizing key management issues and measures** *(continued)*
15.30–16.00	**Case studies of key issues and management solutions for various countries** *Theme: Trawl fisheries management issues, solutions and how to prioritize them.* *Brief presentations of specific case examples (10 minutes each)*
16.00–17.00	**Break into 4 groups to identify common or key issues arising from the case study presentations**

Day 2	1 October 2013
SESSION 5	**Management approaches**
09.00–09.15	**Short introduction and tasks of the day for groups**
09.15–10.30	**Discussion on content and key points in the guidance document Table 7** *Four working groups covering:* • *Conflict between fleet segments, including regulation/compliance* • *Overcapacity* • *Unprofitable trawl sector; carbon footprint* • *Exploitation of low value fish; Impacts on supporting industries*
10.30–11.00	**Morning tea/coffee**
11.00–12.00	**Discussion on content and key points in the guidance document Table 7** *(continued)*
12.00–12.45	***Plenary feedback session from the working groups***
12.45–14.00	**Lunch**
SESSION 5	**Management approaches** *(continued)*
14.00 –15.30	**Discussion on content and key points in the guidance document Table 7** *(continued)* *Four working groups covering:* • *Growth overfishing; bycatch, ghost fishing & other unidentified mortalities* • *Habitat impacts; effects on ecosystem function* • *IUU fishing; needs for effective MCS* • *Needs for science & monitoring; dialogue with industry*
15.30–16.00	**Afternoon tea/coffee**
16.00–16.30	***Plenary feedback session from the working groups***
16.30–17.00	**An introduction to Table 8** *General discussion on key management measures that address several management issues*
Day 3	**2 October 2013**
SESSION 5	**Management approaches** *(continued)*
09.00–09.15	**Short introduction and tasks of the day for groups**
09.15–10.30	**Discussion on management measures in guidance document Table 8** *All four working groups covering:* • *Space closures/time closures*
10.30–11.00	**Morning tea/coffee**
11.00–12.30	**Discussion on management measures in guidance document Table 8** *All four working groups covering:* • *Modifications to fishing gears and practices*
12.30–14.00	**Lunch**

SESSION 5	**Management approaches** *(continued)*
14.00–15.30	**Discussion on management measures in guidance document Table 8** *All four working groups covering:* • *Fishing Capacity Reduction*
15.30–16.00	**Afternoon tea/coffee**
16.00–17.00	***Plenary feedback session from the working groups to modify/complete Table 8***
Day 4	**3 October 2013**
SESSION 6	**Developing management plans – including examples**
09.00–09.30	Introduction to management planning
09.30–10.30	**Group work to develop some generic worked examples of management plans** *3-4 working groups each taking an example trawl fishery:* • *Small-scale coastal trawl fishery* • *Commercial pelagic/pair trawl fishery* • *Trawl fishery targeting surimi/low value fish for feeds* • *A shrimp trawl fishery* *These examples are to be developed for some typical developing country contexts, and also reflect levels 1, 2 & 3*
10.30–11.00	**Morning tea/coffee**
SESSION 6	**Developing management plans** *(continued)*
11.00–12.00	**Presentation of example management plans to plenary**
12.00–12.30	**Plenary discussion on amendments to the guidelines on the management plans**
12.30–14.00	**Lunch**
SESSION 7	**Implementation of management plan**
14.00–14.15	Short presentation of draft content on describing the steps involved in implementing a management plan
14.15–15.30	**Plenary discussion and comments on the draft text regarding implementation of management plan**
15.30–16.00	**Afternoon tea/coffee**
SESSION 8	**Monitoring, compliance and surveillance**
16.00–16.15	Short presentation of draft content on monitoring, control and surveillance
16.15–17.00	**Discussion of points on monitoring, control and surveillance approaches to be included in the guidance document**

Day 5	4 October 2013
SESSION 9	**Information, science and assessment**
09.00–09.15	Short presentation of draft content on Information, science and assessment
09.15–09.45	**Discussion of points on information/science/assessment approaches to be included in the guidance document**
SESSION 10	**Capacity building**
09.45–10.00	Short presentation of draft content on capacity building
10.00–10.30	**Discussion of points on capacity building approaches to be included in the guidance document**
10.30–11.00	**Morning tea/coffee**
SESSION 11	**Next steps in the process**
11.00–12.30	**How the guidance document will be finalized** The review process, commitments on further inputs by the expert group, Presentation to the 33rd Session of APFIC
12.30–13.00	**Lunch**
13.00–16.00	**Field visit**

Appendix 6: List of participants

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