The IUCN Species Survival Commission

Elasmobranch Biodiversity, Conservation and Management

Proceedings of the International Seminar and Workshop, Sabah, Malaysia, July 1997

Edited by Sarah L. Fowler, Tim M. Reed and Frances A. Dipper

Occasional Paper of the IUCN Species Survival Commission No. 25

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Darwin Initiative for the Survival of Species provided the grant for the project to take place.

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Cover photos: ABOVE Whale shark, *Rhincodon typus,* a focus of several papers in this volume. Photo by Jeremy Stafford-Deitsch. BELOW Images taken in Sabah, Malaysia, during the Darwin Initiative project on elasmobranch biodiversity, conservation and management (left to right): baskets of rays landed at Sandakan fish market; village children studying educational posters and leaflets; local fisherman with the Borneo river shark, *Glyphis* sp. B. Photos by Scott Mycock and Rachel Cavanagh.

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Dedication

This volume is dedicated to the memory of Sid Cook, Shark Specialist Group Member, Regional Vice Chair for the Northeast Pacific region of the Shark Specialist Group, advisor to the Darwin Project on Elasmobranch Biodiversity Conservation and Management in Sabah, and friend.

Contents

Foreword

It is my great pleasure to see this compilation of papers published on the diversity of sharks and rays, the socio-economic importance of some of these populations, and the exploitative and non-exploitative threats to their survival. All of these were presented at an International Seminar and Workshop on elasmobranch biodiversity, conservation and management in the Indo-Pacific Region, held in Sabah, Malaysia. This Proceedings Volume covers a wide geographic area, with contributions from authors from 14 countries including Malaysia, Indonesia, Japan, Singapore, Philippines, Taiwan and Thailand, and reports the richness of shark and ray species from freshwater bodies, estuaries, and the seas in this Region. The volume is a vital reference for students, scientists, and resource managers working in this field and will provide valuable guidance for maintaining elasmobranch biodiversity and sustainable fisheries. I hope it will stimulate further studies throughout the Indo-Pacific Region.

I am also pleased that the recommendations developed during the workshop for elasmobranch management are now available to a wider audience in this volume. I note that some of the recommendations are already in place, and I hope that their publication will further the conservation of elasmobranchs around the world.

Since Sabah was the host country of the Seminar and Workshop that resulted in the production of these Proceedings, myself and my colleagues in the Universiti Malaysia Sabah, Department of Fisheries - Sabah, WWF Malaysia and the Sabah Institute for Development Studies are extremely proud that the initial elasmobranch conservation efforts carried out in Sabah make a significant contribution to these Proceedings. May more essential conservation efforts of this kind, built on scientific foundations, be supported by international funding agencies and Governments.

Prof. Dr. Ridzwan A. Rahman
Director, Borneo Marine Research Institute

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An enormous number of people and organisations were involved in the publication of these Proceedings. We thank everyone involved, too numerous to name individually, although the following deserve special thanks:

The study could not have been undertaken without the enthusiastic and invaluable support of the Department of Fisheries - Sabah with fieldwork, administration, and organisation of the final seminar and workshop. We particularly acknowledge the contribution of the Director, Mr Yap Kon Shen, Mr Alvin Wong, Mr Rooney Biusing, Mr Robert Gingkul and many staff at the Fisheries Research Centre and regional offices. The study also benefited greatly from the advice of Dr Junaidi Payne of WWF-Malaysia and the assistance of WWF staff with fieldwork. Dr Ridzwan Abdul Rahman, Head of the then Borneo Marine Research Unit (now Borneo Marine Research Institute) of the Universiti Malaysia Sabah (UMS), allowed the Project Officer, Mabel Manjaji, to continue work on the Darwin Project after joining his staff. The Institute of Development Studies (Sabah) provided essential support for the organisation of the final seminar, and Naturebureau International gave vital administrative support throughout the project.

Valuable contributions were provided by Patricia Almada-Villela, Leonard Compagno, Sid Cook, Frances Dipper, Peter Last, Tyson Roberts and Gordon Yearsley. The assistance of volunteers John Denham, Rachel Cavanagh and Scott Mycock, often under difficult conditions, was very important. In addition, we are most grateful for the generous help and hospitality provided by many Sabahan villagers, market stall holders and fishermen.

Thanks to Ms Suzanne Gendron for her contribution to this volume, Luke Watson and Jean-Christophe Vie for helpful comments on the manuscript, Peter Creed for designing this publication and assistance with editing and Rachel Cavanagh for final editing and providing updated information where possible.

Sarah Fowler
Co-Chair IUCN Shark Specialist Group
May 2002

Executive Summary

The Darwin Elasmobranch Biodiversity Conservation and Management project in Sabah was a collaborative project between the Department of Fisheries Sabah and the IUCN Species Survival Commission's Shark Specialist Group, in liaison with WWF Malaysia and the University Malaysia Sabah, and funded by the UK government's Darwin Initiative for the Survival of Species. It used field, market and socio-economic surveys to examine the biodiversity, conservation and management needs of elasmobranchs (sharks and rays) in the rivers, estuaries and coastal waters of Sabah, East Malaysia, during the period January 1996 to July 1997.

The Darwin Project concluded with a three day International Seminar and Workshop (8-10 July 1997), attended by 67 participants from 14 countries. This meeting was held to highlight freshwater and coastal elasmobranch conservation issues in the region and worldwide, to disseminate the result of the project to other Malaysian states and countries, and to raise awareness of the importance of considering aspects of elasmobranch biodiversity in the context of nature conservation, commercial fisheries management, and for subsistence fishing communities.

This Proceedings Volume contains peer-reviewed papers originally presented at the seminar. These include descriptions of the results of the Darwin Project work in Sabah, where an expanding commercial coastal fishery exploits a wide range of shark and ray species, some of which are still to be described by scientists, and where coastal elasmobranchs are an important resource for subsistence and artisanal fishing communities. Sabah's largest river, the Kinabatangan, benefits from legal protection, and fieldwork during the project confirmed that several rare and threatened elasmobranchs still occur and breed there.

Other papers describe similar studies of elasmobranch biodiversity (with particular emphasis on freshwater and coastal habitats), fisheries and trade elsewhere in the Indo-Pacific (Peninsular Malaysia, Philippines, Thailand, Maldives, West Java, Taiwan, India, Australia and Zanzibar). International and regional reviews of taxonomy, biodiversity, fisheries and trade provide the wider context for these studies, with a species checklist and a review of the importance of regional collections for future taxonomic research providing a basis for more research into fisheries and biodiversity in the region.

Species receiving particular attention in this volume are those recorded from freshwater and estuarine habitats (which are under particular threat and have therefore been the subject of several recent studies by Japanese and Australian research teams) and the whale shark, a highly migratory species which is the subject both of consumptive fisheries and ecotourism activity. This species is considered to have huge additional potential for sustainable ecotourism in the region; another paper summarises the importance of many other species of elasmobranchs as a recreational resource in the Maldives, where dive tourism is a particularly important industry.

Several papers focus on management and conservation, outlining the major threats to shark and ray populations and some of the national and international fisheries management and biodiversity instruments which may be used to promote sustainable use of elasmobranch populations.

The final day of the seminar was dedicated to three workshop sessions on the subjects of 'Future prospects for elasmobranch fisheries and biodiversity', 'Strategies for the conservation and management of elasmobranchs', and 'Carrying forward the Darwin Project'. Workshop participants developed conclusions and recommendations on these subjects, and the workshop report was agreed in outline by the final plenary session, and subsequently refined by correspondence between the participants.

The workshop conclusions highlight the importance of elasmobranchs as top marine predators and keystone species, noting that anthropogenic changes to shark and ray populations are likely to have serious and negative consequences for commercial and subsistence yields of other important fish stocks. The recommendations provide concise guidelines for conservation and sustainable elasmobranch fisheries in the Indo-Pacific and other regions.

Editor's Note

Since the majority of these papers were written in 1997–98, some species names and distributions have changed since the manuscripts were submitted. Where particular species names in the submitted manuscripts have changed, they have been amended to reflect the new system, although checklists in individual papers may contain inevitable minor discrepancies as a result. Please refer to Appendix I for the updated checklist of chondrichthyan fish in the Indo-Pacific region at the time of going to press. Fully updated reviews of chondrichthyan taxonomy will be published in Compagno and Didier (in press).

In addition to classification issues, considerable advances have been made in elasmobranch fisheries management and an editor's note on p.219 provides a detailed update (Visser, this volume). Where papers refer to species' listings on the IUCN Red List, it should be noted the 2000 Red List, available at http://www.redlist.org, provides the latest information on elasmobranch species assessments, and detailed accounts will be published later this year (Fowler, *et al.*, in press). With regard to protection of the whale shark, updated details can be found as editor's notes added to the relevant papers.

Sarah Fowler
May 2002

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Currency converter

The papers in this volume use a variety of currencies. The conversions below are correct at the time of going to press (May 2002), but it must be noted that the majority of these papers were written in 1997-98.

Currency		**Converted to 1 US$**
Australian Dollar	AUS$	1.84
Hong Kong Dollar	HK$	7.80
Indonesian Rupiah		9,285.05
Malaysian Ringgit	RM	3.80
Maldive Rufiyaa	MRf	11.70
Philippine Peso	PhP	51.65
Sterling	GBP	1.46
Taiwan Dollar	NTS	34.56

Acronyms

AFZ	Australian Fishing Zone
AFMA	Australian Fisheries Management Authority
ARTFISH	Software programs produced by the FAO Fisheries Department
ASEAN Agreement	Brunei, Indonesia, Malaysia, Philippines, Singapore and Thailand: agreement on the conservation of Nature and Natural Resources
ASFA	Aquatic Sciences and Fisheries Abstracts
BMRU	Borneo Marine Research Unit (now Borneo Marine Research Institute)
CALM	Western Australia Department of Conservation and Land Management
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
CMS	Convention on the Conservation of Migratory Species
COA	Council of Agriculture
COFI	FAO's Committee on Fisheries
CoP	Conference of the Parties (to CITES)
CPUE	Catch-per-unit-effort
DOF	Department of Fisheries
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
FAO	United Nations Fish and Agricultural Organisation
GDP	Gross Domestic Product
GI	Gonad Index
GBP	Great Britain Pound
GPS	Global Positioning System
HK$	Hong Kong Dollar
hp	Horse Power
ICCAT	International Commission for the Conservation of Atlantic Tuna
ICES	International Council for the Exploration of the Seas
IOTC	Indian Ocean Tuna Commission
IPOA-Sharks	International Plan of Action for the Conservation and Management of Sharks
IPTP	Indo Pacific Tuna Programme
IPUE	Income-per-unit-effort
IRP	Index of Relative Production
MRf	Maldive Rufiyaa
MSY	Maximum Sustainable Yield
nm	Nautical Miles
NMFS	National Marine Fisheries Service
NTS	New Taiwan Dollar
OIC	Officer in Charge
OLDEPESCA	Latin American Organisation for Fisheries Development
PADI	Professional Association of Diving Instructors
PhP	Philippine Peso
RFMO	Regional Fisheries Management Organisations
RM	Malaysian Ringgit
SEAFDEC	South East Asian Fisheries Development Center
SET	South East Trawl Fishery (Australia)
SRI	Shark Research Institute
SSC	IUCN Species Survival Commission
SSF	Southern Shark Fishery (Australia)
SSG	IUCN Shark Specialist Group
TL	Total Length
UMS	Universiti Malaysia Sabah
UNCLOS	United Nations Convention on the Law of the Sea
vBGC	von Bertalanffy Growth Curve
WSRF	Whale Shark Research Foundation

Overview and Conclusions

The 18-month Darwin Project on Elasmobranch Biodiversity, Conservation and Management in Sabah concluded with a three-day International Seminar and Workshop (8-10 July 1997), attended by 67 participants from 14 countries. This meeting was held to highlight freshwater and coastal elasmobranch conservation issues in the region and worldwide, to disseminate the result of the project to other Malaysian states and countries, and to raise awareness of the importance of considering aspects of elasmobranch biodiversity in the context of nature conservation, commercial fisheries management, and for subsistence fishing communities.

Seminar objectives and outputs

The objectives of the international Seminar were as follows:

1. To review the status of sharks, rays and chimaeras in the region with regard to:
   - commercial fisheries and markets;
   - marine and freshwater species distribution and biodiversity;
   - social and economic importance to subsistence fishing communities; and
   - ecotourism (diving and sports angling).
2. To review and assess trends in the above, for example:
   - the changing status of sharks and rays in fisheries and markets;
   - the development of new deepwater fisheries;
   - whether the changing abundance of sharks and rays in fisheries landings and markets may be used as an early indicator of overfishing;
3. To consider needs and options for the management and conservation of elasmobranchs, including:
   - the social, economic and ecological implications of shark and ray fisheries;
   - the requirements and opportunities for sustainable fisheries management;
   - the conservation needs of threatened sharks and rays, particularly obligate freshwater and brackish species;
   - to what extent marine and freshwater protected areas may contribute to the conservation of elasmobranch biodiversity and fisheries management objectives;
4. To identify further research, conservation and survey needs in the region.

The papers included in this Proceedings Volume, presented during the first two days of the meeting, largely fulfil the first two of the above objectives, reviewing the state of knowledge (in 1997) of regional elasmobranch taxonomy, biodiversity and population status, and the importance of elasmobranchs in commercial and subsistence fisheries, markets and international trade, and ecotourism.

Following the presentation of these papers, participants split into three separate workshop sessions to consider the other meeting objectives, with particular emphasis on assessing future prospects for and constraints on elasmobranch fisheries management and biodiversity conservation in the region, and developing recommendations for the formulation of strategies for the conservation and sustainable management of shark and ray populations. Participants at these workshop drew up detailed conclusions and recommendations based on their reviews of the state of knowledge and importance of shark and ray biodiversity, taxonomy, population status, commercial fisheries and markets, conservation, and recreational (including ecotourism) and subsistence use. These were presented in plenary and subsequently refined by correspondence between all participants. These conclusions and recommendations are presented below.

Workshop conclusions

Biology and ecology

Most elasmobranchs (sharks and rays) and the related chimaeras are characterised by slow growth, late age at maturity, low fecundity and productivity (very few young are produced by each mature female), large size at birth, high natural survivorship, and a long life. These species are dependent on a stable environment, have a low reproductive potential and a limited capacity to recover from overfishing. Such biological characteristics have serious implications for the sustainability of shark and ray fisheries. Indeed, existing data from other areas have shown a consistent history of rapid stock collapses, with stock depletion reversed only in cases where appropriate fishery management has been introduced.

The elasmobranchs, and particularly those sharks which are top marine predators feeding on weak and less fit individuals of other fish species, are considered to be a key factor in the health and maintenance of the marine food webs on which all fisheries ultimately depend. **Permanently damaging shark and ray populations is likely to have serious and unexpected negative consequences for commercial and subsistence yields of other important fish stocks.**

Recommendation 1. Regional elasmobranch research efforts should be targeted at understanding the biology and ecology of the elasmobranchs, including population dynamics, critical habitat requirements during their life cycles, and conservation needs.

Recommendation 2. Universities can directly contribute to better management of elasmobranch resources by involving their staff and students in ecological studies that are directly related to fishery problems.

Recommendation 3. The following priorities are considered to be of particular importance:

- Obtaining population data on age, growth and reproduction and carrying out life history studies for the dominant species of sharks and rays in the fisheries, and for threatened species.
- Assessment of the biological productivity of deepwater elasmobranchs.
- Using the whale shark *Rhincodon typus* as the focus of a collaborative biological research and monitoring program in the region.

Biodiversity, taxonomy and conservation

The results of the Darwin Project demonstrate that elasmobranch biodiversity in the region around Sabah is amongst the richest on earth, with many new species recorded. It represents a mixture of many different biogeographical regions with overlapping related species complexes. However, the shark and ray fauna is still poorly known and additional taxonomic studies, particularly among the rays, are needed. Such studies are hampered by the lack of research and reference collections, lack of access to regional data management and information systems, the absence of a regional identification guide to the fish fauna, and a shortage of taxonomists in the region.

Recommendation 1. There is an immediate need to develop a strategy for building a biodiversity baseline through a core national collection of elasmobranchs, other fishes and invertebrates, with provision for temporary working collections in other regional laboratories. (Collection of deepwater species for detailed taxonomic study, prior to development of deepwater fisheries, is of particular importance in this respect.) This will help to develop a local, regional and national capacity for monitoring and managing biological resources of the Indo-Malay archipelago and in other regions.

Recommendation 2. Simultaneously, there is a need to provide a regional standard for biodiversity data management and information systems, of which the Darwin Project in Sabah was the initial step.

Recommendation 3. International training and taxonomic advice is required to build a highly capable research capacity within the region.

Recommendation 4. Preparation of a *Guide to the elasmobranch fauna of Sabah* would be a logical first step towards improving the local and regional capacity for data collection and monitoring.

Coastal species are dependent on nearshore areas and habitats which are under increasing pressure from fisheries activity and other human-induced sources of habitat degradation and loss. The project identified problems of over-exploitation of juveniles and young of the year of several species that utilise inshore nursery grounds. Juveniles of many other species are poorly known, and their nursery areas have not been identified.

The freshwater elasmobranch fauna of the area is imperfectly known, yet particularly vulnerable to deterioration or loss of its restricted habitat. However, several species (e.g. the river shark *Glyphis* sp. and the freshwater stingray *Himantura chaophraya)* not seen for many decades or previously unrecorded from North Borneo are now known to be present.

Recommendation 5. In view of the rapid changes in many coastal and freshwater habitats, regional research efforts should be targeted at identifying habitats of special importance to elasmobranch life cycles, with a view to their conservation.

Similarly, the deepwater species of the area are almost completely unknown. Many are probably confined to very narrow depth bands in small geographic areas. As a result, many unreported regional endemics are likely to exist. Deepwater elasmobranchs are the focus of several expanding fisheries in the region, yet such species usually have even slower growth and reproductive rates than shallow water species. As such, **deepwater species are even more vulnerable to over-exploitation than most other elasmobranchs.** Furthermore:

- some slope species have restricted spatial distributions and relatively small unfished populations. Habitat areas can be disjunct, fragmenting populations of some more widespread species with relatively large total numbers;
- several stocks of deepwater elasmobranchs have already been overfished (Maldives, Sri Lanka, India, Australia, and Suruga Bay-Japan);
- once overfished, deepwater elasmobranch stocks may take many decades to recover; and
- sharks are an important component of deepwater ecosystems, therefore their removal is likely to have a negative impact on such ecosystems.

Recommendation 6. Multinational surveys targeted on deepwater elasmobranchs and other deepwater fauna should be actively encouraged, to establish a population (and taxonomic) baseline prior to development of fisheries.

Overall, the status of elasmobranch populations in the region is largely unknown. This is due to the low economic emphasis placed on a group of fishes which have, until recently, occurred as fishery bycatch, and to the absence of catch-effort data from fisheries.

Recommendation 7. Improved data on population status of important elasmobranchs in fisheries and potentially rare or threatened species should be obtained, through biological, fisheries, fisheries independent, and market surveys, in order to improve the level of knowledge required for the formulation of fisheries and conservation management objectives and strategies.

Recommendation 8. Universities, museums and other relevant institutions should provide their resources to train fisheries staff through workshops and preparation of regional and local species identification manuals.

Commercial fisheries, trade and markets

Shark and ray fisheries and markets in Malaysia and other South East Asian states are expanding rapidly, new fisheries are being actively developed, and the trade in and value of shark products are increasing. In many countries, steep increases in fishing effort and elasmobranch landings have been followed by marked declines in elasmobranch catch rates in fisheries, and a fall in the numbers and biodiversity of elasmobranchs entering markets from coastal waters has been detected. Some historically common species no longer appear to be present in some areas. Multispecies fisheries could potentially result in the local extinction of rare shark and ray species taken as bycatch, and even the complete extinction of rare regional endemics. The lack of management of elasmobranch fisheries is therefore cause for concern.

Sabah is a notable exception in the region; statistics indicate that landings of sharks and rays are still rising steeply here, and the Darwin Project has identified a high diversity of species entering markets. Current elasmobranch fisheries appear, therefore, to be healthy. However, great caution is required. It is impossible to assess the status of elasmobranch fisheries without data on catch-per-unit-effort, and there is a danger of overcapitalisation in the industry. Elasmobranch fisheries are prone to collapse, with populations entering long-term declines. Without the introduction and/or effective implementation of sustainable management for sharks and rays, Sabah's stocks will follow the trend seen in other countries. If this occurs, the result will be the long-term loss of an important economic and biodiversity resource, and ecosystem disruption. Although of a lower immediate economic value than other fisheries, the Sabah elasmobranch fishery was worth RM13.5 million wholesale and RM4 million in processed shark fin exports from 1991–1995 (and values are rising). It is, therefore, necessary to place stocks under management now, because once overfished they will take decades to recover.

The workshop noted that the following measures already in place are of benefit to elasmobranch resources:

- controlling the allocation of fishery licences, which helps control fishing effort;
- establishing protected areas, which help protect species with restricted distribution in both freshwater and marine habitats;
- restricting the level and methods of commercial fishery activity in different zones from the coast. Reduced fishing activity by larger vessels (particularly trawlers) close to coasts benefits shallow inshore elasmobranch pupping or nursery areas, which are often heavily fished in the region, without unduly impacting on traditional artisanal fisheries.

The following conservation measure was, and still is, under consideration in Sabah:

- the banning of large-mesh gillnets, which helpsconserve breeding stocks by allowing the escape of the larger, reproductive females. Large-mesh gill nets are also destructive to endangered sea turtles and marine mammals.

The workshop recognised the need for improving data acquisition and management on elasmobranch fisheries and trade.

Recommendation 1. A shift in fishery management emphasis is recommended: away from the expansion and development of fisheries and increasing yields, and towards a lower-risk policy aimed at sustaining yields. Diversifying markets and improving quality control under such a regime will enable the income of the fisheries industry to continue to rise on a sustainable basis.

Recommendation 2. The introduction of new fishery management measures and/or enforcement of existing measures and legislation described above are necessary to ensure that elasmobranch fisheries are managed sustainably.

Recommendation 3. Greater resources should be allocated to Fisheries Agencies (and other relevant government bodies, e.g. Marine Parks Authorities) for fisheries activity monitoring and law enforcement, so that existing regulations can be more effectively enforced.

Recommendation 4. A precautionary approach to the development of deepwater elasmobranch fisheries should be adopted. Because of the biological constraints on populations of deepwater fish species, these fisheries need to be closely monitored and major investment in such fisheries should be discouraged. More specific management recommendations are not made because it is recognised that conditions and needs will vary between countries and fisheries.

Recommendation 5. The workshop supports the recommendations of the CITES Animals Committee report *[subsequently adopted within FAO's IPOA-Sharks (see Appendix 2)]* regarding improvement of identification, recording and reporting, at species level, of landings, bycatch and trade.

Recommendation 6. Improved data collection on landings (combined with improved biological and population data, see recommendations for biological and ecological research) is essential to provide the information needed to formulate fisheries management initiatives. The greatest need is for more specific fisheries information at taxonomic levels lower than "shark" or "ray". Data on landings at the species or population level would be ideal, but statistics at the family or ordinal level would be a vast improvement over the current situation and would facilitate more effective management.

Recommendation 7. An improvement in landing and effort data from the fisheries by gear type would be particularly useful. To fulfil these needs, more resources should be allocated to Fisheries Agencies.

Recommendation 8. Reporting of fisheries bycatch of elasmobranchs and other species, particularly in high seas fisheries, should be made compulsory.

Recommendation 9. There is a need for improved data management on a regional basis. Solutions to this problem could include:

- Storing fishery data on a common database, such as FishBase, throughout the region.
- Compiling published fisheries related reports within the existing ICLARM system for easy access to the fishery community. Abstracts and data summaries from fisheries reports in languages other than English should be translated into English as part of these efforts.
- Supporting an initiative by SEAFDEC to develop a regional fisheries database accessible through the Internet to the fisheries community.

Recommendation 10. The workshop recognises an urgent need for more information on trade of elasmobranch products at more precise taxonomic levels, and supports the CITES Animals Committee report recommendations that trade statistics should clearly identify which products are in trade (i.e. fins, whole carcasses *etc*). In particular, the workshop requests the FAO and national agencies to provide greater detail in their trade data forms and trade reports.

Recommendation 11. The workshop notes and supports the recommendation of the CITES Animals Committee that Parties should improve their subscription to implementation of the principles and practices in the FAO Code of Conduct for Responsible Fisheries, the FAO Precautionary Approach to Fisheries, and the FAO Code of Practice for Full Utilization of Sharks, and urges these practices to be implemented throughout the region. *[Editors' note: since the Seminar, FAO has approved a voluntary International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks, see Appendix 2) which specifies stock assessment, conservation and management actions for shark fishing nations.]*

Recommendation 12. In view of the vulnerable nature of elasmobranch stocks to overfishing, their important ecological role and the importance of fish protein for human food in the region, it is suggested that the wasteful practice of finning and discard of sharks is carefully reviewed by regional governments and fisheries organisations with a view to regulating the practice.

The socio-economic importance of elasmobranchs for subsistence fisheries

Many Sabahan and other coastal communities in the region are highly dependent on inshore fisheries for their subsistence and income. Subsistence fishing allows families open access to a 'free common-good resource' which provides the majority of their animal protein, as well as cash income from the sale of surplus catch. Trading shark fins and dried shark and ray meat can be particularly important in bringing income into the community.

The catch of fish by these subsistence communities may not be well reflected in fisheries statistics, because the fish are not landed or sold in commercial markets. Assessing the scale and value of fish catches to local communities studied during the Darwin Project was very difficult, because fishers' recall of the quantity of fish caught was often vague. Collection of more detailed cultural and socio-economic data would help decision-makers to better understand resource utilisation by coastal communities and provide the basis for formulating appropriate community-specific management strategies and policies.

Recommendation 1. In order to determine more fully the socio-economic importance of fisheries for coastal communities, and to formulate appropriate management regimes, historical and present information should be collected on:

- Demographic profile
- Fishery profile, including typology of fishers, boats, gears; fishing operations, practices, problems; and fishery systems (coastal, reef-based, lagoon, *etc*.)
- Traditional community structure and institutional management
- Marketing mechanisms and trade flows, including credit facilities and post-harvest processing
- Identification of existing alternative or additional livelihoods, for example sustainable trade for the aquarium industry and live food market, and ecotourism (the latter in a form that is ecologically, culturally, economically and socially equitable)
- Level of existing ecological awareness
- Catch assessment
- Community-managed Fishing Reserves (application and potential)
- Health and Nutrition

Ecotourism and recreation

It is recognised that in the Indo-Pacific region sharks and rays have significant ecotourism value, particularly for diving and recreational angling, but also for display and educational purposes in public aquariums. However, only a few countries have attempted to quantify the present or potential economic importance of the elasmobranchs in this respect.

Diving is a very important, rapidly expanding, sustainable and high-yielding source of tourism income, with huge potential for further development in the region. Revenue from shark and ray diving internationally runs into hundreds of millions of US dollars annually. In the Maldives, divers are estimated to spend over US$3 million annually directly on shark watching dives, while this industry is worth US$6 million in the Bahamas. Indirect revenue from associated dive-tourist expenditure (e.g. food and accommodation) is several times higher. The annual income derived from a single reef shark at a dive site may range from US$3,300 to US$40,000. This is 100–1,000 times more than the value of a dead shark to a fisherman, and this value of the former income is sustainable over the lifespan of the shark.

Recommendation 1. The contribution of sharks and rays to tourism should be considered in the development of any management strategies affecting these resources.

Recommendation 2. Countries in the region should be encouraged to assess the socio-economic importance of and potential for shark and ray interaction activities.

The whale shark *Rhincodon typus* can be regarded as a flagship species in this respect, with demonstrated potential as an ecotourism resource. However, as is the case for most elasmobranchs, there is a lack of knowledge about its biology, ecology, migratory patterns and population dynamics. There is a possibility that recent increases in whale shark fisheries in a number of countries in the region are unsustainable. If so, the sustainable use of this species for ecotourism is threatened.

Recommendation 3. Feasibility studies should be carried out to examine the possible development of sustainable ecotourism activities in areas where there are seasonal aggregations of whale sharks.

Recreational fishing for large game fish is also growing in importance in the region, and there are potentially larger numbers of game fishermen than divers. The economic value of exploitation and sustainable use of elasmobranchs by this sector can be very high. Additionally, a cooperative tagging effort between Fisheries Agencies and recreational fishermen could provide a valuable source of information about the growth, migration and habitat utilisation of elasmobranchs.

Recommendation 4. Sports fishermen and sports fishing organisations in the region should be encouraged to abandon catch-and-kill fishing for sharks (and other large, long-lived fish) and to adopt catch-tag-release shark fishing in order to support conservation efforts and research programmes.

Education and public awareness

There is a very low level of awareness throughout the region and internationally among decision-makers, managers and the general public with regard to the special biological constraints faced by elasmobranchs, and hence their vulnerability to fisheries, their important ecological role in the marine environment, and the need for their conservation and management. Raising awareness of all sectors is essential if sound elasmobranch management and conservation policies are to be sought and introduced.

Recommendation 1. There is an immediate need to raise awareness of the need for sustainable management and the conservation of elasmobranchs throughout the region. This needs to be implemented at least at three different levels:

- Educate fishery managers and other decision-makers about the inherent vulnerability of elasmobranch stocks to rapid overfishing, and urgent need for management.
- Through educational institutions, promote the role of elasmobranchs in the ecosystem and the importance of maintaining their biodiversity.
- Through the media, museums and aquaria, educate the general public on the importance of this group of fishes.

The number of people visiting public aquariums in the region is potentially extremely high, and will include a large proportion of residents as well as tourists. Aquariums can establish important educational programmes on the socio-economic, cultural and ecological importance of elasmobranchs.

Recommendation 2. Educational initiatives directed at raising public awareness about shark and ray conservation and biodiversity issues and management requirements may usefully be targeted at certain 'flagship' species. One important species which should be used in this way is the large, impressive and harmless whale shark *Rhincodon typus,* although this is a very atypical shark. Another group of elasmobranchs which is appropriate for this treatment is the Order Orectolobiformes, the carpet sharks. These are generally small, colourful and attractive (so suitable for presentation in aquariums), particularly diverse in the Indo-Pacific region, and their benthic habitat requirements (typical of the majority of sharks and rays) make them particularly important targets for conservation action. (See also Biodiversity, taxonomy and conservation - **Recommendation 4.)**

Captive husbandry

Captive elasmobranchs can contribute valuable information on biology, diseases and treatments, blood chemistry baselines, and sensitivity to environmental influences such as pollutants and habitat change. Some of the species critically threatened by overfishing, habitat change or other causes can be bred, and data compiled that might contribute to their conservation.

Recommendation 1. It is recommended that support be provided to research institutes, universities and local aquariums for the following activities:

- establishing captive breeding programmes for elasmobranchs, particularly threatened species (e.g. freshwater rays).
- educating communities, both through in-house programmes and outreach programmes to the remote fishing villages.

Recommendation 2. Aquaria with captive populations of elasmobranchs should be encouraged to collect and publish valuable biological information.

Recommendation 3. Aquaria with adequate facilities should be encouraged to keep threatened elasmobranch species for the above purposes.

Recommendation 4. An international registry of elasmobranchs in captivity in the region should be established at a central location.

Recommendations for carrying forward the Darwin Project

This section highlights recommendations specifically related to the Darwin Project. However, some of these also have a much wider regional and international relevance. The other recommendations presented are all intended to be much wider in scope, and many are certainly also of direct relevance in Sabah.

Recommendation 1. The momentum provided by the Darwin Project activities should be continued by setting up a cooperative venture between Sabahan agencies, with links to institutes in other countries, to develop a strategic plan for the evaluation and management of coastal and marine elasmobranchs and other fish stocks, their biodiversity and habitats. This might be called the Sabah Marine Biodiversity Programme.

Recommendation 2. The freshwater component of the Darwin Project should be extended to other rivers in Sabah (e.g. the lower reaches of the Segama River), other Malaysian states and neighbouring countries. Particular emphasis should be placed on the rivers of Sarawak, which are larger, of greater habitat diversity and hence potential species diversity (including unrecorded species), and also under greater threat than the large rivers of Sabah.

Recommendation 3. Further research should be conducted on the biology, ecology, population dynamics and conservation needs of the river shark *Glyphis* sp. and other freshwater elasmobranchs.

Recommendation 4. Hydrographic surveys of the Kinabatangan River (e.g. variations in salinity, freshwater flow, water quality, tidal cycles and bathymetry) should be undertaken at a number of stations from Kg Abai to Kg Kuamut, to determine the habitat requirements of the river shark *Glyphis* sp. and other species of elasmobranchs recorded here.

Recommendation 5. The threatened status of key species of elasmobranchs, including the river shark *Glyphis* sp., all species of the sawfishes (Pristidae), the giant freshwater stingray *Himantura chaophraya,* and the whale shark *Rhincodon typus,* should be investigated.

Recommendation 6. Legal options for the protection of rare, threatened and/or flagship species of elasmobranchs and other fish in Sabah should be reviewed.

Recommendation 7. The river shark, *Glyphis* sp., should be used as a flagship species to raise public awareness and promote freshwater biodiversity and habitat conservation issues in Sabah.

Recommendation 8. Surveys are required to provide data on the population status of important elasmobranchs in fisheries and potentially rare or threatened species, in order to develop conservation and management strategies.

Recommendation 9. Sabahan agencies should investigate means and opportunities for incorporating Darwin Project data and related information into a national and internationally accessible database, in order to improve dissemination of the knowledge gained.

Recommendation 10. In addition to the publication of the final Darwin Project report and workshop proceedings, more detailed and technical information on elasmobranch species recorded during the project should be prepared and the Sabah State Museum approached to publish this. (See also Biodiversity, taxonomy and conservation - **Recommendation 4.)**

Recommendation 11. Sabahan Agencies developing and implementing land use policies should consider the inter-relationship between aquatic and terrestrial habitats, the dependence of river and estuarine species and habitats on the health of the whole catchment area, and promote the sustainable management of whole river catchments.

Recommendation 12. Develop strategies for ensuring that sustainable local resource uses, compatible with marine and freshwater biodiversity and habitat conservation, are developed to maintain and enhance the living standards of coastal and river communities in Sabah.

Keynote Address

Yang Berhormat Datuk Pandikar Amin Haji Mulia
Minister of Agriculture and Fisheries, Sabah

Mr Yap Kon Shen, the Organising Chairperson, Director, Department of Fisheries (Sabah); Dr Mohd. Yaakub Haji Johari, Executive Director, Institute for Development Studies Sabah (IDS); Assoc. Prof. Dr Ridzwan Abdul Rahman, the Representative of the Vice Chancellor, Universiti Malaysia Sabah; Ms Sarah Fowler, Co-Chair of the IUCN Shark Specialist Group and UK Project Leader of the Darwin Initiative for the Survival of Species project in Sabah; Heads and representatives from various government departments and agencies; Foreign and Malaysian Participants, Datuk-Datuk, Ladies and Gentlemen:

On behalf of the State Government of Sabah, the Malaysian Government and all Malaysians in this country, it gives me great pleasure to welcome all participants to this International Seminar and Workshop on Shark and Ray Biodiversity, Conservation and Management. I would like to congratulate the Fisheries Department of Sabah for taking the initiative to jointly organise this workshop together with the Institute of Development Studies Sabah (IDS), Universiti Malaysia Sabah (UMS) and the IUCN Species Survival Commission's Shark Specialist Group.

I am happy to learn - and see for myself - that the response to participate in this workshop has been overwhelming. This enthusiastic response is a clear sign of the growing concern for sustainable elasmobranch fisheries in the region. I was also informed that this workshop is the first in this region. For this, we are grateful for the opportunity to conduct the activity and the privilege of hosting this distinguished gathering.

It is my hope this coming three-day workshop shall translate into the following:

- A review of the state of knowledge of elasmobranch biodiversity, taxonomy, population status, fisheries and markets in the region.
- An assessment of the importance of elasmobranchs for regional biodiversity conservation, commercial fisheries, trade, subsistence communities and ecotourism.
- An assessment of the future prospects for, and constraints on, elasmobranch fisheries management and biodiversity conservation in the region.
- Development of strategies for the conservation and sustainable management of shark and ray populations in the region.

In simple terms, what we are concerned with in Sabah, and in Malaysia in general, is that these shall translate into more employment opportunities, better income, greater food security, and a more sustainable coastal fishery for the people. At the risk of repeating what we all know, fish is the major protein source in the region, with *per capita* consumption being nearly half of all animal protein consumed. In Sabah, the *per capita* fish consumption was 34kg in 1994, and we hope to raise this to 50kg by the year 2010. This would place a heavy dependence on fisheries resources, which unhappily have been dwindling as a result of various forces, not the least of which are exploitative and unsustainable fishery practices. In turn, this would simply mean looking at sustainability and conservation aspects to augment overall fisheries production, and proper resource management to sustain its productivity. But there is a third and more critical factor, and I am happy to note that this workshop is addressing very strongly the social and economic issues related to elasmobranch fisheries. Sustainable development, after all, requires that productivity of resources is not only maintained over time, but that the benefits are equitably spread through society.

Sabah, with a population of 1.7 million people, has the highest incidence of poverty among all Malaysian states. Fishing communities in coastal areas have a particularly high incidence of poverty, and are one of the priority groups targeted by the State Government Poverty Alleviation Programme. In this context, continuous development of the fisheries industry is important. And the sustainable exploitation and rational development of the marine capture fisheries sector (including the exploitation of elasmobranchs) will certainly have a greater role in addressing the coastal poverty in Sabah.

Speaking of elasmobranch fisheries, the sub-sector has an important role in the development of fisheries in the country and in Sabah in particular. During the 1991-1995 period, the elasmobranch fisheries contributed an average of 2.4% by volume, or about 1.0% (or RM13.5 million) by wholesale value, of the total marine fish landings in Sabah.

In 1995, the total of marine fish landings in Sabah was reported at around 166,462 metric tonnes (t) with a wholesale value of RM461 million, an increase by volume of 3.8% over the previous year. This represents about 15% of the total marine landings in Malaysia, which was about 1.11 million t valued at RM2.7 billion.

Elasmobranch meat fetches a low price of RM0.50 to RM3.00 per kilogram, but by-products such as processed shark fins are highly valued (more than RM200 per kilogram export value). During 1991-1995, the cumulative volume of processed shark fins exports from Sabah was reported at about 20t (value RM4 million).

I understand that the recently concluded 18-month project on "Elasmobranch Biodiversity, Conservation and Management in Sabah", under the United Kingdom-sponsored Darwin Initiative for the Survival of Species, came across the mythical Borneo river shark *Glyphis* sp., which had been thought by scientists to be extinct. I also understand that the project has left us with arguably the largest collection of sharks and rays in the region. Therefore, I would like to take this opportunity to congratulate Ms Sarah Fowler's scientific team who made this possible ... thank you and please accept my congratulations for a job well done.

Ladies and gentlemen, the momentum generated by the Darwin Initiative project must continue. Let me assure you that the Ministry of Agriculture and Fisheries under my jurisdiction and the State Government of Sabah in particular will make sure that sincere follow-up actions and result-oriented work will be carried out by both the Department of Fisheries and Universiti Malaysia Sabah, in collaboration with local research institutions in the country and the international scientific community. In this three-day workshop, I hope that you will also try to address the ways and means to make this happen.

My friends, I wish you a fruitful participation and look forward to the output of this workshop in due course. For our guests from other countries, please make yourself at home in Sabah. We hope that the beauty and hospitality of the State will encourage you to come back.

In my capacity as the Minister of Agriculture and Fisheries of Sabah, and as the official representative of the State Government of Sabah, I wish to welcome you again, and offer my best wishes for the success of this workshop. It is with great pleasure that I now declare this International Seminar and Workshop on Shark and Ray Biodiversity, Conservation and Management officially open.

Elasmobranch Biodiversity, Conservation and Management in Sabah

Sarah L. Fowler
Co-chair, IUCN Shark Specialist Group, c/o Naturebureau International, 36 Kingfisher Court, Hambridge Road, Newbury, Berkshire, RG14 5SJ, UK.

The UK government's Darwin Initiative for the Survival of Species was set up to fund collaborative projects which promote the conservation of global biodiversity. The Darwin Initiative supports unusual projects, which break 'new ground' and would otherwise be very unlikely to receive financial support. Specific aims include raising awareness of biodiversity, involving local people, strengthening links between Britain and partner countries, and acting as a catalyst to generate resources for and interest in further projects. The proposal for the elasmobranch biodiversity project in Sabah arose from the discovery that local fishermen could describe several species of freshwater elasmobranchs not recorded in scientific literature, and in recognition of the largely unreported diversity of elasmobranchs entering coastal markets there. The project was therefore proposed in order to study, for the first time, the biodiversity, distribution and conservation needs of elasmobranchs in the region. In addition to taxonomic and biodiversity studies, it was intended to address the local socio-economic importance of elasmobranchs, the need for fisheries management, protected areas, and education of local people, and to provide the information required by decision-makers to advance elasmobranch conservation. The final international workshop (of which this is the Proceedings Volume) was intended to highlight freshwater and coastal elasmobranch conservation issues worldwide. The Sabah project was carried out in collaboration with the Department of Fisheries, with advice from WWF, and the participation of the Universiti Malaysia Sabah. Work undertaken during the 18 months of the project is described briefly, with reference to other papers in the Proceedings Volume.

Introduction

The concept for the Darwin Project for the Conservation and Management of elasmobranchs in Sabah arose in 1995, during a period when concern over the status of sharks and rays was first being voiced (e.g. by Bonfil 1994), and that of freshwater species was considered to be particularly threatened (Compagno and Cook 1995). Although there had never been any records of freshwater elasmobranchs published in the scientific literature for Sabah, local fishermen reported that they fairly regularly caught at least two species of ray over 200km from the sea in the Kinabatangan River and, very rarely, sharks and sawfishes (Fowler and Payne 1995). Additionally, landings and sales of sharks and rays in Sabah's fish markets appeared to be larger and more diverse than in many other Indo-Pacific regions, where catches and biodiversity were declining, but this biodiversity was not being fully recorded and reported.

These observations coincided with one of the annual calls for project proposals of the UK Darwin Project for the Survival of Species. The Darwin Project is a unique venture for funding collaborative projects which will help to conserve global biodiversity. It funds collaborative surveys, research projects, training programmes and other work in centres of biodiversity, and is part of the UK Government's commitment to the aims of the Biodiversity Convention. In particular, the Darwin Project supports unusual projects, which break 'new ground' and would otherwise be very unlikely to receive financial support. Specific aims include raising awareness of biodiversity, involving local people, strengthening links between Britain and partner countries, and acting as a catalyst to generate resources for and interest in further projects.

With the help of WWF Malaysia, the IUCN Species Survival Commission's Shark Specialist Group (SSG) drew up a collaborative research proposal for implementation by the Department of Fisheries-Sabah and the SSG, with assistance from WWF Malaysia and Universiti Malaysia Sabah. It was intended that data obtained during the study would begin to provide the information required by decision-makers to advance elasmobranch conservation in Sabah and the rest of Malaysia. The project aimed to undertake the first dedicated study on the biodiversity of elasmobranchs (sharks and rays) in the region (including the establishment of a Sabahan elasmobranch reference collection to stimulate future research and survey); to examine their socio-economic importance, particularly for subsistence communities; to consider the problems and opportunities for conservation and management (particularly fisheries and habitat issues); to provide educational materials for local communities to increase their awareness of sharks and rays; and to develop recommendations for the management of elasmobranch populations and their critical habitats.

The proposal included a final international workshop (of which this is the Proceedings Volume) to highlight freshwater and coastal elasmobranch conservation issues throughout the Indo-Pacific region and worldwide. The Darwin initiative application was successful, and an eighteen month project commenced in 1996.

Methods

The study was primarily carried out by a combination of regular fish market visits, river surveys, and visits to river and coastal kampungs (villages) where villagers could be interviewed. A few extra surveys were undertaken on an opportunistic basis by participating in routine marine resource survey work carried out by the Department of Fisheries, and by accompanying local trawl and longline fishermen in order to study their catches and fishing methods. Although the project placed particular emphasis on collecting specimens of sharks and rays in order to establish a complete reference collection, care was taken not to create an artificial market for rarities during the study. Fishermen were asked not to target them for collection, but only to keep those specimens for the project which were found as dead bycatch, which would otherwise have been discarded or used for food. These were purchased at current market rates only. This was a particularly successful method of obtaining specimens from those fishers who were most interested in the survey and keen on assisting the project team. Methodology for the freshwater and coastal biodiversity surveys and socio-economic study is described in more detail in other papers in this volume (Manjaji a and b and Almada-Villela) and summarised by Fowler *et al.* (1997).

In addition to field surveys, information was obtained from DoF records (e.g. unpublished reports by Buising) and experienced Fisheries and WWF staff.

Results and discussion

Detailed results and discussion are presented elsewhere in this volume. This paper is intended to present the broad outputs of the Sabah project, with emphasis on how it contributed to improving knowledge of elasmobranch biodiversity in the region, and awareness of conservation and management issues among fishing communities, managers and decision-makers.

Biodiversity and taxonomy

Prior to the Darwin Project, there had been no dedicated detailed study of sharks and rays in Borneo or Malaysia, there were no published records of freshwater species from Sabah, and only two species of freshwater ray had been recorded in literature from the whole of Borneo. Most DoF and WWF staff were unaware that freshwater elasmobranchs occurred in the state. Despite this lack of dedicated attention, some 47 elasmobranch species records were identified during the initial review of published and unpublished literature, including some records from the beginning of the century. Once the Darwin Project commenced, regular market surveys immediately began to yield new records for Sabah and new records were reported throughout the 18-month survey until 25 new records of sharks and rays had been obtained (Manjaji a, this volume, and Appendix 1). It became apparent that a large number of taxonomic groups (particularly among the rays) were very poorly known and that much taxonomic research is necessary before all species can be identified. The number of species recorded by the Sabah project will continue to increase as new species are described when the status of species complexes (such as *Himantura gerrardi, H. uarnak* and *Pastinachus sephen*) is resolved. It may also be possible to identify additional species currently identified only to genus level from specimens retained in the extensive reference collection collected and curated during this project.

The project team largely failed to catch freshwater species, despite periods of quite intensive sampling in two east coast river systems. This was at least partly the result of unfavourable weather and river conditions - exceptionally heavy flooding occurred during most of the first year of the project. All freshwater species records were initially obtained from Orang Sungei fishermen on the Kinabatangan River, who saved small specimens of the giant freshwater stingray *Himantura chaophraya* and several juveniles of an undescribed species of river shark *Glyphis* sp. for the survey team. The latter subsequently obtained one newborn river shark from the location indicated by the villagers. Photographs were provided of a juvenile freshwater sawfish *Pristis microdon* and the specimen's rostrum and fins were saved for the project team. Villagers also donated several dried saws of *Pristis microdon* and the green sawfish *Pristis zijsron* to the collection (Manjaji b, this volume). It is obvious from river fishermen's descriptions that the project did not obtain photographs or specimens of all the freshwater and estuarine rays recently reported in the Kinabatangan River. There is at least one other stingray present upriver over 200km from the sea. Other species occur near the river mouth, and very large guitarfish (possibly *Rhinobatos typus* the giant shovelnose ray) are reported to have been caught occasionally over 100km upstream.

Because surveys concentrated on coastal commercial fisheries landings and freshwater habitats, species records are predominantly of shallow coastal elasmobranchs; only one oceanic species and one deepwater species were observed. Increased attention to pelagic and deepwater fisheries would significantly increase this species list (although there were no registered deepwater fishing vessels operating in the study area during the project, depths reach 2,000m fairly close to the coast). A few coastal species were only obtained from the catches of Sea Bajau (subsistence fisher folk who only visit land to trade) who may use different methods and target different habitats from the commercial vessels that regularly land catches for sale in markets; it is possible that other species taken by these methods were not recorded during the 18-month project. Some historic records from Sabah were not reconfirmed during the study but, because new species records for Sabah were made throughout the study, it is likely that more of these species and others not previously recorded from the state will be reported in future. It was recognised that elasmobranch biodiversity in the region was particularly high, having exceeded researchers' expectations during the short study. A few of the species recorded are apparently rare or restricted in range to around Borneo.

The project aimed from the outset to set up a high quality specimen reference collection of sharks and rays recorded during the project. The aim was to provide a long term resource to stimulate future research activities by researchers in the region and to attract foreign taxonomists to work with local scientists. This is in contrast to many biodiversity projects that have produced reference collections maintained in internationally-recognised museums well away from the region of origin. Last (this volume) describes the importance of local collections to future taxonomic research, and the uses to which such collections may be put. The Darwin Project elasmobranch collection is being maintained by the Sabah State Museum (with duplicate specimens only having been sent to major fish collections abroad).

The project had initially planned to supplement field and market surveys with a diver observation scheme to record sharks and rays. This was not undertaken because of the poor results which had been reported from similar initiatives in the past; this strategy seemed unlikely to repay the effort necessary to initiate and manage it.

Socio-economic study

Detailed results are presented by Almada-Villela (this volume), who examined both the subsistence value and the trade value of sharks and rays (these vary considerably in different communities and for different ethnic groups). Only a few fishermen target elasmobranchs, particularly in certain seasons, but almost all take sharks and rays as bycatch. Surplus ray meat and some shark meat is dried (some for sale), and fresh meat eaten by the fishermen's families. Lower value shark meat is often discarded, but the fins are always traded and provide a very valuable source of cash (their value is proportionate to fin size). A seasonal target fin fishery was identified in one oceanic island and this practice is likely widespread. The white-spotted wedgefish or guitarfish *Rhynchobatus* sp(p). and sawfishes are also targeted for their particularly high value fins. Fins and other saleable fish catches are usually taken to fish traders in the village, who transport them to town for resale. Fish traders also act as money lenders and may supply fishermen with boats and other gear, repaid with a portion of their catches. The study was hampered by the lack of written records in the villages on catch weights, and poor recall by fishermen on details of their catches, but several fishers reported declining catches of sharks and rays and of other species. This was variously attributed to increased fishing effort (by other ethnic groups or larger vessels) and declining habitat quality (particularly as a result of dynamite fishing). Sharks were identified as an important ecotourism resource at Pulau Sipadan.

Education and training

There were two main aspects to the education and training provided during the Sabah Project. Firstly, the Project Officer and Project volunteers received valuable 'on the job' training from visiting taxonomic and fisheries experts, the former leading to post-graduate studies on ray taxonomy and a teaching post in the Universiti Malaysia Sabah's Borneo Marine Research Unit (BMRU). This, and the experience of other DoF staff during the project will ensure that the education of undergraduates and related elasmobranch biodiversity research work will continue through the BMRU in future years.

Additionally, several local fishermen and villagers spent a lot of time with the project team, becoming interested in and supportive of the project and its conservation aims. This was helped by the media interest in the project, particularly the 'discovery' of the river shark, in state, national and local papers and international magazines (copies of the latter were left with key individuals). Village heads and elders were familiarised with the project and distribution of leaflets and posters helped to maintain and extend this interest, particularly through the continued work of WWF and the DoF in the lower Kinabatangan region.

International Seminar and Workshop

The international meeting which concluded the Sabah Project was envisaged as a major component of the project from the outset. The results of the study were presented to a wide range of participants from within Sabah and other Malaysian states, including Sabah's State Minister for Agriculture and Fisheries. The Minister expressed his support for the work undertaken by the project, and for follow-up work by the Department of Fisheries and the Universiti Malaysia Sabah in collaboration with local research institutions and the international scientific community.

By including participants from many other Indo-Pacific states, the meeting not only disseminated the results of the

Participants of a WWF-funded ecotourism and community project in Batu Putih, a village on the Kinabatangan River, with the Darwin Project posters and leaflets.

R. Cavanagh and S. Mycock

project widely in the region, but also enabled the results of similar research elsewhere to be considered. Parallel workshop sessions were used to analyse the results, draw conclusions, and to develop a series of recommendations for continuation of the work both within Sabah and more widely in the Indo-Pacific. Each workshop's conclusions and recommendations were agreed during the final session of the meeting and subsequently finalised by correspondence between all participants. The final version is presented in full in the introduction to this Proceedings Volume. Finally, participants from the Philippines built on the experience of the Sabah Project to develop a very similar study in the Philippines, funded by WWF-US, which ran from 1998 to 2000 (Alava *et al.* 2000).

Conclusions

The Darwin Elasmobranch biodiversity project in Sabah is an example of how a collaborative project can call on the expertise of an international network of specialists to provide a considerable boost to local, regional and international knowledge of and interest in a taxonomic group. Not only did it raise awareness in Sabah and Malaysia of the importance of elasmobranch biodiversity and fisheries, and of the international policy framework stimulating activity in this field, but it provided much wider awareness of research, conservation and management needs in the Indo-Pacific region and has led to at least one very similar project in the Philippines (Alava *et al.* 2000).

As a result of the Sabah project, there is now a high level of awareness among fisheries managers, researchers, non-governmental organisations and the local Sabahan community, of shark and ray populations and their special conservation and management requirements. Local media interest and coverage helped to heighten enthusiasm for continuing to build on the results of the project, for example by continuing to record unusual species and developing new elasmobranch research proposals (both in Sabah and in other states and nations). The importance of maintaining a permanent research and reference collection in the study area and improving taxonomic training has been clearly defined and recognised (Last, this volume).

An important issue highlighted was the poor level of knowledge of many species of elasmobranchs present in Sabah, particularly the rays (Manjaji a, this volume). There are obviously numerous taxonomic problems still to be resolved before all species collected can be identified. The preparation of a catalogue of batoids of the world is of high priority. Without such a publication, it will be extremely difficult for researchers and fisheries managers to undertake similar studies elsewhere in South East Asian and the Indo-Pacific Region without considerable input from overseas taxonomic experts. This is unfortunate, as rays could be an important indicator of mixed species fishery health (because of their vulnerability to fisheries) and of habitat quality. There are likely to be several regional endemics present, including inshore species and the deepwater chondrichthyans, which were not studied during the project. Some of these species are likely already to have been overfished elsewhere in the Indo-Pacific region.

Freshwater elasmobranchs in South East Asia and elsewhere are imperfectly known, very restricted in distribution, and particularly vulnerable to habitat degradation and destruction (Compagno and Cook 1995). The Kinabatangan River is unusual in that a sizeable amount of its catchment is protected by wildlife conservation legislation. This should provide a key foundation for conservation of the river's freshwater elasmobranchs (Payne and Andau, this volume), while the existence of 'flagship' species such as the river shark *Glyphis* sp. and sawfish *Pristis microdon* should help to support future conservation initiatives for the whole catchment.

The project highlighted the value of working closely with local fishermen and other villagers to obtain specimens of rare or unusual species (which are far less likely to be encountered by visiting researchers than by experienced local fishers), while at the same time involving the community in conservation and management issues and increasing their awareness of the international significance and vulnerability of freshwater elasmobranchs and their environment. Fishermen and villagers were invariably helpful and pleased to assist, whether by describing their catches, photographing unusual specimens or keeping rarities in containers provided by the project team.

Finally, the funding for a final international seminar and workshop and for publication of the proceedings was essential to enable the results of the project to be widely disseminated and allow participants to reach a consensus over priorities for future research, conservation and management efforts.

Acknowledgements

The funding from the Darwin Project covered the employment of a local graduate as the Sabahan Project Officer (a full time post based in the Department of Fisheries), her travel and subsistence costs and that of occasional local volunteers. It purchased a second-hand project vehicle and other minor capital equipment and consumables, including temporary containers for the large elasmobranch reference collection. Darwin funds also covered the part time coordination of the UK-based Project Leader, administration and fieldwork and input by SSG members from the UK, and the travel and subsistence costs of a number of volunteers, including students from the UK and the highly valuable expert input of several SSG members from other countries. The Department of Fisheries (DoF) generously contributed office and laboratory accommodation and facilities for the Darwin Project team, extra vehicles, boats and support staff for some field surveys (DoF staff from fisheries offices all over the state participated in the project), and nominated a headquarters Fishery Officer for project liaison. Additional support and advice was obtained from WWF Malaysia and the Universiti Malaysia Sabah. The project also received Darwin funding for the preparation of interpretative and educational materials for local communities, enabling the preparation, printing and distribution of a leaflet and poster in English and Malay on freshwater elasmobranchs.

Darwin funding for an international seminar and workshop to disseminate the results of the project and other work on elasmobranchs throughout the region was supplemented by a grant from the World Bank Small Grants Program to Universiti Malaysia Sabah for participant travel within the Indo-Pacific region, and logistical assistance from Sabahan Project Partners, including the Institute for Development Studies (Sabah). Participants from 13 countries attended, and over 30 papers were presented (most of these are published in this volume).

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Trends and Patterns in World and Asian Elasmobranch Fisheries

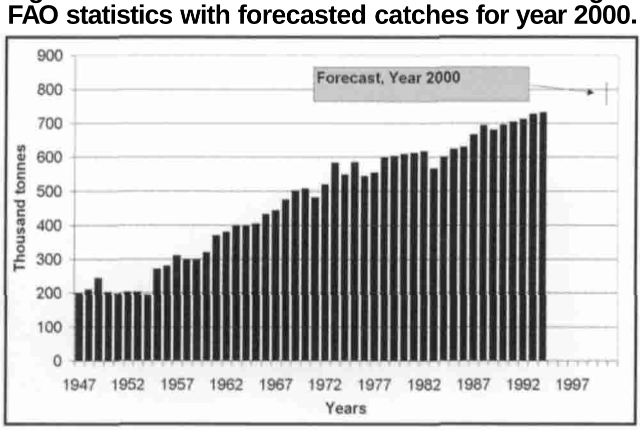
Ramón Bonfil
Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, NY 10460, USA.

International concern over the fate of elasmobranch fisheries has grown recently. This results from two major causes: first, due to their life history characteristics, sharks and rays are prone to overexploitation; second, continued expansion in global catches of sharks and rays seems to be running unchecked. Elasmobranch fisheries remain little known and poorly characterised. This paper presents an overview of fisheries for sharks in the world based on official statistics of FAO, SEAFDEC and various other national and international agencies, and is complemented by an extensive literature review. The paper covers the diversity of world shark fisheries, artisanal and industrial, commercial and recreational, and, where possible, provides information on the most common gears used and the most important species caught. Catch trends for the different regions of the world are presented, together with an analysis of production in each of these regions. Out of the 15 FAO fishing areas, four show decreasing trends in the catches while nine others have increasing trends and two show almost no trend. An analysis of relative production by areas suggests that increases in yield could potentially be obtained in the south-east Pacific and the south-east Atlantic Oceans. Although some industrial fisheries for sharks exist in several countries, most of the catches are actually produced by small-scale fisheries all over the world. Globally, various types of gillnets provide a greater part of the total catch. The bycatch of sharks in other fisheries also accounts for a significant part of the total. Estimates on a worldwide scale indicate that about the same amount of sharks are caught in directed fisheries as are caught as bycatch in other fisheries, mostly longline fisheries for tunas. Sharks are used for food in many countries, and in some parts of the world the hides are used for the leather industry. However, the traditional Chinese shark-fin soup market has expanded greatly in the past 10 years and the high prices paid for dried shark fin are putting pressure on shark stocks around the world. A very controversial novel utilisation of sharks is the production of a shark cartilage pill as a supposedly "magic" cure for cancer. The paper ends with a brief discussion of the needs for management and conservation of sharks around the globe, and the problems faced when attempting to do so.

Introduction

International concern over the fate of elasmobranch stocks has grown recently (Bonfil 1994, Rose 1996, TRAFFIC 1996). At least two main causes can be identified for this. First, due to their life history characteristics, sharks and rays are thought to be especially prone to overexploitation: sharks and rays are typically K-selected organisms and many species - but not all - have: a) a late age of first sexual maturity; b) low fecundity; and c) long gestation cycles. and hence a low reproductive potential. Moreover, because of their eco-trophic role, elasmobranch abundance is, typically, relatively low. Secondly, continued expansion in global catches of sharks and rays seems to be running unchecked, putting increased fishing pressure on these vulnerable stocks (Figure 1).

Figure 1. World elasmobranch catches according to FAO statistics with forecasted catches for year 2000.



Elasmobranch fisheries remain little known and poorly characterised. Global reviews of shark fisheries and trade (Bonfil 1994, Rose 1996) indicate that in most cases there are large gaps in basic information that preclude any serious attempt to manage these resources. This paper provides an updated overview of fisheries for sharks in the world with a particular focus on Asian countries. Information for this paper is based on official statistics of the United Nations Fish and Agriculture Organisation (FAO), South East Asian Fisheries Development Center (SEAFDEC) and various other national and international agencies, and is complemented by an extensive literature review.

Utilisation

Sharks and rays have many uses which can be classified broadly in three groups: traditional uses, modern uses, and novel or recently developed uses.

Traditional uses

The two main traditional uses of sharks and rays have been for food, and for the production of tools and weapons. Elasmobranchs as food are sold mainly fresh on ice, although in tropical countries their meat and fins are usually salt-dried. For the manufacture of weapons and tools, shark teeth are used by the natives of the south Pacific islands to build swords and knives. The spines of rays were used for ceremonial purposes among the ancient civilisations of mesoamerica, such as the Aztecs and the Mayas.

Modern uses

The modern uses of sharks and rays include, apart from food, several industrial applications. Shark skins are used for the production of leather and abrasives. Extracts from the blood are used to produce anticoagulants, and the corneas of sharks are used in medical applications. The livers are perhaps the most versatile part of sharks, being used in the production of vitamin A, the manufacture of paints, cosmetics and many other products derived from squalene.

Novel uses

A relatively recent use of sharks is the production of cartilage pills for the alleged control and cure of cancer. The value of direct intake of shark cartilage as a treatment for cancer has not been demonstrated scientifically. On the contrary, there are several tests showing that it does not have any positive effect. Despite not being approved anywhere in the world as a *bona fide* medical product, the sale of shark cartilage has unfortunately grown through outlets such as organic food stores.

The direct observation of live elasmobranchs in their natural habitat - either from boats or using SCUBA gear- is another recently developed use. Whale sharks, manta rays and various grey sharks (genus *Carcharhinus)* are some of the species most commonly observed around the tropical world.

Fisheries

Fisheries for elasmobranchs are very diverse. Many shark fisheries are small scale, such as the Maldivian fisheries for deep water gulper sharks, which utilise wooden sailing boats without any type of mechanisation (Anderson and Ahmed 1993 and Anderson and Hafiz, this volume). However, there are also industrial high-tech fisheries for sharks, such as the Taiwanese driftnetters that operated in the Arafura and Timor Seas during the 1970s (Stevens 1990).

Shark and ray catches are to a large extent incidental to effort targeted at other species, and very frequently form part of multi-specific fisheries. These two characteristics seriously complicate the assessment and management of elasmobranch stocks. Basic fisheries data on such catches are almost never reported by species, and measures of the fishing effort are seldom recorded for these low-value fish.

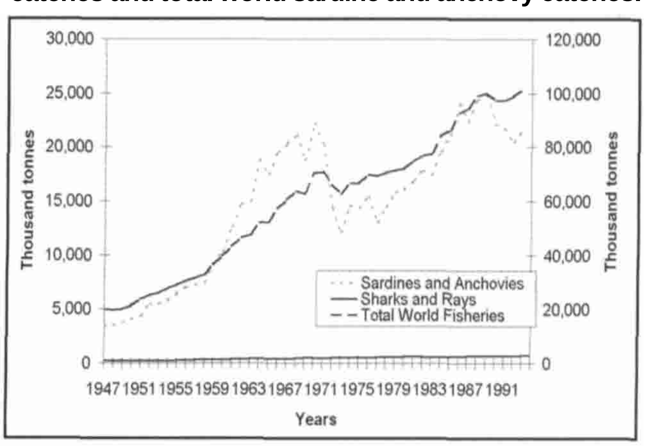
Fishing methods

The fishing methods used to catch elasmobranchs are also very diverse. The two most common methods for catching sharks are gillnets and longlines. Other methods are also used. Hand harpoons were used by Mexican fishermen to fish sharks in the 1960s in the area of Yucatan, and are still used to harvest whale sharks in the Philippines (Alava *et al.* this volume). Harpoon guns are used to harvest basking sharks, mainly in the North Atlantic. A very common method for catching rays, other batoids, and some smaller sharks is the bottom trawl-net. This fishing gear is responsible for a large amount of bycatch and discard of elasmobranchs throughout the world.

Patterns of global exploitation of elasmobranchs

Elasmobranch fisheries are extremely small and almost irrelevant in comparison to other marine fisheries (Figure 2). In addition to their small volume, shark and ray fisheries have relatively low monetary value, thus they have traditionally been of minor importance especially when compared to other fishery resources such as sardines and anchovies (Clupeiformes), cods (Gadidae), shrimp or tuna (Scombridae). Given their minor importance, it is not surprising that sharks and rays have received little attention from most scientists and research institutions, as can be judged from the number of papers published for different groups of fishery resources (Figure 3). This imbalance partially explains why our knowledge about elasmobranch populations and the management of their fisheries is at present less than satisfactory.

Figure 2. Comparison of total world catches from all fisheries (right axis) against world elasmobranch catches and total world sardine and anchovy catches.



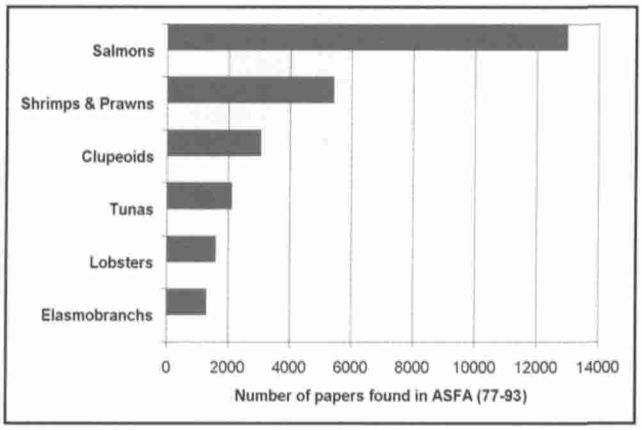


Figure 3. Number of papers published for each of several fishery resources and contained in the ASFA database.

The official statistics indicate that total world catches of eiasmobranchs surpassed 730,000 tonnes (t) during 1994. According to Bonfil (1994), nominal catches are expected to reach between 755,000 and 827,000t by the year 2000 (Figure 1). The relative production of elasmobranchs in different regions of the world is shown in Figure 4, where an Index of Relative Production (IRP) of elasmobranchs is used to characterise the patterns of elasmobranch exploitation. This index is simply the average elasmobranch catch (since 1967) within each of FAO's Statistical Areas, divided by the square root of the surface of each Statistical Area. Areas with an IRP higher than 10 are arbitrarily considered to have the highest relative yields, and are probably fully exploited if not already over-exploited. Note that most of the areas corresponding to Asian countries already have very high relative yields. Accordingly, we should not expect to see large increases in catches in these areas. Areas which have a medium level of production (IRP between 5 and 10) could perhaps sustain small increases in catches if effort is carefully distributed. Finally, areas with the smallest relative production (IRP <5) are perhaps the most promising for fishery expansion. However, this index should be used with caution, as it assumes that sharks and rays are evenly distributed in the world's oceans.

The trends of shark and ray landings in each FAO Statistical Area in the period 1983-1994 are given in Table 1. Areas 27 and 87 show clearly declining trends in landings, while Areas 37,47,61 and 87 have slightly declining trends. There is a slightly increasing trend of catches for Areas 31, 41, 67, 77 and 81. Only Areas 51, 21, 71 and 57 show relatively high increasing trends. Within the Asian region. Area 61 has a decreasing trend, while Areas 71 and 57 have very high increasing trends. Worldwide, there are six Areas that show decreasing trends in elasmobranch catches.

The data presented above imply that the possibilities for maintaining a steady growth in world elasmobranch catches depend largely on what happens in a few key areas of the world, such as Areas 61, 67, 51, 57 and 21. How sustainable the growth of catches is in these key Areas is of great concern, especially considering the state of some of the fisheries in the Asian region, and the generalised lack of management for eiasmobranchs throughout most of the world.

In terms of catches, Asia is the geographical region that has by far the most important fisheries for sharks and rays; Europe is second, but with much lower catches

Figure 4. Index of Relative Production of eiasmobranchs in each of the 15 FAO Statistical Areas. IRP= Index of Relative Production.

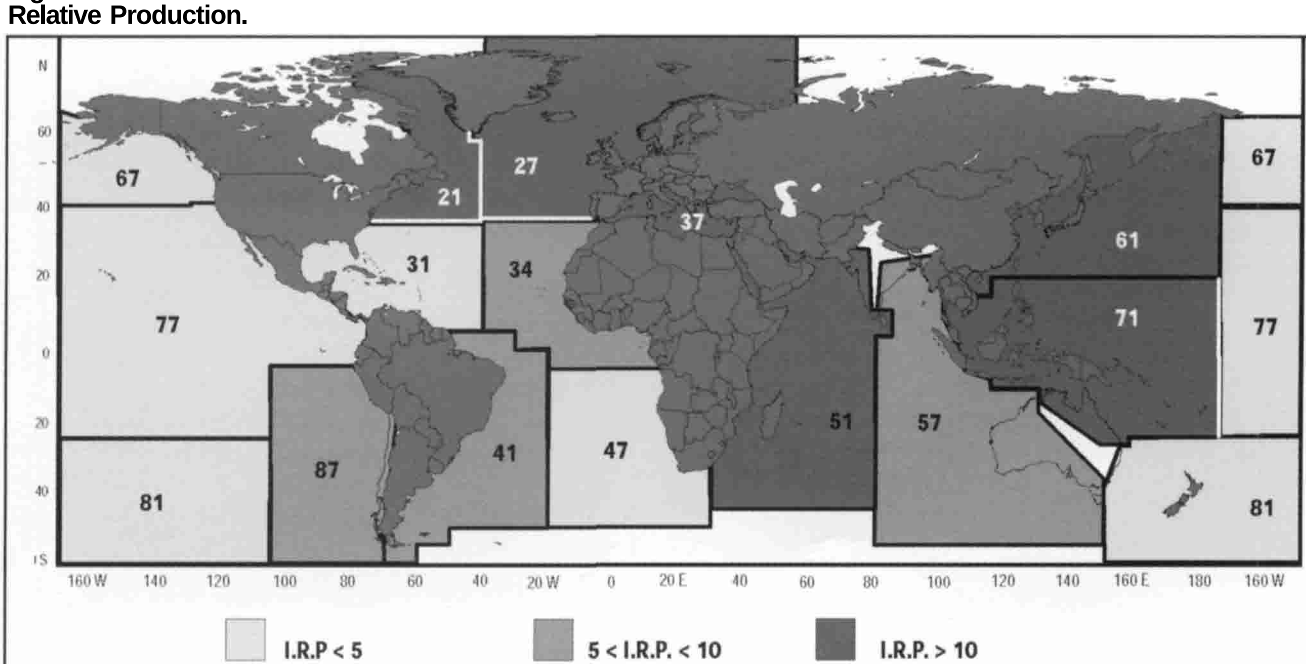


Table 1. World trends and patterns of shark and ray exploitation, divided by FAO Statistical Areas.

FAO Statistical Areas	Mean catch area (million km²)	(1,000s metric tonnes)	Coefficient of variation	IRP average catch/sqrt size	Trend 1983-1994 (1,000s metric tonnes/year)
27 NE Atlantic Ocean	16.9	92.3	12%	22.45	-2.05
61 NW Pacific Ocean	20.5	101.1	10%	22.34	-0.72
51 W Indian Ocean	30.2	101.1	19%	18.40	5.79
21 NW Atlantic Ocean	5.2	28.4	57%	12.44	3.56
37 Mediterranean and Black Seas	3.0	18.4	29%	10.62	-0.65
71 W Central Pacific Ocean	33.2	63.3	38%	10.98	3.84
41 SW Atlantic Ocean	17.6	36.0	30%	8.57	0.94
57 E Indian Ocean	29.8	46.2	32%	8.47	2.26
34 E Central Atlantic Ocean	14.0	28.4	29%	7.59	-0.14
87 SE Pacific Ocean	16.6	20.5	32%	5.03	-1.57
31 W Central Atlantic Ocean	14.7	18.8	47%	4.89	0.54
77 E Central Pacific Ocean	57.5	22.1	34%	2.92	0.61
81 SW Pacific Ocean	33.2	11.0	47%	1.91	0.18
67 NE Pacific Ocean	7.5	5.2	60%	1.91	0.21
47 SE Atlantic Ocean	18.6	6.4	42%	1.48	-0.09

(Figure 5). The trend of elasmobranch catches by region shows that production is intensifying in Asia and to a lesser extent in North America, the latter due mainly to the recent growth in US catches.

Asia and, in particular South East Asia figure prominently in shark and ray fisheries worldwide. As a whole, Asian countries currently contribute about 60% of the total world elasmobranch catches, while South East Asian countries hold about a 25% share of this total. Both regions seem to be increasing their share of the world elasmobranch catches (Figure 6).

The distribution of catches among world economies indicates that the so-called developing countries produce about two-thirds of the total world elasmobranch catch. The trend seems to be for further increases in the contribution of developing countries to the total (Figure 7). This has the unfortunate implication that the main stakeholders, because of their slower economies, will have a harder time allocating resources to the management of, and research into, elasmobranchs. However, the lack of efforts towards managing shark and ray fisheries seems to be a general pattern among most fishing nations. Figure 8 shows the 10 countries with the highest average catches of elasmobranchs in the last 10 years. Notice that wealthy nations like Japan, France and Great Britain are among the top 10; however, none of these countries has implemented management of their shark or ray fisheries.

Figure 5. Historical catches of sharks and rays by geographical region.

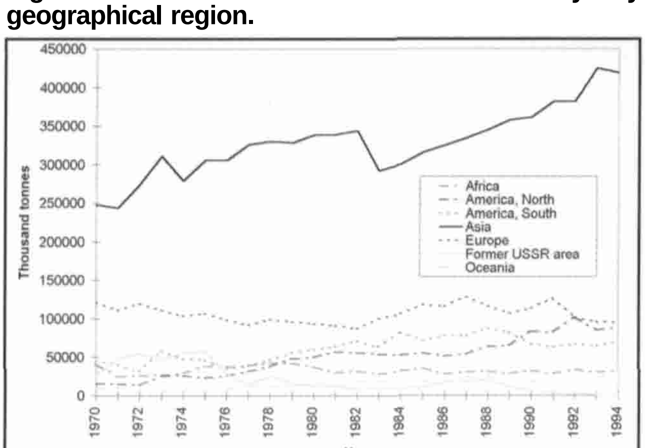


Figure 6. Proportion of world elasmobranch catches contributed by Asia and South East Asia.

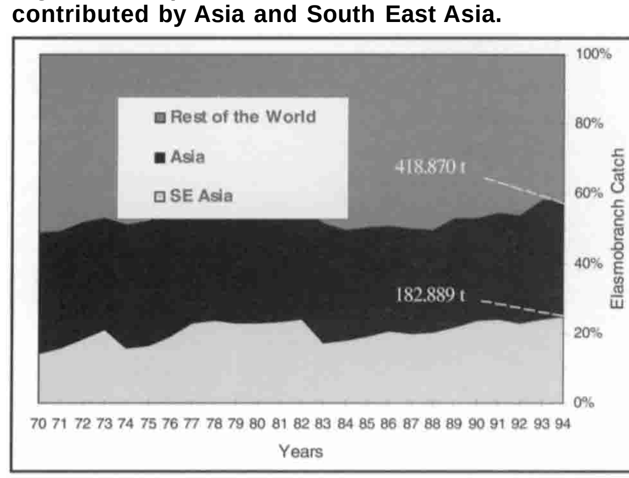
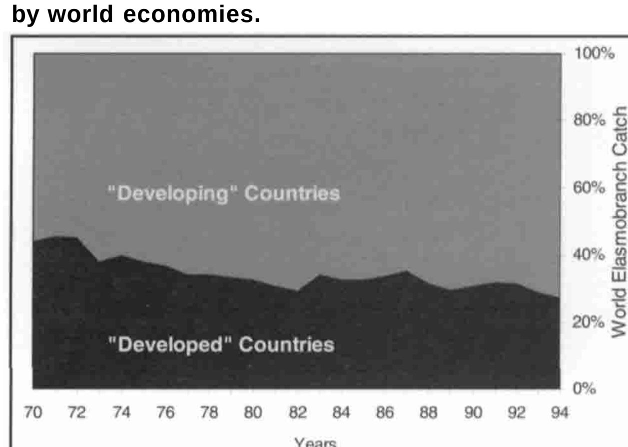


Figure 7. Contribution to total elasmobranch catches by world economies.



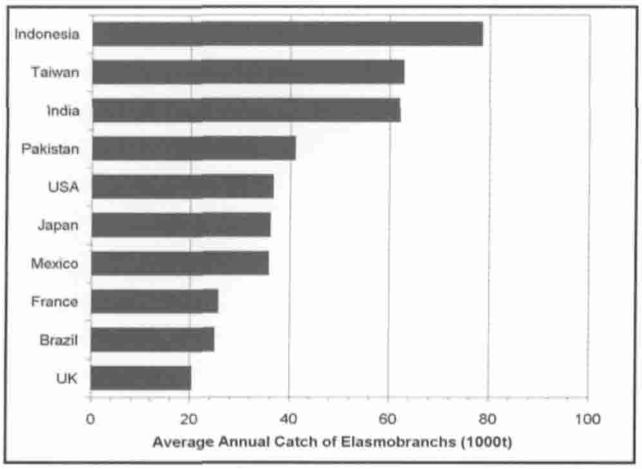


Figure 8. Average elasmobranch catches (1984-1994) of the 10 most important elasmobranch fishing nations.

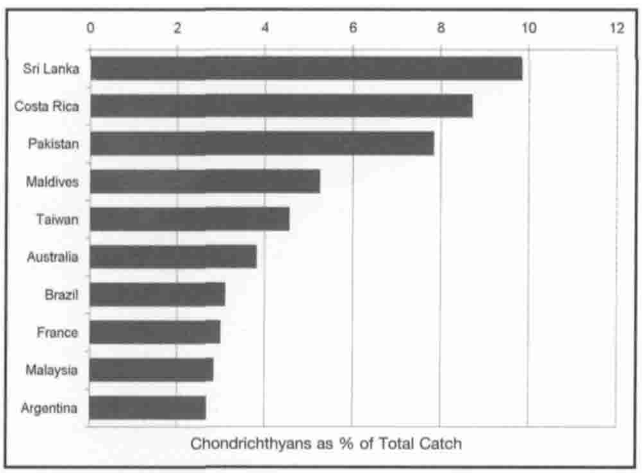


Figure 9. The 10 countries with the highest relative importance of elasmobranch catches as proportion of total catches of that country.

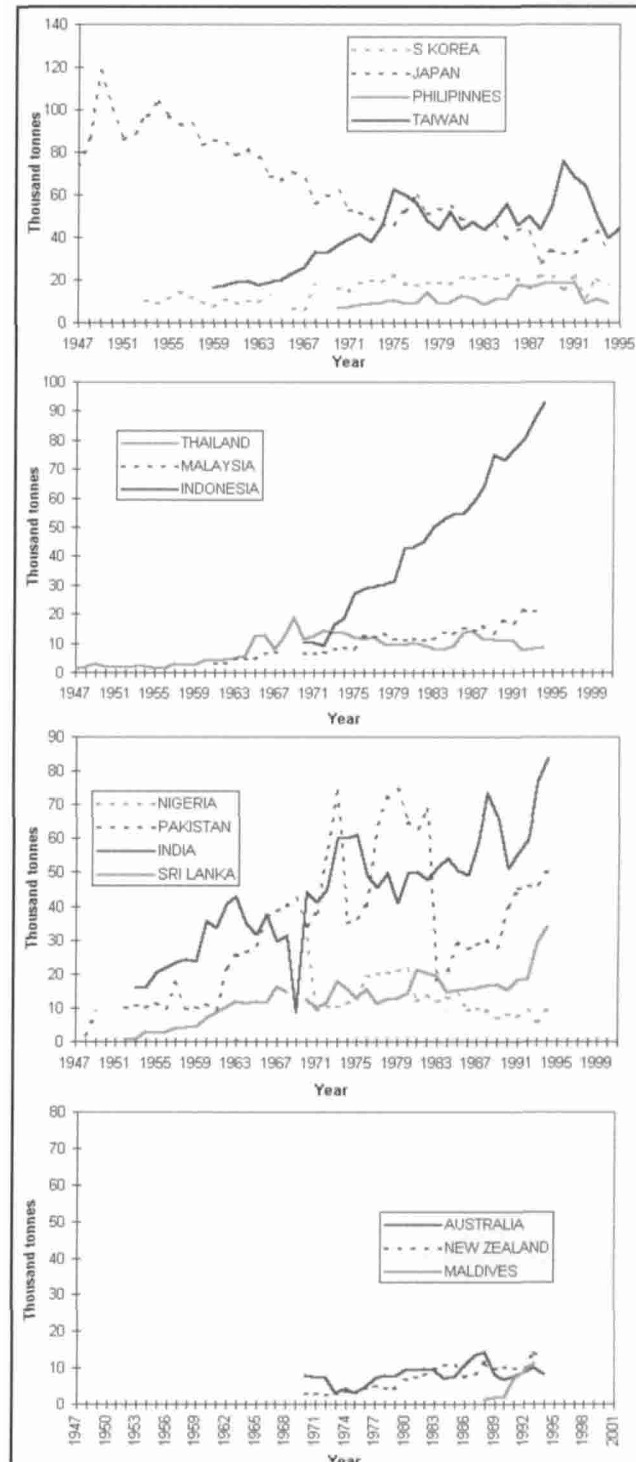
Worldwide, only four nations (Australia, Canada, New Zealand and the USA) have explicit management systems for elasmobranch fisheries.

According to the relative importance of sharks and rays in the total catches of each country (Figure 9), nations such as Sri Lanka, Costa Rica, the Maldives and Australia rank very high, despite having relatively small elasmobranch fisheries. How relevant elasmobranch fisheries are for each country must be taken into account if restrictions in shark trade are ever contemplated, because the social and economic impacts these measures could have on the fishing sector of countries with relatively important elasmobranch fisheries could be great.

Trends of catches in important elasmobranch fishing nations

The historical catch trends of the main elasmobranch fishing countries are shown in Figures 10 and 11. Japanese catches, once the largest in the world, are in clear decline, apparently as a consequence of shifts in consumer preferences spurred by increased economic status. On the other hand, Indonesia's elasmobranch catches have grown at an alarming rate, apparently due to the rocketing price

Figure 10. Historical elasmobranch catches for main shark and ray fishing countries of Asia, Africa and Oceania.



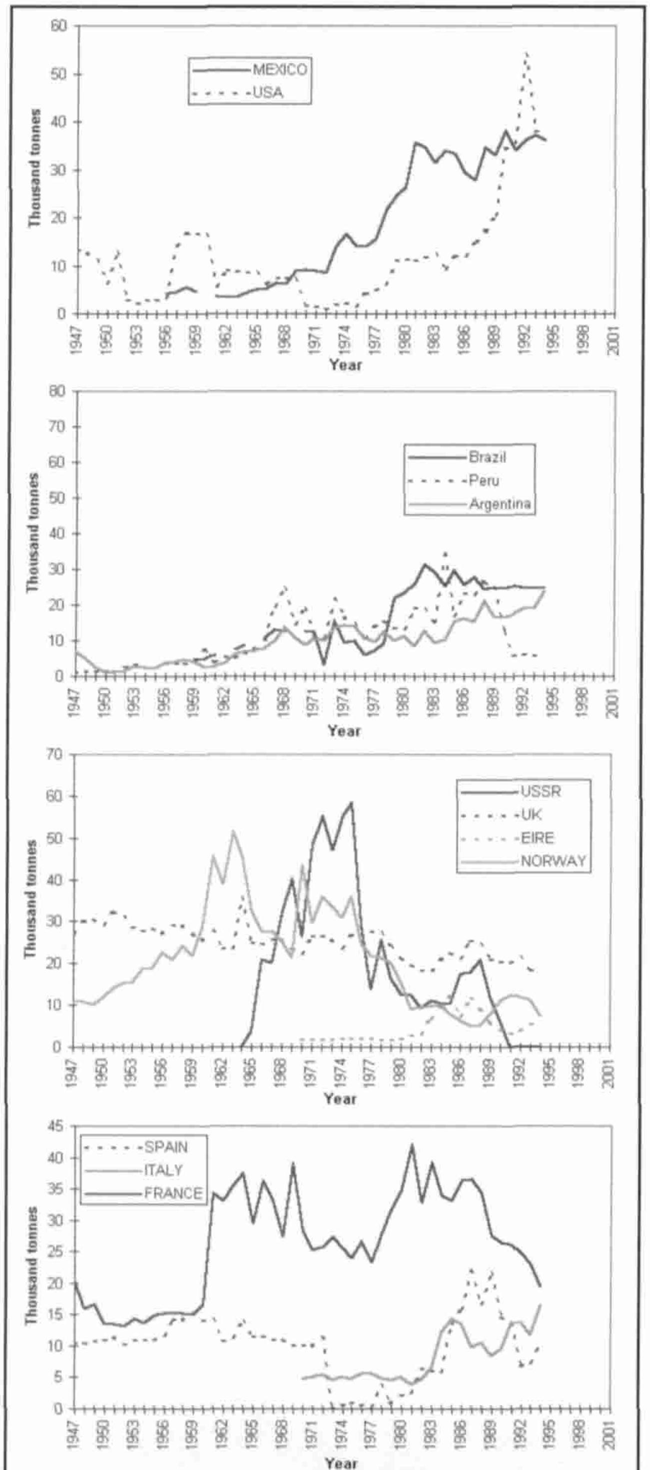


Figure 11. Historical elasmobranch catches for main shark and ray fishing countries of America and Europe.

of shark fins during the late 1980s. It is not clear if Indonesian figures are reliable; however, such steep growth in shark and ray catches should be a major cause for concern. In fact, there are already some reports suggesting declines in the abundance of elasmobranch stocks in this region. India has very important catches of elasmobranchs that show a higher rate of increase in the last few years. Elasmobranch fisheries in Pakistan have also been important, but are highly variable. In contrast, Australia and New Zealand have relatively small and cautious fisheries. They are among the few in the world under relatively strict management regimes. Fisheries in the United States grew very rapidly until recently, when a management plan was finally implemented.

One of the most pressing problems in the understanding of elasmobranch resources is the lack of adequate fisheries data. It is frequently almost impossible to get even basic information such as separate catches for sharks and rays, let alone for individual species. In general, fisheries information for elasmobranchs is very poor and difficult to obtain. Figures 12 and 13 show only two examples of the limitations of catch statistics for elasmobranchs throughout the world. The larger part of the catch in India is reported only as elasmobranchs, either from the east coast or from the west coast. Similarly, the larger part of the Brazilian catches are reported only as "elasmobranchs". Without proper information on the catches by species, or species group, it is going to be very difficult to assess either

Figure 12. Breakdown of shark and ray catches of India, as reported to FAO.

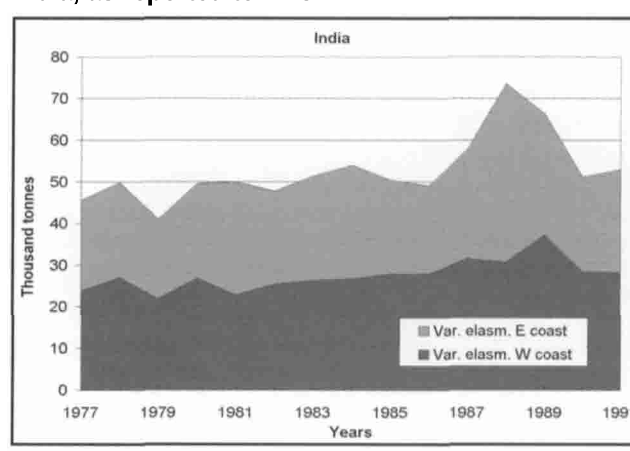
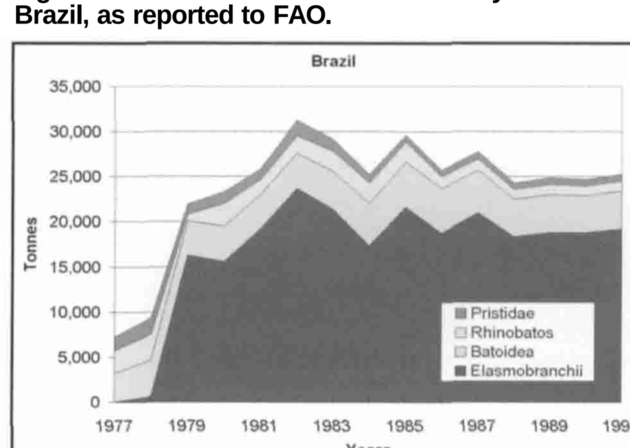


Figure 13. Breakdown of shark and ray catches of Brazil, as reported to FAO.



of these countries' fisheries. This happens not only in India and Brazil but in many parts of the world. It is the author's belief that this is largely a problem with origins in basic economic forces: the markets have just not been developed enough to set differential pricing for each elasmobranch species or species group.

Elasmobranch exploitation in the South East Asian and Asian Regions

Four countries figure prominently in Asian elasmobranch fisheries, and thus worldwide. Figure 14 shows the relative importance of shark and ray catches in Asia. Indonesia and India have the largest catches, and together with Pakistan and Japan comprise almost three-quarters of the Asian elasmobranch catches. Some of the worrying aspects of shark and ray fisheries in the region are briefly illustrated in the following paragraphs based on information for Korean and Indonesian elasmobranch fisheries available from the recent TRAFFIC report on world trade in sharks (TRAFFIC 1996).

According to Parry-Jones (1996b), elasmobranch catches in South Korea have fluctuated around 20,000t

Figure 14. Share of shark and ray catches by Asian and South East Asian countries (1979-1984).

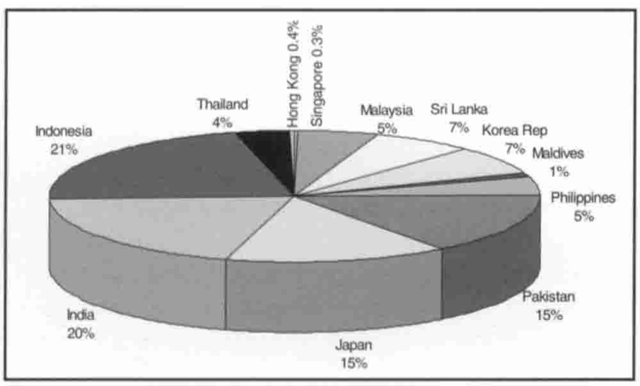
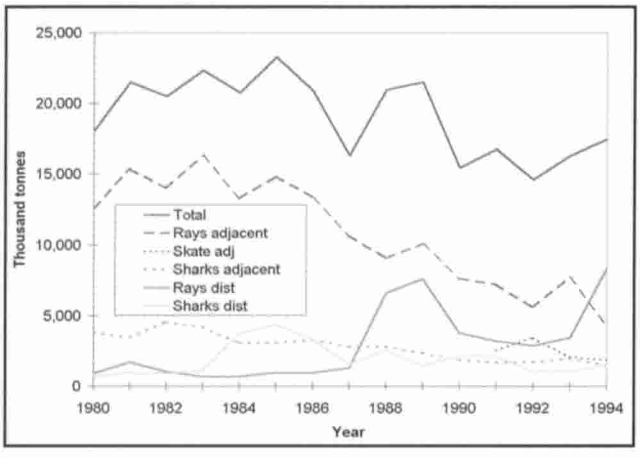


Figure 15. Breakdown of elasmobranch catches of South Korea (data taken from Parry-Jones 1996a).



since 1980 (Figure 15). Looking at the total South Korean elasmobranch catches, there seems to be a slight decline since the mid-1980s, although catches appear to have increased in the early 1990s. However, it is evident from a breakdown of the total catches that the landings of elasmobranchs from adjacent waters – particularly those of rays–are in sharp and steady decline. In fact, shark and ray catches in waters adjacent to South Korea have declined by more than 50% in the last 15 years. This could be signalling depletion of the local stocks. The reasons given by South Korean sources for these declines are various and unclear, but there is a good chance that they are the result of overexploitation (Parry-Jones 1996b).

Troubled and unchecked shark and ray fisheries also seem to be a pressing problem in Indonesia, which has the largest elasmobranch catches in the world: according to FAO statistics, 93,000t were harvested during 1994. However, there are reports suggesting that Indonesian fishery statistics might be quite unreliable (Dudley and Harris 1987), with inaccuracy reaching factors of 0.8 to 3.8 times the reported catches. Keong (1996) mentions that the real catches of sharks and rays in Indonesia could very well be over l00,000t. Given that the trend of elasmobranch catches in Indonesia shows a very steep increase in recent years, there are reasons to be worried about the shark and ray fisheries of this country. Keong (1996) provides plots of Indonesian shark catches by locality every five years since 1977. These figures show a pattern of effort shifting from west to east. Additionally, a few localities already show decreases in shark catches. These two patterns, although difficult to interpret without effort figures, are typical of sequential localised depletion. Concerns are further fuelled by reports of declines in the abundance of the giant guitarfish *Rhynchobatus djiddensis* in the Aru Islands, and possible local depletion of grey sharks in other localities such as the Spermonde Archipelago (Keong 1996).

Overall, the available statistics show that shark catches in many parts of Indonesia are either stable or growing. Nevertheless, there are clear declines in the shark catches of the south coasts of West and East Java, north coast of East Java, and South Kalimantan, while more recent declines are evident in Western Nusa Tengara, North Suluwesi, Muluku and Irian Jaya (Keong 1996). A point of scepticism is that there are no declines detectable in the limited data available on shark catch-per-unit-effort (CPUE) for Indonesia (total catches divided by total number of gillnets). This could be explained by:

1. a lack of an adequate measure of effort (i.e. gillnet-days);
2. obscuring effects due to the pooling of catch and effort data from different and very distant localities (possibly including independent stocks); or perhaps more likely by
3. gross errors in the fishery statistics.

Independently of the origin of this mismatch, from the fisheries point of view it is impossible to reconcile that after more than a twofold increase in catches during an 18-year period, there is not even a small decline in the CPUE of shark stocks in Indonesian waters.

Bycatch of elasmobranchs: the unofficial statistics

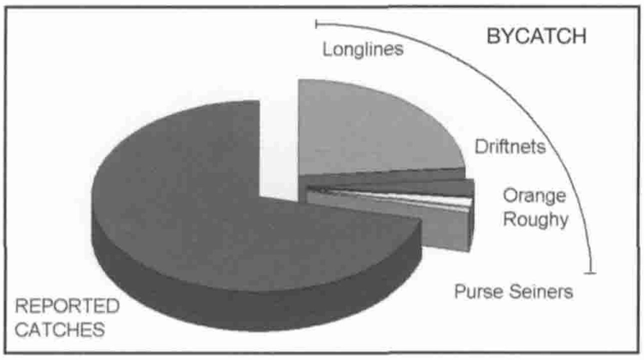
While the present analysis has focused on the official statistics of elasmobranch catches, there are many other sources of catches of elasmobranchs that are usually never accounted for. In particular, the large scale fisheries of the high seas, such as the driftnet fisheries that existed in the 1980s, or the numerous tuna fisheries that still exist worldwide, have always taken large numbers of sharks and rays as bycatch in their operations. Until recently there had been no attempts to quantify the levels of bycatch and discards of elasmobranchs in these fisheries on a global basis.

Available estimates of bycatch of elasmobranchs suggest that during the late 1980s and early 1990s about 11-13 million sharks were taken each year in the main high-seas fisheries of the world (Bonfil 1994). This is equivalent to about 260,000–300,000t. The discards from these fisheries were estimated to be around 230,000t. The bycatch of the longline fisheries for tunas was, and still is, by far the most important contribution to the total -just because of their sheer effort (Figure 16). The presently banned driftnet fisheries were the second most important source of elasmobranch bycatch. Note that, according to these results, the amount of sharks taken as bycatch represents about half the reported elasmobranch catch in the official statistics.

Recreational fisheries

Recreational fisheries for elasmobranchs are mainly centred in a few countries such as the USA, the United Kingdom, Australia, New Zealand and South Africa,

Figure 16. Proportion of estimated bycatch of elasmobranchs on high seas fisheries (taken from Bonfil 1994) as a proportion of total elasmobranch catches (bycatch + reported catches from official statistics).



although sharks are certainly caught in sport fisheries elsewhere. Unfortunately, information on these fisheries is very scarce and difficult to find. Recreational fisheries for sharks need to be more carefully monitored because they can be specifically targeted and thus potentially impact on individual populations (e.g. great white sharks *Carcharodon carcharias*).

Shark fishing tournaments were especially important in the USA for a few decades. During the 1980s it was estimated that up to 35,000t of sharks were caught every year in the eastern US recreational fisheries (Hoff and Musick 1990). This situation has changed since - thanks apparently to the concerted efforts of scientists, authorities and sport fishermen - and many tournaments in Australia and the US have turned into tag-and-release programmes. This trend is very encouraging as tag-and-release tournaments not only decrease the amount of potential mortality of sharks induced by sport fishing, but also provide a vehicle for increased research on the different species and stocks targeted by recreational fisheries.

Discussion

The general situation of elasmobranch fisheries in Asia is worrying (Table 2). About one-third of the 13 countries considered in this analysis show declining trends in shark and ray catches (Taiwan, Hong Kong, Japan and Philippines); two others show slight declines (Thailand and Korea); and four countries have very steep increases in catches (India, Indonesia, Maldives and Pakistan). Meanwhile, the status of shark and ray fisheries in China is still a total mystery. Despite an intensive survey carried out recently (Parry-Jones 1996a), not even the total elasmobranch catches are known for China.

Perhaps the most worrying aspect for the long-term sustainability of elasmobranch fisheries in Asia is that, at the time of writing, none of the countries in this region has implemented, or is known to be planning, management of their elasmobranch fisheries. In the light of the prominent position of the Indo-Pacific region as the world centre of elasmobranch biodiversity, this is indeed very worrying. If this was not enough reason for concern, none of these countries collects data by species or by meaningful species groups. Although presently the general situation of shark and ray fisheries seems relatively optimistic in most Asian countries, judging from their production levels, the future outlook is rather distressing. Given the current levels of exploitation and growth in catches, if Asian countries - and for that matter most of the important elasmobranch fishing countries in the world do not start implementing adequate programmes for fisheries data collection, and do not enact - even more swiftly - preventive management measures, it is almost certain that shark and ray stocks will be in **a** precarious situation very soon.

Table 2. Trends and patterns of elasmobranch fisheries in Asian countries.

	Recent trend	Catch 1994 (t)	Management plan	Fishery data by species	Notes
China	???	???	no?	no?	concern over juvenile catch
Taiwan	decline	44,000	no	no (partial)*	distant water 85%+: some species in decline (unexplained)
Hong Kong	decline	7-12	no	no	catch crash since early 1970s; 50% shark fin trade
Japan	decline	33,500	no	no (partial)*	declines in dogfish and mako shark CPUE
Philippines	decline	9,000	no	no	
Thailand	slight decline	8,500	no	no	
Korea	slight decline	17,500	no	no*	distant water 50%: various "reasons" for declines
Malaysia	slight increase	21,000	no	no	
Sri Lanka	increase	34,000	no	no (partial)	
Pakistan	steep increase	50.000	no	no	drop in 1980
India	steep increase	84,000	no	no	
Indonesia	steep increase	93,000	no	no	catch rates "stable"; reliability of data?; localised depletion suspected
Maldives	steep increase	11,000	no	no	

* some available from TRAFFIC surveys

There are at least two reasons to be worried about the conservation of elasmobranch stocks, particularly sharks. First, the increasing worldwide demand for shark fin soup has meant that the price paid for shark fins has increased at an unprecedented rate over the last decade. The exorbitant sums paid for shark fins are a tremendous incentive for fishermen all over the world to fish more eagerly for sharks, and sometimes forces them to take part in what is known as finning fisheries. This consists of catching sharks, cutting off the fins and throwing the rest of the shark - often still alive - back to the sea. This is a very widespread habit among tuna fishermen. The popular press is full of accounts of vessels being caught with hulls full of shark fins, but no trace of shark carcasses. Because of finning, it is obvious that most of the estimates of discards from bycatch in high seas fisheries can be accounted for as actual dead sharks. Secondly, the newly-developed market for shark cartilage as a supposed cure for cancer, means that there is now a new and growing demand for more dead sharks. There is now increasing fear of new fisheries being encouraged by the cartilage demand. More recently, American and British entrepreneurs have been marketing shark cartilage as a miracle cure for arthritic maladies in pets. Shark cartilage is now very successfully sold as a food supplement for cats and dogs.

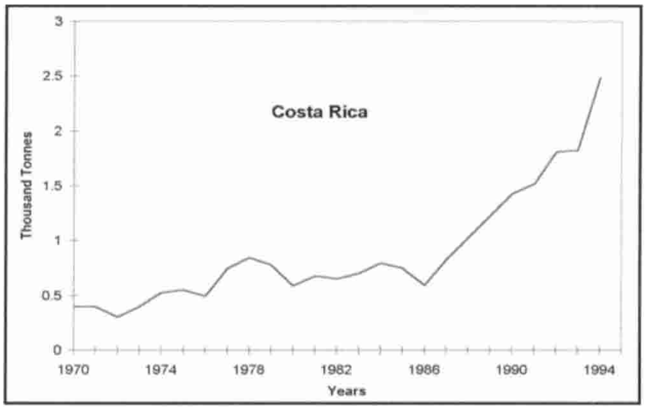
Although shark cartilage fisheries are apparently a rarity at present, there is at least one enterprise specifically devoted to this in Costa Rica (Jimenez 1994). Judging from the trend in the catches of this country, it is apparent that the cartilage boom is beginning to contribute to shark exploitation (Figure 17).

On the other side of the spectrum, there are a few signs of hope for the conservation of elasmobranchs. Sport diving to see sharks and rays in their natural environment has become increasingly popular around the world. This not only offers an opportunity to educate the general public about the need for elasmobranch conservation, but in some cases it provides an alternative and optimal use of sharks and rays. According to an analysis made in the Maldives by Anderson and Ahmed (1993), a live gray reef shark *Carcharhmus amblyrhynchos* brings 100 times the money value of the same shark dead in the fishery. The local economy receives an estimated $2.3 million/year as a result of shark diving. Clearly, there is a great advantage in keeping grey sharks alive in order to provide this level of income *for a number of years* instead of cashing a few dollars per shark *one single time* (Anderson, this volume).

Conclusions

- The multispecific and largely incidental nature of shark and ray fisheries, together with the lack of information about the catches and abundance of each species, are a tremendous obstacle for the assessment and management of these resources.

Figure 17. Trend of shark and ray catches of Costa Rica (FAO figures), attributed to the recent boom of the cartilage industry.



Given the biological susceptibility of sharks to overexploitation, it is worrying that only four countries in the world have management plans. This situation must be improved if we want sustainable fisheries and elasmobranch conservation.

The high levels of bycatch and discards in high-seas fisheries are worrying because we lack an understanding of the potential impact of the reduction in shark abundance on the oceanic ecosystems.

Two of the most threatening recent developments in shark exploitation are finning practices and the potential for damage as a result of cartilage fisheries.

Recommendations

The diversification of markets for elasmobranch species, and an increased quality control in the harvest system, should raise the profitability of the fishery for the communities that depend on sharks and rays for a living. This should also improve the reporting of fishery statistics on sharks and rays. This alone will have an immediate effect on the possibilities of implementing wise management of these fisheries, and is perhaps the only real solution in the long run. The compulsory reporting of bycatch in high-seas fisheries would provide the basis for a possible solution for the potential problems of oceanic shark depletion, especially if this is matched with a worldwide banning of finning practices. The United Nations' initiatives for the Conference on Highly Migratory and Straddling Fish Stocks, the eventual widespread adoption of the Code of Conduct for Responsible Fisheries, and a precautionary approach to fisheries management should all provide a timely framework for the management and conservation of elasmobranchs. Finally, the promotion of non-lethal uses of sharks, such as shark-diving and display in aquaria, will be an important step towards preserving sharks and educating the general public about the need for shark and ray sustainable management and conservation.

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An Overview of Sharks in World and Regional Trade

Noorainie Awang Anak
TRAFFIC Southeast Asia, Unit 9-3A, 3rd Floor, Jalan SS23/11, 47400 Taman SEA,
Petaling Jaya, Selangor, Malaysia

TRAFFIC Network carried out a study of the shark trade in Europe, India, east and southern Africa, South East Asia, East Asia, Oceania and North and South America between early 1994 and end of 1996. The study highlights the fisheries and trade of sharks and shark products in domestic and international trade. The study used a number of different sources of information including FAO data, regional research centres, national fisheries data, national trade data, SEAFDEC, etc., as well as field observations and interviews with traders, fishers, researchers and government sources. The statistical information was found to have a number of limitations. Chondrichthyan fish are caught in targeted fisheries or as bycatch. The former is of a much smaller volume compared to incidental bycatch although it is not possible to accurately compare the two. The trade in sharks includes live specimens, parts and products such as meat, fins, skin, liver oil, internal organs and other edible products such as brain, eggs, ovaries, cartilage, teeth, jaws and other curios, fishmeal, fertiliser and fish oil and bait. Fins are the most valuable parts of a shark, and represent by far the largest proportion of parts and products traded. This study recommends that the principles and standards in the FAO's "Code of Conduct for Responsible Fisheries" that address fisheries research and data collection should be applied by all nations. The collection of data could be much improved, and further monitoring efforts on domestic and foreign vessels should be initiated. Ecologically sustainable management plans are urgently required for the region and Parties to CITES should continue to monitor the work of relevant agencies in improving the collection of data, perhaps through the formation of a CITES marine fisheries working group.

Introduction

Sharks and shark products are a large and increasingly important fisheries resource in many countries. In many regions, this expansion has been due to the increase in trade in shark products such as fins, cartilage and liver oil. Sharks are caught both as targeted and incidental catches. The biology of most of the chondrichthyans is such that they are extremely vulnerable to over-exploitation. Catching of sharks is largely unregulated or unmonitored.

In 1994, FAO reported that of the total chondrichthyan landings, approximately 182,000t were recorded as sharks, 197,000t as skates and rays, 5,000t as chimaeras, and 347,000t as unidentified chondrichthyan species.

This paper presents an overview of the findings of TRAFFIC studies in regions of Europe, India, east and southern Africa, South East Asia, East Asia, Oceania, and North and South America. The study, which was carried out from early 1994 until the end of 1996, highlights the fisheries and trade of sharks and shark products, including the processing, preparation and use of the products in domestic and international trade.

Sources of information

A number of different sources were used, including published reports on national fisheries production, national trade data, FAO data, other sources such as regional research centres and international bodies, supplemented by interviews with experts and fishers, and observations at harvesting and landing sites.

National fisheries data

Historically, chondrichthyan fisheries made only relatively minor contributions to overall fisheries production. Therefore information on catches is often sparse, where it exists at all. When chondrichthyan catches are reported by national agencies, the data are usually grouped within a single category, and do not differentiate between species. In Malaysia, information is taken from the Fisheries Department annual report and regional fisheries agencies such as Infofish.

National trade data

National trade data present similar problems to other data sources, including incomplete data collection, failure to record the volumes and prices of many different products in trade, and a general grouping of data. The standard six-digit customs tariff heading adopted under the 'Harmonised System' of classification is not very specific, categories used being "dogfish" and "other sharks", with, in general, an additional sub-heading under "shark fin".

FAO - catches and landings data

FAO provides the most comprehensive data available on world fisheries production, and the only published sources of such data on a global scale. The principal sources are the *Yearbook of Fisheries Statistics: Catches and Landings* and *Yearbook of Fisheries Statistics: Production.* However, these data are based on reports from the fisheries agencies of individual nations, and are consequently affected by the same limitations (Rose 1996).

FAO trade data

In an analysis of FAO statistics, Rose (1996) found that production and trade data often differed significantly from national customs statistics, and also highlighted the frequent discrepancies between reports by national fisheries and customs agencies. For example, FAO reported the world production of shark liver oil from 1984 to 1993 as 412t, and other shark oil 227t. However, for South Korea alone, the average volume of shark liver oil imported annually was 327t. For shark fin exports, FAO reported that a total of 15 countries were involved in the export, while Hong Kong customs data detailed imports from a total of 125 countries during 1980-1995.

Other data sources

In South East Asia, some data were also collected from SEAFDEC (South East Asian Fisheries Development Center), based in Trengganu, Malaysia, as well as from other regional sources such as the annual report from the Fisheries Departments of Thailand and Philippines. In some cases TRAFFIC Southeast Asia (in common with other TRAFFIC offices) conducted interviews or distributed questionnaires to traders and fishers, and collected data from regional and inter-governmental bodies, even though the information from these sources remained limited. It should be noted that information was also obtained from the International Council for the Exploration of the Seas (ICES), which compiles catch and landing data for sharks, skates and rays, and the International Commission for the Conservation of Atlantic Tuna (ICCAT), which recently began to request incidental shark catch information from member nations involved in Atlantic tuna, scombrid and billfish fisheries. Some TRAFFIC offices also conducted field observations at landing sites and at various stages of the fisheries.

Types of chondrichthyan fisheries

Table 1 lists chondrichthyan species commonly caught in fisheries.

Targeted

The catch from fisheries targeted or directed at sharks is of a much smaller volume than from incidental catches. In targeted fisheries the gears commonly used are longlines, gillnets and trawls, and sharks are targeted both in coastal and offshore waters.

Bycatch

Sharks are frequently caught as incidental bycatch in fisheries directed at other species, such as tuna. The volume of sharks caught as bycatch is thought to be large, although it is not possible to accurately compare the production of incidental and targeted shark fisheries. The types of fishing gear used are related to the scale of the fisheries. Gear for large-scale fisheries includes purse seine, trawl, otter trawl and gillnet, and small-scale gears are gillnet, driftnet and hook and long line. Bycatch occurs in deep waters, as well as in coastal and offshore pelagic fisheries.

Trade in shark products

Meat

Shark meat is becoming increasingly popular in domestic and international markets. However, the relatively low value of chondrichthyan meat products, in comparison to other species such as tuna, encourages a very high rate of discard at sea. Shark meat needs careful and proper handling as a table meat because of the high concentration of urea in the body. To avoid the formation of ammonia, it requires immediate icing or freezing and it also cannot be left too long in the water after the shark's death. Generally, both carcasses and fillets for fresh consumption require washing or soaking in a brine solution.

Connoisseurs consider the shortfin mako *Isurus oxyrinchus* as the world's finest quality shark meat and it is used for sashimi in Asia and as a high-value fresh seafood in American and European markets. Other high-value sharks include thresher sharks *Alopias* spp. and porbeagle shark *Lamna nasus,* caught in large numbers in directed fisheries and as bycatch in tuna and swordfish fisheries. However, some nations have particular preferences for other species of shark meat, such as smoothhounds *Mustelus* spp. in Argentina.

Between 1985 and 1994, according to FAO data, the world exports of fresh, chilled and frozen shark meat more than doubled, from 22,203t in 1985 to 47,687t in 1994. The number of exporting nations rose from 18 to 37, and importing countries rose from 12 to 36 in the same period. Supermarkets in Europe, in particular Italy, France, United Kingdom, Denmark and Germany, and in South America (Argentina) and the USA now commonly offer fresh shark steaks and fillets.

Consumer taste has not developed to the extent that shark meat can be readily sold as 'shark meat'; it is more often labelled as 'grayfish', 'rock salmon', 'huss', 'rigg', 'flake', or '*galina del mar*' ('chicken of the sea'). Table 2 lists the species most preferred in the meat trade.

Fins

TRAFFIC found documented evidence that shark fin soup has been a popular delicacy among the Chinese for 2,000 years. The fins are essentially tasteless and the processed shark fin needles resemble rice noodles in wet, dried or cooked forms, with flavouring needed to add taste. Shark fins are among the world's most expensive fishery products. The value of the fins varies according to colour, size, thickness and fin needle content, but nearly all species have commercially valuable fins (Kreuzer and Ahmad 1978, Subasinghe 1992)

Shark fins are processed and marketed in the following forms (Kreuzer and Ahmad 1978, Lai 1983):

- Dried, with the skin intact.
- Semi-prepared, with the skin removed but the fibres intact.
- Fully prepared with individual strands of the cartilaginous platelets showing separately.
- Frozen prepared fins.
- In brine.

Table 1. Commonly fished chondrichthyan species*

Family	Scientific name	Common name
HEXANCHIDAE	*Notorynchus cepedianus*	Broadnose sevengill shark
SQUALIDAE	*Squalus acanthias*	Piked dogfish
CENTROPHORIDAE	*Centrophorus* spp.	Gulper sharks
SQUATINIDAE	*Squatina* spp.	Angelsharks
ODONTASPIDAE	*Carcharias taurus* *Odontaspis ferox*	Sand tiger shark Smalltooth sand tiger
ALOPIIDAE	*Alopias* spp. *Alopias pelagicus* *Alopias vulpinus*	Thresher sharks Pelagic thresher Thresher shark
CETORHINIDAE	*Cetorhinus maximus*	Basking shark
LAMNIDAE	*Isurus* spp. *Isurus oxyrinchus* *Isurus paucus* *Lamna nasus*	Mako sharks Shortfin mako Longfin mako Porbeagle shark
SCYLIORHINIDAE	*Scyliorhinus canicula*	Smallspotted catshark
TRIAKIDAE	*Galeorhinus galeus* *Mustelus* spp. *Mustelus antarctlcus* *Mustelus lenticulatus*	Tope shark Smoothhounds Gummy shark Rig
CARCHARHINIDAE	Carcharhinidae spp. *Carcharhinus albimarginatus* *Carcharhinus brachyurus* *Carcharhinus brevipinna* *Carcharhinus falciformis* *Carcharhinus leucas* *Carcharhinus limbatus* *Carcharhinus longimanus* *Carcharhinus melanopterus* *Carcharhinus obscurus* *Carcharhinus plumbeus* *Carcharhinus sorrah* *Galeocerdo cuvier* *Prionace glauca* *Rhizoprionodon acutus* *Triaenodon obesus*	Requiem sharks Silvertip shark Bronze whaler Spinner shark Silky shark Bull shark Blacktip shark Oceanic whitetip shark Blacktip reef shark Dusky shark Sandbar shark Spottail shark Tiger shark Blue shark Milk shark Whitetip reef shark
SPHYRNIDAE	*Sphyrna* spp. *Sphyrna lewini* *Sphyrna mokarran* *Sphyrna zygaena*	Hammerheads Scalloped hammerhead Great hammerhead Smooth hammerhead
RHYNCHOBATIDAE	*Rhynchobatus djiddensis*	Giant guitarfish
RAJIDAE	*Raja clavata*	Thornback skate
CALLORHINCHIDAE	*Callorhinchus* spp.	Elephantfish

* This list was developed on the basis of TRAFFIC Network research and includes species frequently appearing in available information on worldwide shark fisheries. The list of commonly fished species is intended to guide preliminary efforts to improve species-specific reporting of catches and landings. Inclusion in this list does not suggest that the species commonly occurs in international trade. Nor does it indicate that the species is vulnerable to, or threatened by, overexploitation. Indeed, many of the species listed here are included as a result of their broad geographic distributions.

Table 2. Preferred species in meat trade*

Family	Scientific name	Common name
HEXANCHIDAE	*Notorynchus cepedianus*	Broadnose sevengill shark
SQUALIDAE	*Squalus acanthias* *Squalus megalops*	Piked dogfish Shortnose spurdog
CENTROPHIDAE	*Centrophorus granulosus* *Centrophorus squamosus*	Gulper shark Leafscale gulper shark
PRISTIOPHORIDAE	*Pristiophorus cirratus*	Longnose sawshark
SQUATINIDAE	*Squatina* spp.	Angelsharks
OROLECTOBIDAE	*Orectolobus maculatus*	Spotted wobbegong
ALOPIIDAE	*Alopias superciliosus* *Alopias vulpinus*	Bigeye thresher Thresher shark
LAMNIDAE	*Carcharodon carcharias* *Isurus oxyrinchus* *Lamna ditropis* *Lamna nasus*	Great white shark Shortfin mako Salmon shark Porbeagle shark
TRIAKIDAE	*Galeorhinus galeus* *Mustelus lenticulatus*	Tope shark Rig
CARCHARHINIDAE	*Carcharhinus plumbeus* *Carcharhinus longimanus* *Carcharhinus melanopterus* *Galeocerdo cuvier* *Prionace glauca*	Sandbar shark Oceanic whitetip shark Blacktip reef shark Tiger shark Blue shark
SPHYRNIDAE	*Sphyrna zygaena*	Smooth hammerhead
PRISTIDAE	*Anoxypristis cuspidata* *Pristis pectinata*	Knifetooth sawfish Smalltooth sawfish
RHYNCHOBATIDAE	*Rhynchobatus djiddensis*	Giant guitarfish
RAJIDAE	*Raja brachyura* *Raja clavata*	Blonde skate Thornback skate

" Shark species preferred for human consumption vary by country and region according to species availability and customary processing and techniques. Source: **TRAFFIC research**

Table 3. Preferred species in fin trade*

Family	Scientific name	Common name
GINGLYMOSTOMATIDAE	*Ginglymostoma cirratum*	Nurse shark
RHINIODONTIDAE	*Rhincodon typus*	Whale shark
ODONTASPIDAE	*Odontaspis ferox*	Smalltooth sand tiger
ALOPIIDAE	*Alopias vulpinus*	Thresher shark
CETORHINIDAE	*Cetorhinus maximus*	Basking shark
LAMNIDAE	*Carcharodon carcharias* *Isurus* spp. *Lamna ditropis* *Lamna nasus*	Great white shark Makos Salmon shark Porbeagle shark
TRIAKIDAE	*Galeorhinus galeus*	Tope shark
CARCHARHINIDAE	*Carcharhinus falciformis* *Carcharhinus obscurus* *Carcharhinus plumbeus* *Carcharhinus tilsoni* *Galeocerdo cuvier* *Negaprion brevirostris* *Prionace glauca* *Scoliodon laticaudus*	Silky shark Dusky shark Sandbar shark Australian blacktip shark Tiger shark Lemon shark Blue shark Spadenose shark
SPHYRNIDAE	*Sphyrna lewini*	Scalloped hammerhead
PRISTIDAE	Pristidae spp.	Sawfish
RHYNCHOBATIDAE	*Rhyncobatus djiddensis*	Giant guitarfish

*Interviews and field research by TRAFFIC investigators reveal widely different rankings by species, presumably owing, at least in part, to regional differences in species availability. Source: TRAFFIC research

Table 4. Preferred species in shark skin trade

Family	Scientific name	Common name
HEXANCHIDAE	*Notorynchuscepedianus*	Broadnose sevengill shark
SQUALIDAE	*Squalusacanthias*	Piked dogfish
CENTROPHORIDAE	*Centrophorusniaukang*	Taiwan gulper shark
DALATIIDAE	*Dalatiaslicha*	Kitefin shark
PRISTIOPHORIDAE	*Pristiophorusnudipinnis*	Shortnose sawshark
SQUATINIDAE	*Squatinaaculeata* *Squatinaoculata*	Sawback angelshark Smoothback angelshark
OROLECTOBIDAE	*Eucrossorhinusdasypogon* *Orectolobusmaculatus* *Orectolobusornatus*	Tasselled wobbegong Spotted wobbegong Ornate wobbegong
GINGLYMOSTOMATIDAE	*Ginglymostomacirratum* *Nebriusferrugineus*	Nurse shark Tawny nurse shark
CETORHINIDAE	*Cetorhinusmaximus*	Basking shark
LAMNIDAE	*Carcharodoncarcharias* *Isurusoxyrinchus* *Lamnanasus*	Great white shark Shortfin mako Porbeagle shark
CARCHARHINIDAE	*Carcharhinusaltimus* *Carcharhinusbrevipinna* *Carcharhinusleucas* *Carcharhinuslimbatus* *Carcharhinuslongimanus* *Carcharhinusobscurus* *Carcharhinusplumbeus* *Carcharhinussignatus* *Galeocerdocuvier* *Negaprionbrevirostris* *Prionaceglauca*	Bignose shark Spinner shark Bull shark Blacktip shark Oceanic whitetip shark Dusky shark Sandbar shark Night shark Tiger shark Lemon shark Blue shark
SPHYRNIDAE	*Sphyrnalewini* *Sphyrnamokarran*	Scalloped hammerhead Great hammerhead
PRISTIDAE	Pristidae spp.	Sawfish

Source: TRAFFIC research

- As fin nets, in which the cartilaginous fin needles have been boiled, separated and dried and packaged in loose groupings.
- In canned shark fin soup.

Taiwan is considered to be one of the largest producers of shark fins, with annual production of nearly l,000t from 1980 to 1996. Most of it is consumed locally.

According to Hong Kong customs statistics at least 125 countries are involved in the shark fin trade. Hong Kong is the centre of this activity and together with China and Singapore, is the biggest shark fin trader and processor.

From 1980 to 1995 Hong Kong recorded imports of shark fins from 125 countries and re-export to 75 countries. During this time the most important suppliers appeared to be China, Singapore, Japan, Indonesia, USA and the United Arab Emirates. According to Hong Kong customs data the reported imports of shark fins rose from 2.7 million kg in 1980 to 6.1 million kg in 1995. However, these figures and those in other regions appear to be misleading as they imply that shark harvesting has increased at a proportionate rate.

From TRAFFIC Network findings, it seems that much of the increase appears to be the result of double or triple counting of fins. For example, fins imported by Hong Kong from the USA are exported to China for processing, reimported to Hong Kong and then exported back to USA, so are counted twice as imports and probably twice as exports. Multiple counting also occurs in trade statistics for China, Singapore and regional trade centres such as the USA and Yemen.

Asia has long been the consumption centre for shark fins and this prominence will continue with the opening of China as a potentially unlimited market for shark fins since the mid-1980s, which in turn has contributed to a significant increase in world shark fin consumption. Retail prices generally range from US$40 to US$564 per kg, and a bowl of shark fin soup can cost up to US$90 in a Hong Kong restaurant (Table 3).

Shark skin

The skin in its rough form is known as shagreen. Originally used as an abrasive for rasping and polishing, it is now also used in the leather industry. The skins are removed by starting a main cut down the centre of the back of a shark from which the fin has already been removed. In a number of countries the skin is used in a variety of leather products including handbags, watchstraps, cowboy boots and belts. Some tanneries have been set up, for example in Europe, Japan, Australia and Thailand, to process shark leather, but production and trade data are not available.

The USA imported over US$3.5 million worth of sharkskin from 1978 to 1987, primarily from Mexico, as well as from France and Japan. USA customs data from 1984 to 1990 showed that on average annual imports were 11,984 whole skins, rising from 1,189 in 1984 to 36,818 in 1989 (Table 4). Ray leather is also increasing in value.

Shark liver oil

Historically, the oil and its constituants (which include vitamin A and squalene) have been used as a lubricant, for

Table 5. Preferred species for production of shark liver oil

Family	Scientific name	Common name
HEXANCHIDAE	*Hexanchus griseus*	Bluntnose sixgill shark
ECHINORHINIDAE	*Echinorhinus brucus*	Bramble shark
SQUALIDAE	*Cirrhigaleus barbifer* *Squalus acanthias* *Squalus cubensis* *Squalus mitsukurii*	Mandarin dogfish Piked dogfish Cuban dogfish Shortspine spurdog
CENTROPHORIDAE	*Centrophorus acus* *Centrophorus lusitanicus* *Centrophorus niaukang* *Centrophorus squamosus* *Deania calcea*	Needle dogfish Lowfin gulper shark Taiwan gulper shark Leafscale gulper shark Birdbeak dogfish
SOMNIOSIDAE	*Centroscymnus owstoni* *Centroselachus crepidater* *Proscymnodon plunketi*	Roughskin shark Longnose velvet dogfish Plunket shark
DALATIIDAE	*Dalatias licha*	Kitefin shark
SQUATINIDAE	*Squatina aculeata* *Squatina oculata* *Squatina squatina*	Sawback angelshark Smoothback angelshark Angelshark
GINGLYMOSTOMATIDAE	*Nebrius ferrugineus*	Tawny nurse shark
ODONTASPIDAE	Odontaspidae spp.	Sand tiger sharks
ALOPIIDAE	*Alopias vulpinus*	Thresher shark
CETORHINIDAE	*Cetorhinus maximus*	Basking shark
LAMNIDAE	*Carcharodon carcharias* *Isurus oxyrinchus* *Isurus paucus* *Lamna ditropis* *Lamna nasus*	Great white shark Shortfin mako Longfin mako Salmon shark Porbeagle shark
SCYLIORHINIDAE	Scyliorhinidae spp.	Cat sharks
TRIAKIDAE	*Galeorhinus galeus* *Mustelus manazo*	Tope shark Starspotted smoothhound
HEMIGALEIDAE	*Hemipristis elongatus*	Snaggletooth shark
CARCHARHINIDAE	*Carcharhinus altimus* *Carcharhinus brevipinna* *Carcharhinus falciformis* *Carcharhinus leucas* *Carcharhinus limbatus* *Carcharhinus longimanus* *Carcharhinus melanopterus* *Carcharhinus obscurus* *Carcharhinus plumbeus* *Galeocerdo cuvier* *Negaprion acutidens* *Triaenodon obesus*	Bignose shark Spinner shark Silky shark Bull shark Blacktip shark Oceanic whitetip shark Blacktip reef shark Dusky shark Sandbar shark Tiger shark Sharptooth lemon shark Whitetip reef shark
SPHYRNIDAE	*Eusphyra blochii* *Sphyrna zygaena*	Winghead shark Smooth hammerhead
PRISTIDAE	Pristidae spp. *Pristis pectinata*	Sawfish spp. Smalltooth sawfish

Source: TRAFFIC research

tanning and curing of leather, for cosmetic manufacturing and for pharmaceutical products.

Several methods have been reported for the extraction of liver oil. For example, in the Philippines the liver is chopped and boiled with water, and as the oil rises to the surface it is skimmed off and allowed to cool before residues are removed.

Historically, Japan has been the most prominent squalene producer, but South Korea appears to be the world's largest consumer of shark oil and squalene which is intended for human consumption, with 364t of shark liver oil imported in 1994 alone. From 1987 to 1994 the main suppliers were Indonesia, Japan, Norway and the Philippines. In 1994 Indonesia supplied about 93% of the total import of shark liver oil. However, production and trade information is very limited (Table 5).

Internal organs and other edible products

In addition to fins and meat, other parts taken for human consumption include the ovaries, brain and eggs. For example, in Japan the hearts of salmon shark *Lamna ditropis* are eaten as sashimi (Kiyono 1996). So far, no reliable data are available for these products.

Cartilage

Shark cartilage is a relatively new product on the market thus information on production or trade volume is limited. Several medicinal and food products are produced from cartilage. A chemical compound, chondrichthyan natrium, found in the hard and soft cartilage of shark is used in Japan as a treatment for eye fatigue and rheumatism -blue shark *Prionace glauca* is considered a good source - and chondroitine is a pharmaceutical subsistence used in eye drops (Kiyono 1996).

Cartilage has been marketed extensively worldwide as a treatment for cancer, in powder or capsule form. But, so far, no conclusive tests involving humans have been able to demonstrate that shark cartilage administered orally contains sufficient amounts of active ingredients to be effective, or even that it reaches the affected area (Luer undated, Dold 1996).

From TRAFFIC'S research, the major cartilage producing nations appear to include Australia, Japan and the USA. In Europe shark cartilage products are commonly marketed in Belgium, France, Germany, Greece, Italy, the Netherlands, Spain and the UK. Preferred species are listed in Table 5.

Teeth, jaws and other curios

These have been used in many cultures, both as functional and ceremonial objects and for sale to tourists as souvenirs. This has been reported in India (Hanfee 1996), the Maldives (Anderson and Ahmed 1993), the South Pacific (Hayes 1996b), Thailand (Chen 1996), east and southern Africa (Marshall and Barnett 1996), Europe (Fleming and Papageogiou 1996), North America and South America (Rose 1996a).

Fishmeal, fertiliser, fish oil

The waste from processing sharks, skates and rays may be used as fishmeal to feed domesticated animals, as fertiliser, or to yield fish oils for industrial uses. For example, in Thailand fishmeal is used to feed shrimps being cultured in cages.

Shark as bait

Small and unmarketable sharks are usually used as bait, often in shark fisheries themselves, or as bait for crustaceans and mollusc. Catches used as bait are not landed and are therefore unreported.

Aquarium specimens

Many aquaria keep sharks as live specimens, or for sale to private hobbyists. For example, live catshark juveniles and egg cases are imported to the USA from Indonesia (Rose 1996d).

Conclusions

TRAFFIC'S study of the trade in sharks and shark products suggests that this trade is becoming an increasingly important part of total fisheries production and consumption. The trade is earning cash income for coastal communities, and foreign exchange in the fisheries processing and export sectors. However, fundamental difficulties exist in trying to assess the management and conservation implications of the growing chondrichthyan fisheries. The available data on catch, landings and trade are incomplete and the species landed are rarely specified. These issues can be addressed through concerted effort in data collection and management. There is an even more urgent need to improve fisheries management and research, since much of the population and ecology of sharks and their environment is still incompletely known.

TRAFFIC'S recommendations are summarised as follows:

- The principles and standards in the FAO's "Code of Conduct for Responsible Fisheries" that address fisheries research and data collection should be applied by all nations.
- Collection of data should be improved; this can be initiated by FAO, international fisheries agencies, and regional and national fisheries agencies to indicate the

species of sharks caught in commercial, subsistence and recreational fisheries.

- Logbook reporting, dockside monitoring and other monitoring efforts should be initiated (and should be mandatory for domestic and foreign vessels operating in national waters or landing their catch in domestic ports).
- Regional and national fisheries agencies should develop ecologically sustainable management plans.
- Parties to CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) should continue to monitor the work of relevant agencies in improving the collection of data. This could be facilitated through the formation of a CITES marine fisheries working group.

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Pilot Fisheries Socio-economic Survey of Two Coastal Areas in Eastern Sabah

Patricia C. Almada-Villela
MesoAmerican Barrier Reef System Project, Coastal Resources Multi-Complex Building, Princess Margaret Drive, P.O. Box 93, Belize City, Belize

A pilot socio-economic study of two kampongs (villages) in eastern Sabah, one located on an estuary and the other on a reef island, show that a considerable amount of sharks and rays are caught and consumed by artisanal and subsistence fishermen. However, in spite of this, sharks and rays are still considered as low-price catches. Fishing and fishing-related tasks (net mending, boat building, etc.) are the main income generating activities for both kampongs. The role of women is important as food gatherers in both villages.

Introduction

The people of Sabah have been associated for centuries with the natural resources of their surrounding area. Many depend entirely on the harvesting of the aquatic resources, both marine and freshwater, including elasmobranchs. Fishing has been the main activity in the project area for many generations, as coastal and island communities have had little or no opportunities to earn a living from alternative livelihoods. In riverine areas, fishing is usually done by choice and fishermen may often also farm or be involved in other activities. On small islands, however, fishermen do not have a choice and activities such as wood collecting and thatching are usually unwaged and supplementary to their main income from fishing.

The main objective of this study was to gather information from indigenous and traditional sources in order to provide an overview of the present use and value of elasmobranchs and other fish species to the rural fishing communities in eastern Sabah. The present report represents a pilot survey of two coastal areas: Kampongs Pulau Tetabuan and Pulau Mabul located in the Beluran and Semporna areas respectively (see Manjaji, this volume).

Material and methods

Two representative fishing kampongs (villages) were selected with the help of the Fisheries Department personnel in Kota Kinabalu and Semporna. This selection was based on previous knowledge of elasmobranch landings and sightings for those areas by the Beluran and Semporna Fisheries Departments, the area offices responsible for the two sites selected: Pulau Tetabuan and Pulau Mabul. Pulau Mabul and Pulau Danawan in the Semporna area are recognised as main localities for the capture of sharks; indeed, Pulau Danawan is believed to be more important than Pulau Mabul. However, its closeness to the Philippines border, with the potential threat of border conflict between fishermen from more than one country, ruled it out of the present study for safety reasons. The study was carried out from 30 July to 14 August 1996 and the visits to the villages lasted for five and three days respectively.

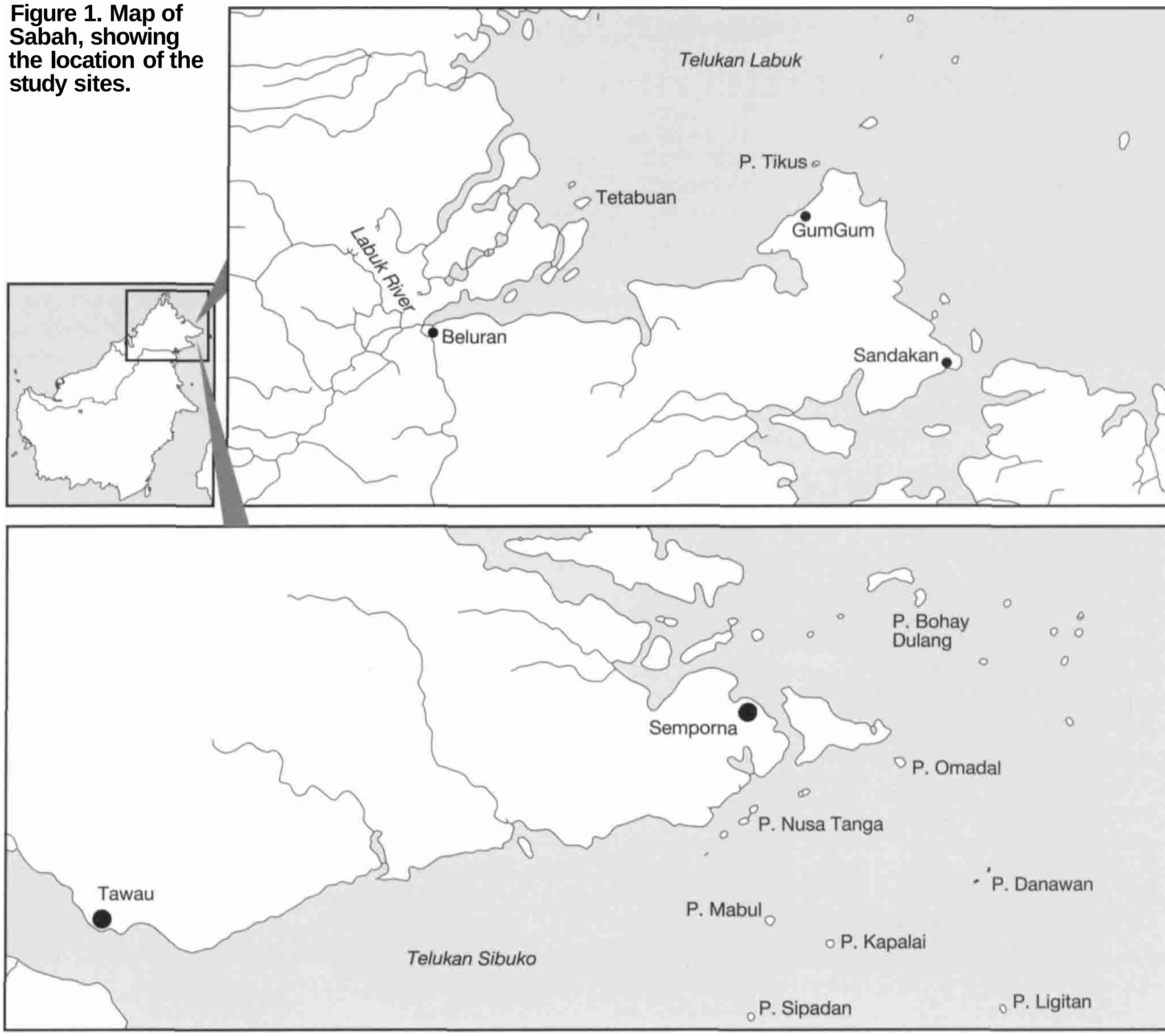
A series of interviews were carried out in these villages to gather information on fish species, catches, prices and human nutrition in the villages. Interviews were undertaken with the help of a translator, although in the case of the *Bajau Laut*, a complex translation process involving three translators was needed due to the complexity of the languages spoken. In general, there were varying degrees of difficulty in obtaining accurate information as not everyone who was interviewed felt comfortable providing details on their finances, health and family situation. Interviews thus had to be carried out with the utmost tact and consideration. Information gathered was entered in a survey form based on methodology developed for similar projects in Asia and Africa (Gumti Phase II Sub-Project Feasibility Study, 1993; Naga Hammadi Barrage Development Feasibility Study, 1995).

Study sites

Kampong Tetabuan is located on the Labuk River, approximately 25km from Beluran (Figure 1). It has approximately 127 households with a combined total of 1,100 people (adults and children). The Beluran Fisheries Office reports a figure of 764 people, although it is unclear if this figure includes both adults and children. Most villagers, including women, are fully involved in fishing. There is no electricity except for a few generators, thus catches cannot be kept fresh for more than a few days. The village was visited during 2 to 6 August 1996.

Kampong Pulau Mabul, located in south-east Sabah in the Sulawesi Sea, was established around 1974-1975 and can be reached by boat from Semporna in approximately 1.30 hrs. There is also an army base camp, a school and two

Figure 1. Map of Sabah, showing the location of the study sites.



tourist resorts (Sipadan Water Village and Sipadan-Mabul Resort). Two generators in the village supply electricity for part of the day; however, the tourist resorts are totally self-contained. There are 252 households on the island with approximately 3,000 inhabitants (adults and children), and it is common to find more than one family living together. Fishing is their main income-generating activity, although there is an increasing amount of part time workers at the resorts. Pulau Mabul was visited from 7 to 9 August 1996.

Fish market surveys

Six fish markets were visited in total during this visit in order to formulate a preliminary concept of how prices per species vary from source to market. In addition, price variation between fresh and dry produce was also investigated.

Socio-economic context of the elasmobranch fisheries in the area

Substantial numbers of people engage in subsistence fishing worldwide, either in freshwater or coastal ecosystems. Indeed in coastal areas, fishing is a major activity, which is carried out either as a full time operation or simply as part of their everyday lives. This type of subsistence fishing is best described as the utilisation of a free common-good resource by family members in order to provide them with the majority, if not all, of their animal protein. Subsistence fishing usually applies to people who are too poor to buy fish at markets and who therefore enter a wageless labour system producing food for their families by catching fish. In some extremely deprived or exploited areas, it is often this subsistence fishing which keeps these people marginally on the survival level. In Sabah, however.

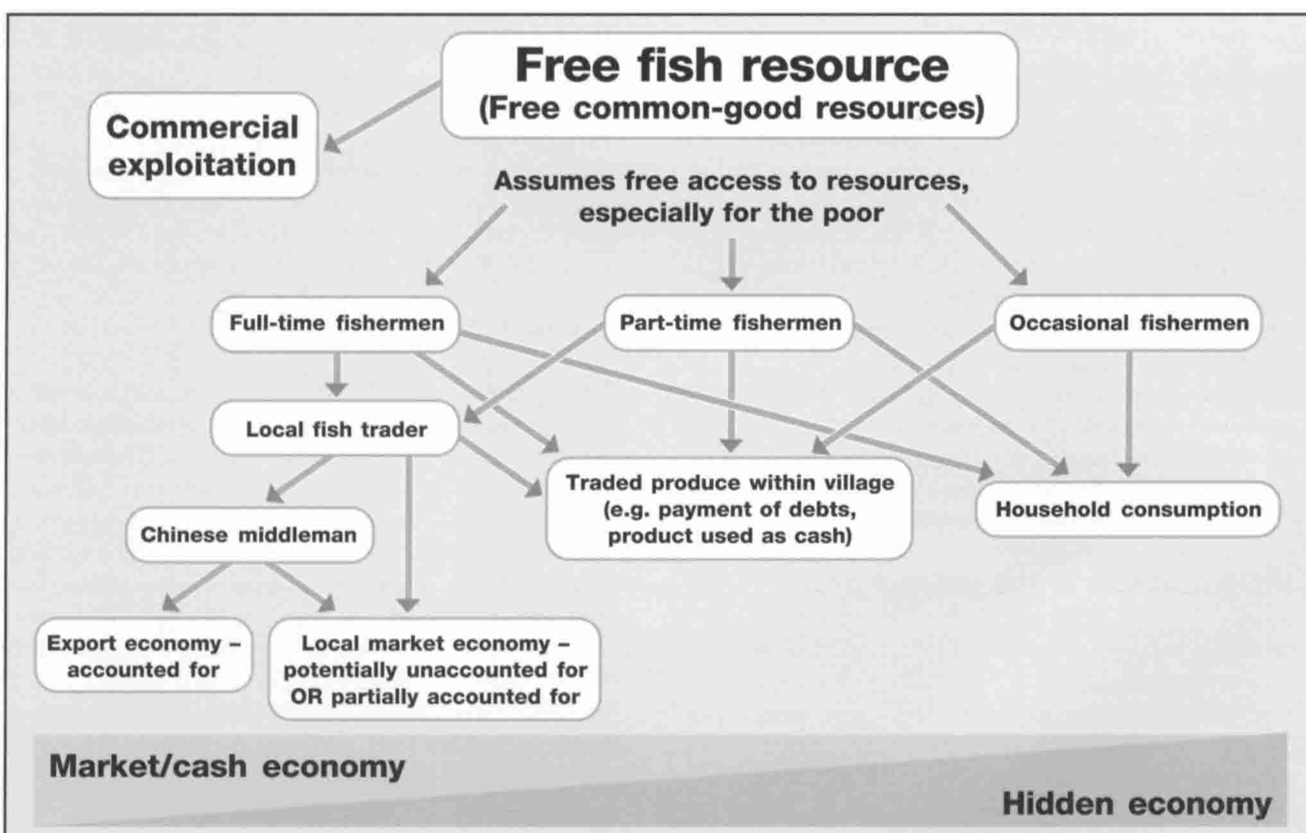
because the marine and coastal resources are still comparatively plentiful, subsistence fishing should be viewed under a slightly different light; the vast majority of the fishermen will only take what is necessary for their daily consumption, knowing that they can do the same the following day.

In general, a substantial proportion of the fish consumed in rural coastal areas requires no immediate market mechanisms because it is outside the cash economy and it costs families and/or communities nothing but their labour. The availability of free or low cost fish has important implications for population stability and welfare in the rural society. People from such rural areas have been able to remain in their own communities as a direct result of these subsistence fisheries and thus, the loss of these subsistence fisheries could drive these people to move to the cities. The importance of the species which make up the bulk of the subsistence catches lies in the fact that they are usually the ones with lower economic value and are therefore, less regulated by commercial interests. They are, nevertheless, high in nutritional value, easy to catch with cheap gear and independent of leasing mechanisms, i.e. formal or informal fishing permits granted by either local and/or regional authorities, or by local village headmen. Elasmobranchs fall into this category. with shark and ray meat being easily available and at very low prices. A preliminary model of the links between subsistence coastal fisheries and the market mechanism in rural Eastern Sabah is shown in Figure 2. The actual proportions of each of the elements of the model still need to be assessed.

Subsistence fishing was definitely a major activity in both kampongs, Pulau Tetabuan and Pulau Mabul, sampled during this visit. However, in contrast to areas where resources are at a premium, e.g. Bangladesh, kampong people are used to sharing the resources either by dividing the catch amongst those who partake in fishing, or by simply providing others with the necessary fish or shrimp in exchange for other goods or services without any money being involved. Furthermore, older people often receive surplus fish from fishermen's catches for free.

In addition, a mechanism of free access to this common-good resource was also clearly in place in both areas, allowing the communities to access a wide variety of coastal resources. This highlights the extent to which these communities, especially their poorer sectors, rely on a wide variety of species to meet their protein needs. Species diversity is therefore, also relevant to subsistence fishermen as it is a major component of the nutritional profile of these rural populations.

Figure 2. Preliminary model of the likely links between coastal subsistence fisheries and market mechanisms in rural Eastern Sabah.



Results

Number and typology of fishermen

Beluran area: According to the Beluran Fisheries Office, there is a total of 3,000 fishermen (full time and part time) in this area, of which 1,450 are full time marine fishermen (Beluran Fisheries Office, unpublished information, 1996). In Tetabuan itself, there has been a fishing community for about five generations and, at present, there are approximately 200 fishermen. Nearly 20 fishermen were interviewed during this pilot study, 13 of these interviews were recorded in survey forms. Of these 13 fishermen over half (62%) were full time fishermen, while 15% were part time and 23% were occasional fishermen. There appears to be a lack of interest in fishing in the younger generations. According to the local fishermen interviewed, fishing can be a dangerous occupation as a result of threats from pirates, mainly from the Philippines, and the lack of appropriate fishing technology to lift and operate nets when full.

In Tetabuan there were only very few dedicated elasmobranch fishermen, although elasmobranchs - rays in particular - were caught by nearly everyone as incidental catches. Sharks and rays are caught with long lines; sharks are finned, and dried fins go to a Chinese middleman in Sandakan; the meat is consumed by the fisherman and his family. Ray or shark meat does not fetch high prices, and typical prices are: whole ray (45cm) = RM2; half body = RM1; dried ray meat = RM2/kg. However, dried shark fins are sold for RM180/kg.

Semporna area: There is a total of 2,500 fishermen, most of them living on islands scattered around the surrounding area. In 1994, there were 289 fishermen in Pulau Mabul and, although fishing is their main livelihood, some of them also engage in coconut planting or work part time in dive resorts/shops. It appears that up to 70% of fishermen on the island are illegal immigrants originally from the Philippines and/or Indonesia, who are usually employed directly and illegally by boat owners and, thus, are paid much lower wages. This situation is partly due to the fact that many of the locals are not interested in this type of work. Further details on holdings and origin of fishermen are held by the Fisheries Department.

Ethnic makeup in the project area

The *Bajau,* originally from the Philippines, was the only ethnic group found in Pulau Tetabuan, with the exception of a Chinese man and his family who ran a small village shop.

In Pulau Mabul, however, there were four main ethnic groups: the *Bajau*, the *Suluk,* the *Bajau-Suluk* (inter-marriages between the *Bajau* and the *Suluk)* and the *Bajau Laut.* The *Bajau* and the *Suluk*, originally from Zamboanga in southern Philippines, basically have the same origin, characteristics and culture although there are some differences in their language. These two groups co-exist harmoniously in Pulau Mabul, but this is not the case in other islands. Prior to 1974, there was only one family from Indonesia on the island. There are four distinctive areas in Pulau Mabul: (1) the main kampong area where the *Bajau, Suluk* and *Bajau-Suluk* live; (2) a separate settlement area where the *Bajau Laut* live and which is the poorest area in the island, (3) the area of the resorts, and (4) the area in between the resorts where the resort workers live in small brick houses.

The *Bajau Laut* (Sea Bajau), originally intended as one of the focal points of this study, are notable because they spend most of their lives on their boats or *Lepas.* They usually travel in groups of three boats on tow, and may also have small boats (for one or two people) at the back of the chain of boats. The main areas where the *Bajau Laut* gather within the Semporna area are: Bohay Dulang, Pulau Kulapuan, Kampong Labuan, Haji, Kampong Halo, Kampong Bangauz, Pulau Omadal, Pulau Mabul, Pulau Nusa Tanga, Pulau Gusungan (a sandbar), and Pulau Danawan. The largest groups are found in Pulau Omadal and Pulau Danawan.

Fishing periods and seasons

In general, the fishing season lasts throughout the year and most fishermen go out every day, except on Fridays. Occasional fishing does occur on Fridays, but this is carried out before midday prayers. Young fishermen fish for an average period of 21 days per month.

The main elasmobranch season is from August to December, when the wind is from the north. The peak season for all species (fish, sharks, rays, shrimps) is from the beginning of October to April, when all catches are high.

Fishing methods

A variety of gears is used, although the main fishing gears were hook and line, and long line, which is often baited with anchovies or "eels". In Pulau Tetabuan the main three gears used were: hook and line (62%), gill nets (54%) and long lines (38.5%). In Pulau Mabul the main fishing gears were: hook and line (87.5%) and long line (62.5%). Men will usually fish in groups of five often composed of members of the same family, or close friends. The number of fishermen per boat may be governed by the size of the boats, although this needs to be confirmed. Gears are often set at night and recovered in the morning. In Pulau Mabul, the norm appeared to be a three-day fishing trip followed by three days ashore.

Bigger boats from Pulau Mabul are able to stay out fishing for two or three days at a time, every three days or so. They go beyond Pulau Sipadan into Indonesian waters near the Exclusive Economic Zone (EEZ) border, and it is common for Malaysian fishermen on the island to go into Indonesian waters and vice versa. In Pulau Mabul, women only fish in order to gather enough for a meal, or when the men cannot provide for them or are absent.

Bivalve gathering by women

Bok: The method for collecting *Bok* (species unknown, a type of Otter Shell *Lutraria* with brown shell approximately 10cm in length) is simply to dig them out of the sandy substratum. *Bok* usually bury themselves down to approximately 30-50cm, leaving a small breathing hole (<lcm in diameter) in the sand which could easily be missed. A thin proving stick, usually made out of a palm leaf, is used to identify a viable *Bok* chamber, although this is difficult to do during the rainy season. The women must start digging quickly until they reach the bivalve, which by then would have tried to bury itself further into the sand. They will gather *Bok* until the tide comes in. This harvesting method requires great stamina and is certainly not well paid; *Bok* fetch only RM2/25 shells.

Bok are targeted by women; the average Bok harvest is approximately 10kg for 2-3 hrs work. Most of this catch will be sold locally and part of the harvest will be kept for their own consumption. The peak harvest season could not be identified. Women harvest groups tend to remain the same as they are often composed of family members.

Cockles: These are harvested from the muddy shores near Pulau Tetabuan. Women slide on the surface of the mud on a small piece of wood to dig up the cockles which are kept in a basket tied to their ankles. Cockles are sold for 50 sen/kg.

Likup-likup: To collect this bivalve, that resembles a small razorshell, the women put a stick in the sand and sprinkle sodium carbonate (locally known as *kapur*) in powder form. The bivalve reacts by surfacing. Approximately 100 small animals (approximately 5-6cm) make up lkg in weight, which could fetch RM2/kg. The harvesting area for this species is Lintang Melanga, in the vicinity of Pulau Tetabuan.

Fish and shrimp catches

Although no specific data were available, the local fishermen believe that catches in general have declined in Tetabuan since 1976. At that time, according to their recollections, a boat full of shrimp was harvested in only 2-3 hrs. The population then was approximately 6,000, but some people have since moved north and along the river. At the time of the present study, the majority of the species in the catch were reported to be shrimp/prawns and fish (probably more shrimp than fish, although this aspect needs to be verified). Shrimp catches were usually in the region of 3kg/day/person (RM150/3 days at approximately RM15/kg). However, when winds blow from the north, they may catch up to a total of 1 ton (it has been assumed that they meant metric ton) of shrimp per day. Rays that are caught are dried and consumed by the fishermen and families. The most common size of ray caught in Tetabuan is approximately 50cm in length.

In the Tetabuan area, the whitespotted wedgefish *Rhynchobatus djiddensis* appeared to be targeted by fishermen. In addition, Filipino mother ships were reported to be actively targeting the sawfish *Pristis* spp. somewhere in the neighbouring area.

In Pulau Mabul, targeted fish species vary according to season. During the shark season, fishing gear and bait are set up especially for this purpose. The average individual weight of a shark during this season is 50kg. The hook and line gear used for this purpose is made of polythene rope with a diameter of 4mm; hooks are 20.5cm in length. Fishing trips are usually 2-3 days long. During the shark fishing period sharks are finned and the meat discarded due to its low value (30 sen/kg), although more expensive species will be kept whole. Sharks are caught around Pulau Ligitan. Skipjack tuna *Katsuwonus pelamis* cut up in slices (approximately 8 x 6cm) is used as bait. Tuna are caught between Pulau Mabul and Pulau Sipadan. The average catch of skipjack tuna is approximately 130t per month. Rays are also targeted on demand. In general, dried fish is not popular and is only kept by the *Bajau Laut* (Sea Bajau), who always operate from their boats. The *Bajau Laut* only come to Semporna to trade or for shelter from rough seas.

The estimated average total catch reported for all fishermen in Semporna is l,200t per month (OIC, Semporna Fisheries Office, pers. comm., August 1996). Sharks are also caught incidentally with hook and line, mostly 8-10 animals per day (per boat). Small sharks are about 10kg while large ones reach 60kg and are larger than 1.5m (TL). At this stage it is not easy to differentiate the proportion of this catch that originates in the Pulau Mabul area, although it could potentially be as high as 269t per month (139t being the proportion of the catch landed at Semporna and the remaining 130t being targeted tuna - see above).

With extremely few exceptions, there were no major landing sites in either of these two kampongs. Fish catches are mainly landed at the fisherman's own house, as most people live on the edge of the estuary or sea.

Species diversity

It was not feasible to prepare a full species list of the fish and elasmobranchs mentioned and/or observed during the interviews and the market visits within the tight time frame of this pilot study. Valuable information was, however, gathered during the interviews on most of the species utilised by the rural communities in both study areas. This could lead to the compilation of a fuller species list, not only for elasmobranchs, but also for the rest of the species currently utilised in the villages studied.

Declining species and catches

In general, fishermen considered that fish were more abundant and catches were larger in the past. Fishermen did not have to go fishing too far away from home. Nowadays, they have to travel much further to catch the same amount of fish. In the Tetabuan area, sawfish used to be common in the 1960s, but are now rarely found. Villagers believe this is due to the increased number of big operators (Japanese and Filipino fishermen) who have access to bigger boats and fishing gear. In addition, it was reported that in the 1950s, more sharks used to be caught in Tetabuan but catches are now not considered to be high enough for commercial purposes. Fishermen believe that both sharks and rays have declined as a direct result of dynamiting for fish, which are often sold dry. Ordinary people do not favour dried shark meat but, once dried, it is very difficult to differentiate between fish caught with nets and fish caught using dynamite. Thus, people avoid buying dried shark meat. In the past, only the meat would be used and the fins would be discarded. More recently, however, shark fins have become more popular as main components of traditional Chinese dishes, such as shark fin soup, with the obvious result that sharks are being targeted for this purpose.

According to other local fishermen in Tetabuan, sawfish used to be caught mostly as an incidental catch and the saws kept for decoration. Six or seven year ago, a sawfish was caught in a gill net around Pulau Ticus. Filipino fishermen catch sawfish in the same area but it is not known if the fish are kept or discarded, although both the saw and dry fins fetch high prices in Sandakan. Chinese men from Sandakan come to the area looking for fins and saws although will only pay for the fins; saws are considered as gifts. The largest sawfish seen by one of the headmen in Tetabuan weighed approximately 3t. According to this gentleman, sawfish come out at night and are speared when surfacing; it is possible to hear and see them in the open sea as they move slowly. Local fishermen in Tetabuan reported that sawfish seldom come into the river.

There is the feeling in Pulau Tetabuan that catches are lower as a result of the arrival of the Filipino fishermen in the area around 1979, although their effects have only been felt since about 1989. In contrast, according to some of the local fishermen and the dive master of one of the resorts, in Pulau Mabul the decline in the catches is believed to be a result of the deteriorating quality of the reef, which has resulted in a loss of diversity as well as a dramatic reduction in the number of large specimen fish previously seen in Mabul. The actual situation is likely to be a combination of impacts, and needs to be established with adequate fish and habitat surveys over a period of time to account for natural seasonal species fluctuations. Similarities to this situation have been found commonly in other areas, e.g. Bangladesh (Gumti Phase II Sub-Project Feasibility Study, 1993) and Egypt (Naga Hammadi Barrage Development Feasibility Study, 1995) when the ecological balance in the species composition is changed due to overexploitation, habitat degradation, or other factors.

New species

It appears that as a result of recent research (i.e. Rudie Kuiter and colleagues), some 17 new species of small coral reef fishes have recently been recorded from Pulau Mabul. These are small cryptic species that are still able to hide amongst the coral rubble in the island which has resulted from past dynamiting by Filipino fishermen. It is most likely that these species had always been present in the island but were only found recently.

Resource use

Fish, crustaceans, bivalves and other invertebrate species are harvested on a daily basis by all members of the coastal communities visited. By and large, fishing for commercially-important species is considered men's work; while food gathering is done exclusively by the women. Any surplus catch, either fin fish or elasmobranchs, is freely shared amongst the villagers. Rays are always dried, fresh meat is only used for the fisherman's own consumption, while sharks are eaten fresh or dried. Anchovies are caught in large numbers but, due to the lack of refrigeration facilities in the villages, cannot be kept long and are soon discarded. Unfortunately, they are difficult to dry and do not fetch good prices.

The shell of *Nautilus*, which is found in the area, is also harvested both for food and for decoration. A large shell in its natural state is sold for RM2.5; a small one is sold for RM1. However, prices rise substantially for polished shells, to reach RM30 for the large one and RM15 for the smaller one. Seaweed is also consumed. That described by the villagers has grape-like 'seeds' approximately 5mm long and could potentially be *Caulerpa*, which is known to be consumed in other areas (Dipper, pers. comm., 1999). Women and children collect a wide variety of food items for their own consumption from the reef flat in Pulau Mabul, including several species of sea urchins, shells and seahorses. They usually harvest them at noon when the tide is out.

Coconut palms have numerous uses: leaves are used for roofs and cake wrapping; dried coconut shells for firewood and to sprinkle water on the dead. During festivities, coconut shells are used as water containers for guests. *Pandan* (presumably *Pandanus* palm) is used for mat making.

Fish marketing

In general, fishermen take their catch to fish traders in the village who, in turn, usually take the product to a Chinese middleman in Sandakan. Licensed fish traders in towns may refuse to buy from the fishermen allegedly due to high prices. It takes two to three days for a village fish trader to gather enough product to take to Sandakan, and this product must be kept refrigerated or at least on ice. Fish traders mostly deal with shrimps, although there are some who specialise on fish. There appeared to be up to 23 fish traders in Tetabuan, and a select few fish traders may have up to 50 fishermen in their books. However, it was difficult to verify these figures. Written records of sales and prices are largely unavailable, and only one trader appeared to be keeping records of this type of information.

In Pulau Mabul, there were five fish traders although most of them did not appear to keep records. In addition, fish were also sold to a middleman in the island, but the fishermen are now taking the product to market directly in an effort to better their prices. People from Semporna also go to Pulau Mabul daily to buy fish.

Fish market surveys

Fish prices varied little within each market, however, this is not surprising as these results were obtained during the same fishing season. In general prices for fresh and dry fish, including elasmobranchs, were fairly similar.

Fish prices at source

In general prices vary according to the phase of the moon: there is no fishing during the full moon. Fish availability will therefore decline with a resulting price increase. Prices also vary according to the fishing season. During the season fish may fetch RM1.50/kg, while out of season the same species will fetch RM2.50/kg. This visit was out of season (August). A small shark jaw of a 6-7kg shark (approximately 10cm in length transversally) could fetch RM2. Large jaws from sharks longer than 1.65m would fetch RM5. Unfortunately, they have no use for the skin for the leather industry as in other countries, e.g. Mexico. The shovelnose ray (it is unclear if they are referring to the whitespotted shovelnose ray) is extremely expensive as few are caught, fetching an average of RM380/kg.

In Tetabuan only about five fishermen take their catches to bigger towns such as Beluran or Sandakan, where they get better prices for their catches. For example, in Beluran fish would fetch RM5/kg while in the village, the same catch would only fetch RM3.50/kg. Shrimps are sold to the fish trader at RM7/kg.

Shark fins: The most valuable part of the sharks are the fins, which are sold by size; the bigger they are the more expensive they become, even when they are from the same species. These were commonly sold in both kampongs, although the number of fishermen targeting sharks appeared to be greater in Pulau Mabul. The percentage profit made by the middleman or fish trader on a set of fins is 25% to 50%. Shark fin sizes are estimated using the distance from the extended thumb to the little finger *(jengkal)*. Thus, 2 *jengkals* = RM120-150. Fins are also sold in sets of four per fish: one dorsal, two pectoral, one caudal, which will fetch approximately RM130-150.

Income from fishing

Fishermen: Typically, most able men will be full time fishermen with some also engaging in wood collecting, nipa palm gathering and other minor activities which do not necessarily earn them any cash, but which will enhance their standard of living. The contribution of the free resources to the local economy, although substantial, is not easy to estimate in the present study, but certainly merits a closer examination in the future. Surprisingly, average catches were also difficult to estimate, simply because the vast majority of the people interviewed could not (or would not) recall their catches or income from them adequately. This is in sharp contrast to similar communities in other countries such as Bangladesh and Egypt, where fishermen have very clear and remarkably accurate recollections of their recent catches and income.

According to the small sample taken during this study, the average monthly income for a full time fisherman is RM283, although the range of income recorded varied from RM150 to RM630 per month. Only one part time fisherman in Tetabuan provided information on his average monthly income (RM175). Occasional fishermen earn an average of RM242 per month, although the discrepancies in earnings in this category are notable (RM26.25 to RM625). It is also noticeable that those fishermen engaged in elasmobranch fisheries earn less on average than those engaged in shrimp fisheries.

Only one full time female fisher was interviewed in Tetabuan. She fishes for finfish, crabs and bivalves. She owns a boat and recycles fishing material given to her by family members. She sells her product in the village or takes it to Beluran.

In general, income from fishing is barely enough to sustain a family in the villages. Fishermen supplement

Table 1. Summary of interviews with fish traders showing estimated cash flow.							
Fishing season	**Fuel/trip RM**	**Men/ trip**	**RM/trip (men)**	**Trips/ week**	**Kg/trip sold**	**Profit/ trip RM**	**Monthly income RM**
Average	100	2	50	1-3	30	15	180
Peak	100	2-3	50	7	300	150	4,200

their income with many of the other free food resources available to them. However, almost certainly, this income would not be enough to support them outside the village. Unfortunately, many of the younger generation are now losing interest in fishing due to the lack of government incentives.

After a fishing trip of 2-3 days, a group of five fishermen from Pulau Mabul may net RM 1,000 from the sale of high quality fish. Normal catches are usually in the region of RM500–700 net. The group will share the catch, 50:50 (50% for the boat owner and 50% between the rest of the crew). Based on this figures, the crew may earn around RM87.5 each while the boat owner gets RM350. An average catch of 0.5t will not leave a big profit margin, just enough to cover costs.

Fish traders: Fish traders act as money lenders to the fishermen, lending capital to these men for boat, engine and gear purchases. The fishermen will in turn pay the trader with a portion of the catch and will sell the rest of the catch to them. Traders also go into town to buy merchandise for the fishermen when they are not able to do so themselves. This merchandise ranges from fishing gear and engines to food items such as meat, which can only be bought in town. However, this type of loan takes some time to be re-paid.

The trader also pays for everyone's expenses during the trip. Some profits are also lost due to a decrease in the quality of the product once it reaches its final destination; e.g. buying at RM7/kg and only able to sell at RM5/kg. Thus, the fishermen owe the fish trader, who in turn owes the Chinese middleman or a bigger company in town. Three fish traders were interviewed in Tetabuan. A summary of these interviews is presented in Table 1.

Cost of fishing gear and boats

Government subsidies are not enough to cover the cost of engines, nets, and/or other gear. Apparently, only one engine has been given to the villagers by the Fisheries Department. Traditional wooden boats can cost from RM150 to RM3,800; while boat-making materials cost RM800 and labour RM700, for a boat that may last up to 10 years if well kept. The average cost of engines is just over RM3,000 (see Table 2). Fishing licenses are only needed by fishermen working in marine waters; those fishing in freshwater are exempt from paying.

Table 2. Summary of average monthly income and expenditure by village.

	Pulau Tetabuan	**Pulau Mabul**	**Average**
Monthly income (RM)	257	278	283
Monthly expenditure (RM)	370	174	210
Cost of fishing gear (RM)	396	377	389
Cost of boats (RM)	642	1,764	1,271
Boat length (m)	6.3	10.8	
Boat life (years)	4.4	5	4.5
Engine power (HP)	15	40	
Cost of engine (RM)	3,004	3,062	3,033

In general, many boats in the area are based on Filipino designs and some of them are built there as well. Most boats in Pulau Mabul appeared to have been made in Indonesia and modified according to local designs. Painting of the boat and the final details are done in Pulau Mabul.

Role of women

In general, women are mostly involved with household duties and with fishing post-harvest activities such as drying fish and shrimp, net mending (skills passed on within family members), etc. In Tetabuan, there are also several harvest methods which are considered exclusive to women, or in which women are involved at all stages. Pearl collection is one of the latter and women are involved in the collection from the wild, shelling and meat extraction. They may also fish in shallow waters together with the men (usually husbands or family members), but the men will always carry out the heavy jobs such as loading the boats, rowing, etc. Women also clean boats although it is usually within their own households or family units. Older women weave mats, but this skill is being lost. Average age at marriage is 20 years old.

In Pulau Mabul, the women will typically harvest the reef flat and will do the household chores. They appeared to have extended families whereby they help each other with child care and household duties. Young women are allowed to harvest the reef when they reach 17-18 years old.

Nutritional aspects

In general, there was no lack of protein in either of the two villages visited as it would appear that all people had access to various marine resources, i.e. fish, rays, bivalves, crabs, etc. However, there was little evidence of vegetables in their diet. In addition, they had fairly poor access to other forms of protein, either animal or vegetable. Indeed, although pulses and lentils were freely available in market towns (visited regularly by the kampong fishermen or their representatives), these are not consumed by the villagers visited. Apparently this is due to cultural differences, as the *Bajau* consider these foods as part of the Indian diet and not of their own. Some households also had chickens, which were raised free-range at the back of the houses, on the edge of the river bed (Pulau Tetabuan) or around the houses (Pulau Mabul).

Despite the amount offish consumed, a lack of calcium seemed apparent, in particular in Pulau Tetabuan. In this kampong, most inhabitants, even children as young as 10 years old, suffer severely from tooth decay. The majority of the adult population have lost most of their teeth. Large amounts of sugar were used in their tea and coffee. The Chief Dental Surgeon in Tawau, interviewed during this study, informed us that dental health in rural communities is very poor indeed. The government has started some rural campaigns to teach people to care for their teeth but there seems to be little interest from the part of the villagers concerning these efforts. It is possible to attend a government dental clinic and have a tooth extracted for RM1, which in many people's eyes is much better than spending time, effort and money to try to prevent and combat tooth decay.

Not surprisingly, children in Pulau Mabul appeared to be smaller in size than children in the UK. An 11 year old boy appeared to have a similar size to an 8 year old in the UK and possibly, to other parts of Malaysia. It is not possible however, to make any conclusions on the basis of these superficial observations without the full support of a complete health and nutritional study. It is almost certain though, that they may not be achieving their full growth potential in the absence of a varied diet (i.e. at present high in animal protein from fish and other marine resources, but very low in vegetables, fruit and milk products - calcium).

Cultural and social aspects

There did not appear to be any special cultural or traditional customs regarding shark or ray fishing. If they existed before, the new generations appear to have forgotten them and only use shark parts for decoration. However, a pilot study such as this one is simply not adequate to unravel this aspect fully. In the past, people used the teeth and jaws to protect them against spirits. In addition, ray tails were used to scare away spirits/ghosts in the jungle. Other uses for the tails include making holes in boats, using the roughest part. Denticles were formerly used as sandpaper but not anymore.

In Beluran market we were informed of an old belief concerning the sawfish. It was believed that hanging the sawfish saw from its base in front of a house would scare spirits/ghosts away, especially when pregnant women were inhabiting that house. As a result of this belief, they used to actively hunt the sawfish.

The only ritual linked to the harvest of resources was found in Pulau Tetabuan and it concerned pearl oysters and cockles. A group of people known as *Sarib* will carry out a ritual over the shells; only after this ritual is conducted will the villagers go out to harvest the bivalves. A collection will be made and over RM 1,000 could easily be gathered for the *Sarib* conducting the ritual. The pearl oyster season may last for 1 to 2 years. The villagers will stop collecting bivalves for some time to allow the shells to grow and reach a certain size. Everyone benefits financially or otherwise from the pearl oyster season.

Pearls are used in a variety of ways, such as Chinese medicine; for this purpose the smaller the pearl, the more expensive they are. Bigger pearls are used in jewellery. Pearls are also mixed with bird's nests for human consumption (100g = RM15). Villagers use this as medicine for fevers, or whenever they feel unwell. These are marine pearls (possibly *Placuna* sp.), found more abundantly along the coast at low tide where they can be harvested from the boats. Villagers consider these pearls as the most important resource for them, as they can go to Mecca (both men and women) with the profits they make from these pearls.

In Pulau Mabul, coconut shells are very important in relation to the newborn and the dead. After childbirth, the mother's placenta is buried inside a large shell. When the baby is about one month old, a lock of hair will be put inside a very young coconut, which is sealed and tied up with a string. The coconut is then hung from a tree in the belief that this will ensure the child's healthy growth as well as keeping the child's spirit nearby. The tree is located in paths utilised by people and not in isolated areas. Coconut shells are used to sprinkle water on the dead.

Many families are large (more than six children) as parents see the children as an investment for their own future. In general, although these people live modestly, they appeared to be in good health, reasonably well dressed and had permanent houses. In addition, some households had televisions and radios, and other signs of modern technology, e.g. a mobile telephone at the headman's house in Pulau Mabul (cost of a mobile telephone = RM60 per month rental), baby powder in an ordinary fisherman's house, etc. The headman's house was substantial in comparison to others and had many assets (e.g. a full crockery set, TV, radio, video, etc.).

Land tenure and housing

All land in Tetabuan appeared to be government owned, and only one family was found to own land granted to them by the previous government. (This land may have been taken away by the present government.) This family has a garden with more than 10 mature fruit trees including mangos and jackfruit. Mangos are sold for 20 sen each. They also had chickens for their own consumption. There were 36 other people in Tetabuan who own land in GumGum, although there seems to be a dispute about land ownership there. It would appear that this land may have been sold without their knowledge.

Houses which were built on stilts were privately owned. Villagers are able to build new houses with government permission, and although it is easy for the locals to obtain such a permit, it is not possible for outsiders to build any houses within the existing village area. Some Filipino and Indonesian people have tried to build houses in the village, but have been stopped by the locals through a complaints procedure. In general, houses are very close to each other and the villagers consider this a fire hazard. They are hoping that in the future they will be built about 4-5m apart.

In Pulau Mabul land ownership has changed several times since the island was first settled. At the time of this study, some of the island inhabitants owned land and had land titles. In the beginning, *Bugis* (Indonesians) were first employed by the first owner of the island to look after the coconut plantation. After the *Bugis* left a few months later, some of the present occupants arrived and used to pay rent to the landowner. However, an agreement was reached by which these people could remain on the island without paying rent but instead, would look after the coconuts. They collect and sell the coconuts and share profits with the landowner on a 50%-50% basis. They also developed a system of self-help, assisting each other with any of their problems.

Tourist development

One of the resorts in Pulau Mabul is a joint Japanese-Malaysian (Tawau) investment (Sipadan Water Village and Tours) and employs 60 staff, some from Pulau Mabul and others from Tawau. At the time of the visit, this resort accommodated 70 guests in 35 chalets, but was expanding to include a second dining room and a gift shop. The peak tourist season is from August to October, although the resorts are open throughout the year. We have no information for the Sipadan-Mabul Resort.

Some of the villagers, both male and female, and usually the younger ones, are employed by the tourist resorts on the island: men as electricians, builders and boatmen, the women as cooks, cleaners and waitresses. There is a modest housing development near the resorts that houses resort employees. However, many of these people are from Semporna.

General issues to be considered

Government incentives

Most of the people interviewed mentioned the lack of government support for the purchase of fishing gear, boats and fish holding facilities. The lack of a continuous supply of electricity is a real obstacle for the welfare of these people who are unable to keep fresh products, either for sale (fish and shrimp catches) or for consumption (perishable food such as fruit, vegetables and milk products). In addition, government incentives are perceived as vital by the locals to maintain the interest of the younger generations in fishing. The OIC in Semporna suggested that perhaps an aquaculture development (e.g. seaweed, oyster, etc.) might rekindle such interest. (Government incentives are, of course, viewed increasingly as a threat to sustainable captive fisheries.)

Threats from pirates

Pirating from Filipino fishermen was reported in both kampongs. In Pulau Tetabuan, at least 20 people have lost their engines to pirates, who were reported to have firearms. Some fishermen no longer venture further than half a mile from base due to the fear of attacks from pirates, who may take their catches, fishing gear and engines. This situation is particularly critical in the area around Pulau Danawan, a prime area for sharks which is very close to the Philippines border and thus could not be visited during this study. It has not been easy for the government to enforce existing regulations due to the fragmented nature of the geography of the region, i.e. numerous small islands. Sadly, it would appear that, provided tourists are not involved, the situation could continue indefinitely.

Illegal fishermen

There appears to be a large number of illegal fishermen and their families in the Pulau Mabul area, most probably because of its closeness to Indonesia and the Philippines borders. Many of these people have been there for a long time but still have no documentation and they will be deported if caught by the police. This situation frequently affects their deals and sales of their catch as they are always under the fear of being caught.

Illegal immigrants often settle on sand bars along the coastline. In Semporna, for example, there are large settlements, overcrowded with Filipino immigrants who would welcome protection and official assistance from the Malaysian authorities.

Conservation concerns

As mentioned previously, there is an interest in aquaculture development (seaweed, oyster, etc.) in the Fisheries Department in the Semporna area, especially since it is seen as a potential tool for rekindling the interest of the younger generations in fishing. Any such development should however, be considered with caution to avoid any further adverse effects on the environment and follow guidelines.

There is regular dynamiting of reefs and islands. According to Cindy Harris, the Dive Master of the Sipadan-Mabul Resort, Pulau Mabul and Pulau Kapalai (a neighbouring island) have been subjected to this illegal and destructive fishing method for the last 20 years, with devastating consequences. Dynamiting destroys the reef and its fauna and flora with the resulting loss of diversity, large specimens and cover. Only young or small cryptic species are able to use the coral rubble to hide from predators. Dynamiting is a critical problem in the area as Pulau Ligitan and Sebuan have been completely destroyed by it, with bombs originating from the Philippines (C. Harris, pers. comm., 1996). The neighbouring Pulau Sipadan is not currently at risk because of its high profile as a tourist attraction, a situation which affords it a certain degree of protection. Further efforts are being made towards granting protected area status to Pulau Sipadan (Dipper, pers. comm., 1999). This Dive Master has started a naturalist course in the tourist resort in an attempt to raise environmental awareness concerning the reefs. However, resort owners fear that by restricting tourist activities, they may not return.

At the time of the study, the diving capacity of Pulau Sipadan was approximately 200 divers per day (C. Harris, pers. comm., 1996), although this is currently under review for the whole area (F. Dipper, pers. comm., 1999). Some of these divers have reported hearing dynamiting at least once a day in neighbouring areas.

For generations, subsistence fishermen have depended on the reefs and their resources, however, dynamited reefs are unable to sustain even these low levels of exploitation nowadays (Semporna Fisheries Department OIC, pers. comm., 1996). According to some of the local fishermen and the dive master of one of the Sipadan-Mabul Resorts, the decline in the quality of the reef has resulted in a loss of diversity as well as a dramatic reduction in the number of large specimens previously seen in Mabul. However, the resorts are providing indirect protection to Pulau Mabul as dynamiting has been controlled somewhat since the construction of the resorts. Although widely practised, dynamiting is a dangerous activity and many fishermen have either been attacked and died while collecting the dynamited fish, or have been killed or maimed while using the dynamite (Dive Master, Sipadan Water Village and Tours; pers. comm., 1996).

Pulau Sipadan is in excellent condition, has a high diversity and sizeable schools of large-sized fish abound there (Wood, 1994; 1997; Wood, *et al.*, 1993; Wood, *et al.*, 1996). Whitetip reef sharks *Triaenodon obesus* are commonly seen in large groups. In Pulau Mabul the situation has changed substantially as a result of dynamiting of the reefs and only smaller species are found there. As mentioned previously, around 17 new species have recently been described from its decimated reefs, including small gobies, cardinal fishes, pipefishes and other small fishes which may have been inhabiting the crevices of the reef. Despite the poorer quality of its reef, Pulau Mabul has become a desirable place for experienced divers to visit because of its newly found species (Dive Masters of Sipadan-Mabul and Sipadan Water Village and Tours; pers. comm., 1996).

According to the Dive Masters of both tourist resorts in Pulau Mabul, sharks are an attraction for diving tourists in Pulau Sipadan but not in Pulau Mabul. Sharks seen there include: whitetip reef shark, grey sharks (presumably the gray reef shark *Carcharhinus amblyrhynchos)* and hammerheads *Sphyrna* spp.. The latter occurs in large shoals in deep water but divers report a decline in numbers seen in recent years. There is some concern that large numbers of divers may disturb some sharks, e.g. Dive Masters report less frequent sightings of leopard (zebra) shark *Stegastoma fasciatum* (C. Harris, pers. comm., 1996). In 1995, this species was seen about twice a week but it had only been seen twice in two months by the summer of 1996 when these interviews took place. It is unclear if this is a direct impact by divers. Whale sharks *Rhincodon typus* are occasionally sighted between Pulau Sipadan and Pulau Mabul and are a considerable tourist attraction although also attract shark-fin fishermen. A single whale shark approximately 6m long had been seen several times in the area of Pulau Sipadan in 1996. There are large numbers of bluespotted maskrays *Dasyatis kuhlii*, but both the fantail stingray *Taeniura meyeni* and the manta *Manta brevirostris* are considered uncommon. A facility for a marine biology course was being planned at the Sipadan Water Village and Tours (Sipadan Water Village and Tours Dive Master, pers. comm., 1996).

Full Environmental Impact Assessment (EIA) procedures should be carried out before any further developments take place on the islands. Public participation should be an integral part of the study to ensure that the locals benefit from this type of development. The Semporna OIC suggested to them that they should try to preserve their fishing lifestyle since too much development would ruin the island. Not surprisingly, some of the people employed at the tourist centres are not interested in fishing anymore. As a fisherman, a young man would earn between RM200 and RM300 per month. Now as an electrician at one of the resorts, his regular income is RM700 per month. It would be regrettable to loose the cultural and social traditions as a result of development.

Conclusions

It is remarkable that in general fishermen in both kampongs were unable (or reluctant) to recall their catches adequately, even when asked about their morning catches later on in the afternoon. They were able to recall an approximate number of fish, but seemed to have little ability, or willingness, to estimate the weight of their catches in kg. Recall data for previous days, weeks or months were therefore not possible to obtain. This is in sharp contrast to the ability of the Bangladeshi or Egyptian rural fishermen who were able to provide fairly good estimates of their catches in kg per species or group of fishes (Gumti Phase II Sub-Project Feasibility Study, 1993; Naga Hammadi Barrage Development Feasibility Study, 1995).

It may be possible to explain this situation on the basis of ecological or climatic landmarks. For example, in Bangladesh major environmental events take place nearly every year (e.g. floods, cyclones), which have serious consequences to the living conditions and indeed to the very survival of these communities. In rural Egypt, they also are subjected to flooding in the River Nile, which affects agricultural crops and fishing patterns. People in such communities use this type of events to aid their memories and relate these to events in their lives. In rural Sabah, life seemed to be a great deal more relaxed as there was a constant food supply for even the poorest groups. People here did not appear to have many ecological or climatic aid to their memories. However, despite this, the Sabahan fishermen were only too aware of a general decline in the catches, and this was reported by everyone who was interviewed.

It is clear that the present pilot study was insufficient to decipher the intricate web of social, economic and cultural aspects relating to the lives of rural fishermen in Sabah. Nevertheless, extremely valuable information was gathered to provide a much needed baseline for future work. Indeed, these preliminary results have identified some of the key issues regarding the use of the coastal and marine resources by the two communities that were investigated.

Preliminary recommendations

1. A further catch assessment survey should be carried out in the kampongs in order to obtain a better estimate of the subsistence fisheries of the area. This could be done either by staying at the kampongs for a period of time and working with the fishermen's catch to monitor species composition and actual catches; or by carrying out a separate catch assessment survey.
2. Estimate subsistence fishing from above to attempt to value the economic contribution of these fishery resources to the economies of the area.
3. The use of destructive fishing methods such as dynamite in the reef areas around Pulau Mabul merits further investigation, as it is directly impacting the entire reef ecosystem.
4. The *Bajau Laut* still remain poorly known and thus, a more detailed socio-economic study focused on this group of people should be carried out. An estimate of the subsistence catches for this group alone would provide new and much needed information on this unique group and their lifestyle.
5. A full health and nutritional study of the two villages examined during this study should be carried out, especially in Pulau Tetabuan (where the problem of tooth decay may well be an indicator of further health problems in the village as a whole).

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Elasmobranchs as a Recreational Resource

R. Charles Anderson
Marine Research Section, H. Whitewaves, Male, Republic of Maldives

Changing patterns of recreation over the last decade have brought changes in attitudes towards elasmobranchs. In particular there is a growing realisation that there are powerful incentives for sustainable (and often non-extractive) recreational utilisation of many elasmobranch resources. There are three large groups of recreational users: 1. Recreational divers. The growth of recreational diving in recent years has been little short of explosive. Divers like to see sharks and rays in their natural habitats and are willing to pay large sums of money to do so. Revenue from shark and ray diving internationally runs into hundreds of millions of dollars annually, as a result of which divers have become a powerful force for shark and ray conservation. 2. Recreational fishers. Fishing is one of the most popular leisure activities worldwide. There is a growing trend among elasmobranch fishers to release catches alive, often after tagging. As a result, mortality in some stocks has been reduced while at the same time information of value to resource managers has increased. 3. Aquarists. Recent improvements in aquarium technology have led to a boom in the display of live elasmobranchs both in big new public aquariums and in domestic tanks. As a result there has been a great increase in awareness of the importance and vulnerability of elasmobranch resources.

Introduction

Shark and ray stocks are under increasing pressure from commercial fishing activities, and some species are also affected by habitat degradation. Many stocks have been reduced to a fraction of their original size. It seems almost inevitable that demand for elasmobranch products, and in particular for shark fins, will continue to increase in the foreseeable future. As it does so, the majority of elasmobranch populations around the world may be fished towards commercial extinction.

Commercial fishing is by far the most important means of utilising elasmobranch resources in financial terms, but it is not the only one. With the growth of a middle class and the expansion of leisure opportunities in south-east and eastern Asia, recreational utilisation of many marine resources, elasmobranchs among them, is becoming increasingly important. These trends (which are already well advanced in North America, western Europe and Australia) are resulting in more and more people becoming aware that elasmobranchs have uses other than just being harvested for food.

The aim of this paper is to review three major types of recreational utilisation of elasmobranchs: recreational diving, recreational fishing and aquarium display. The paper is based on a review of published information on recreational utilisation of elasmobranchs. The significance of each for elasmobranch resource utilisation and conservation is discussed, with special reference to the Asia-Pacific region.

Recreational diving

Diving is one of the fastest growing recreational activities worldwide. There are no figures for worldwide participation, but PADI (the Professional Association of Diving Instructors, the largest international training agency) now issues over 600,000 new certifications per year. The total number of currently active recreational divers must run to several million. The sport has grown rapidly in recent years, and continues to grow. Growth in the Asia-Pacific region, not only of local diver and dive operator numbers but also of dive tourist arrivals from other regions, has been especially rapid.

One of the greatest attractions for recreational divers is observing large marine animals underwater in their natural habitats. Sharks are always the major attraction wherever they occur (Anderson 1994), but rays too can be of significant interest. Magazines for divers regularly carry features on where to see sharks (e.g. Murphy 1993, Saunders 1995) as well as advertisements for shark and manta ray *Manta birostris* diving. Table 1 lists some of the many elasmobranch diving locations in the Asia-Pacific region that are being advertised in the contemporary diving press. Gray reef sharks *Carcharhinus amblyrhynchos*, whitetip reef sharks *Triaenodon obesus* and manta rays are the most often encountered species, but there are over a dozen species that can be more or less guaranteed in this region alone.

While divers are at the forefront of shark and ray watching activities, snorkellers and even beach walkers are also participating in growing numbers. Off Ningaloo Reef in northwestern Australia, whale sharks *Rhincodon typus* appear regularly every March-May, and have stimulated a local shark-watching industry; most of the watching is done by snorkellers (Newman *et al.*, this volume). In the Maldives, much manta ray watching is done by snorkellers, while fantail stingrays *Taeniurameyeni* are a regular attraction at several resort island beaches. In French Polynesia, trips are offered to snorkel with blacktip reef sharks *Carcharhinus melanopterus.*

The economic value of elasmobranchs as attractions for recreational divers and snorkellers is enormous. There has been no worldwide survey, but the total amount spent annually must run into hundreds of millions of dollars. Divers typically pay US$25-75 for a single dive with sharks or rays. In Ningaloo, Australia, tourists pay about US$200 per day to swim with whale sharks. In South Australia, participation in an expedition to cage dive with great white sharks *Carcharodon carcharias* may cost several thousand dollars.

In the Maldives in 1992, it was estimated that divers spent about US$2,300,000 on shark-watching dives (Anderson and Ahmed 1993). Since then tourist arrivals (and hence divers visiting shark-watching sites) have increased substantially. In addition, money spent on ray watching (both manta rays and stingrays) has not been calculated but must run into hundreds of thousands of dollars annually (unpublished data). The current total spent by divers on elasmobranch watching in the Maldives is therefore likely to be in excess of US$3,000,000 per year. This is direct diving revenue only; indirect revenues (including food, accommodation, transport) are several times higher.

Anderson and Ahmed (1993) estimated that in 1992 a single gray reef shark was worth about US$33,500 per year at what was then the most popular shark-watching site, "Fish Head." For all shark watching dive sites, the average value of a live gray reef shark was estimated at about US$3,300 per year. Since gray reef sharks can live for at least 18 years (Radkte and Cailliet 1984) and in the Maldives recognisable individuals have been seen at dive sites for many years in a row (pers. obs.) the total value of each shark is several times higher. In contrast, a dead gray reef shark was calculated to have a one-time value of about US$32 to a local fisherman.

In the Bahamas, one of the premier shark-watching destinations for divers, several species of sharks are regularly seen at a number of locations. It has been

Table 1. Some major shark and ray watching locations in the Asia-Pacific region.

Country	Location	Scientific name	Common name
Maldives	Several sites	*Carcharhinus amblyrhynchos* *Triaenodon obesus* *Sphyrna lewini* *Taeniura meyeni* *Manta birostris*	Gray reef shark Whitetip reef shark Scalloped hammerhead Fantaii stingray Manta
Myanmar	Burma Banks	*Nebrius ferrugineus* *Carcharhinus albimarginatus*	Tawny nurse shark Silvertip shark
Thailand	Richelieu Rock Shark Rock (Phuket)	*Rhincodon typus* *Stegostoma fasciatum*	Whale shark Zebra shark
Malaysia	Layang Layang Sipadan	*Sphyrna lewini* *Triaenodon obesus* *Sphyrna lewini*	Scalloped hammerhead Whitetip reef shark Scalloped hammerhead
Indonesia	Sangalakki, Kalimantan Maumere, Flores	*Manta birostris* *Rhincodon typus*	Manta Whale shark
Australia	Christmas Island Ningaloo Reef, WA Neptune Islands, SA Seal Rocks, NSW GBR/Coral Sea	*Rhincodon typus* *Rhincodon typus* *Manta birostris* *Carcharodon carcharias* *Carcharias taurus* Several species	Whale shark Whale shark Manta Great white shark Sand tiger shark
Vanuatu	Bokissa Island	*Carcharhinus amblyrhynchos*	Gray reef shark
Papua New Guinea	Silvertip Reef Several sites	*Carcharhinus albimarginatus* *Carcharhinus amblyrhynchos* *Triaenodon obesus* *Sphyrna lewini* *Manta birostris*	Silvertip shark Gray reef shark Whitetip reef shark Scalloped hammerhead Manta
Philippines	Several sites	*Carcharhinus amblyrhynchos* *Triaenodon obesus* *Sphyrna lewini* *Manta birostris*	Gray reef shark Whitetip reef shark Scalloped hammerhead Manta
Palau	Blue Corner	*Carcharhinus amblyrhynchos*	Gray reef shark
Yap	Mil Channel and others	*Manta birostris*	Manta
Marshall Islands	Bikini Atoll	*Carcharhinus amblyrhynchos*	Gray reef shark
French Polynesia	Rangiroa Moorea and Bora Bora	*Carcharhinus amblyrhynchos* *Carcharhinus melanopterus* *Dasyatis* spp.	Gray reef shark Blacktip reef shark Stingrays

reported that some US$6,000,000 is spent annually on shark viewing there (Hall 1994). The values of single Caribbean reef sharks *Carcharhlnus perezi* at particular dive sites have been roughly estimated at between US$13,300 (Amsler 1997) and US$40,000 (S.H. Gruber, pers. comm.) per year. Again, total revenues per shark are likely to be much higher, perhaps something of the order of US$200,000 (S.H. Gruber, pers. comm.). A dead Caribbean reef shark has been estimated to have a one-time value of about US$50-60 (Hall 1994).

With such enormous sums of money involved in recreational elasmobranch watching, there is clearly considerable interest among diving operators in preserving 'their' sharks and rays. The ability to demonstrate that elasmobranchs are worth very much more alive as attractions for divers than they are dead to fishermen is a powerful argument for governments to act to conserve stocks. In the Maldives, fishing was banned at several top shark diving sites in 1995 because of the economic importance of diving tourism to the country. Also in the Maldives, the export of ray products was banned to prevent the development of an export-oriented fishery. In the Bahamas, longline fishing (which had been threatening shark populations at some dive sites) has been banned throughout the country, as a result of these economic arguments.

Apart from providing a purely economic incentive for elasmobranch conservation, recreational divers and snorkellers can have other positive effects, for example:

- They are often at the forefront of efforts to protect elasmobranchs. In addition to the examples from the Maldives and Bahamas cited above, divers played a part in the campaigns to have the great white shark protected in both California and South Africa. Diving magazines regularly carry editorials and articles on shark and ray conservation (e.g. Cousteau 1996, Sigel 1996, Stafford-Deitsch 1996, Amsler 1997).
- They are often in the best position to see and report incidents such as shark netting within marine reserves or the dumping of finned carcasses (e.g. Newman 1994, Perrine 1994).
- They can provide information on shark behaviour and ecology, if properly organised by researchers. For example, divers' sightings are being used to obtain a better understanding of the migrations and abundance of the basking shark *Cetorhinus maximus* in the British Isles and of the sand tiger or grey nurse shark *Carcharlas taurus* off south-east Australia.

Despite all these apparent benefits, recreational elasmobranch watching is not without its problems. It can lead to increased 'harassment' of the sharks and rays themselves, as divers hitch rides or tweak tails. This can lead to elasmobranchs leaving the area, perhaps permanently. There is also controversy over the feeding of sharks and stingrays. Feeding is a sure way of attracting them, but one which has implications for diver safety and the behaviour and ecology of the animals being fed. Some experienced divers advocate shark feeding as a means of promoting shark watching and consequently shark conservation (Amsler 1997). Others advocate an absolute 'hands-off policy for all interactions with large marine animals (Strickland 1994, Hanauer 1995).

Sports fishing

Fishing is one of the most popular of all recreational activities. Tens of millions of people worldwide count fishing among their hobbies or sports. Elasmobranch fishing, and especially shark fishing, is popular in many areas. This has undoubtedly led to significant drops in abundance of some local shark populations. However, a heartening trend in recent years has been the increase in numbers of recreational shark fishermen choosing to release their shark catches, often after tagging (Hueter 1996).

The rise in popularity of catch-and-release shark fishing can have a positive impact on shark populations by reducing the numbers of sharks killed. For example, the Shark Angling Club of Great Britain, whose members are responsible for most recreational catches of blue sharks *Prionace glauca* off the south-west coast of Britain, reports that only four blue sharks were killed out of 524 caught in 1996 (Vas 1997).

If catch-and-release is combined with tagging, then much information about shark biology and population trends can be gained, leading to the possibility of more informed management. The long-term tagging carried out under the US National Marine Fisheries Service (NMFS) Co-operative Shark Tagging Program provides perhaps the best example of such a programme. Between 1962 and 1995, more than 128,000 sharks of 40 species were tagged, from which over 6,000 sharks of 32 species have been recovered (Kohler 1996). Among other things, analysis of returns has provided considerable insights into the distribution and migration of shortfin mako *Isurus oxyrinchus* and blue shark *Prionace glauca* in the western North Atlantic (Casey and Kohler 1992, Casey 1985).

Tagging can in itself provide a powerful incentive for release. In the Elkhorn Slough Shark Derby, a long-running annual elasmobranch angling competition in California, 65% of elasmobranchs caught were tagged and released alive in the third year after tagging was introduced (King and Cailliet 1992). Prior to the introduction of the catch-tag-release programme, all elasmobranchs landed were killed.

While the early developments in catch-and-release and tagging of elasmobranchs occurred in North America and Europe, other regions are now showing signs of following suit. In Singapore, one renowned shark angler has recently abandoned shark killing and is working to establish a shark tag-and-release programme in the South East Asian region (Watkins 1996). Further developments of this sort are needed, and the encouragement of catch-and-release and tagging of elasmobranchs among sports fishermen is certainly one area where fisheries managers and researchers in the Asia-Pacific region can make an impact.

Even if elasmobranchs are landed by fishermen, much information of use to resource managers can be obtained (Stevens 1984, King and Cailliet 1992, Pepperell 1992). In some cases the presence of a recreational fishery can be used to reduce total fishing mortality by reducing commercial fishing effort. In areas where recreational fishing is particularly popular, sports fishermen make enormous financial contributions to the economies of coastal communities. Such communities therefore have a vested interest in the sustainability of their resources. For example, on the northwest coast of Australia, recreational fishermen are a strong economic force and have successfully negotiated restrictions to access by foreign longliners to the western Australian Fishing Zone (Caton and Ward 1996). While these recreational fishermen are interested in a variety of pelagic fishes, not just elasmobranchs, the reduction in commercial longline effort has presumably reduced pelagic shark mortality. In the case of the oceanic blue shark fishery in the eastern North Atlantic mentioned above, recreational catches are much less than 1% of commercial catches (Vas 1997). In the case of coastal shark fisheries, the proportion of the total catch made by recreational fishermen may be much higher (Anderson 1990). In either case, any limitation of commercial catches by recreational fishing lobbies should have a profound effect on total mortality.

While recreational elasmobranch fisheries can certainly bring benefits to the resources they exploit, they can also have negative impacts. Most obviously, the fisheries do kill elasmobranchs. Where capture-and-release regimes are not in place, recreational fisheries may cause local stock depletion (Walker 1996). Furthermore, as the popularity of sports fishing increases and starts in new areas, shark mortality is bound to increase.

Even if a recreational fishery is almost entirely capture-and-release oriented, it may not be without problems. The most obvious problem is post-release mortality (Hueter 1996, Skomal and Chase 1996), which may be significant for some species or fisheries. Tagging can further increase post-release mortality (Heuter 1996). The use of inappropriate tags was shown to increase mortality in juvenile lemon sharks *Negaprion brevirostris* in the Bahamas (Manire and Gruber 1991).

Aquarium display

In recent years there has been a revolution in aquarium technology. The use of new materials and techniques has allowed the development of massive public display tanks. This in turn has encouraged the holding and exhibition of sharks and rays.

Over 100 million people visit public aquariums each year in North America alone, and shark exhibits are consistently popular with visitors (Sabalones 1995). The key role of public aquariums is in education. If threatened elasmobranch species are to receive the management and conservation they need, public support is vital. The display of living elasmobranchs supported by appropriate educational materials goes a long way towards dispelling misconceptions about elasmobranchs in general and sharks in particular. The display of a diversity of small species demonstrates how inappropriate is the 'Jaws' image (Croft 1993). Sabalones (1995) suggests that displays and presentations should cover three main issues:

- The negative image of sharks should be countered, for example by discussing the relatively low incidence of shark attacks in comparison to other animals.
- The positive contributions and aspects should be stressed, for example by discussing their importance to environmental balance.
- Their conservation needs should be emphasised.

Large public aquariums are also sources of information for the media, and so their influence on the public's image of sharks can be spread far beyond those who walk in (Sabalones 1995). In addition to this primarily educational role, public aquariums can promote elasmobranch conservation through their research activities (Sabalones 1995). For example, studies of reproductive behaviour (Uchida *et al.* 1990), reproductive physiology (Rasmussen and Murru 1992) and growth (Van Dykhuizen and Mollet 1992) have been successfully carried out on captive individuals. There have also been considerable improvements in the understanding of physiological changes in elasmobranchs subject to live capture, transportation and maintenance, as a result of which captive mortality has been reduced (Murru 1990, Smith 1992).

In parallel with the developments in the major aquariums, there have also been improvements in domestic aquarium technology and practice. This too has led to increased interest in keeping elasmobranchs in captivity (Fenner 1996). The smaller, demersal, strikingly patterned sharks such as the epaulette shark *Hemiscyllium ocellatum* are favoured. The USA is the largest market, and many of the elasmobranch species favoured by aquarists there originate in South East Asian waters (Table 2). Rose (1996) notes that live catshark (Scyliorhinid) juveniles and eggcases are exported from Indonesia to the USA for sale to private aquarists.

A problem for domestic aquarists is that even small elasmobranchs are relatively large. Table 2 lists the approximate maximum sizes of sharks commonly kept in captivity in the USA. Most sharks are purchased by

Table 2. Some sharks commonly kept in captivity in the USA.

Scientific name	Common name	Family	Distribution	Size
Squalus acanthias	Piked dogfish	Squalidae	Antitropical	160cm
Squatina californica	Pacific angelshark	Squatinidae	E Pacific	152cm
Heterodontus portusjacksoni	Port Jackson shark	Heterodontidae	Australia	165cm
Heterodontus zebra	Zebra bullhead shark	Heterodontidae	W Pacific	122cm
Eucrossorhinus dasypogon	Tasselled wobbegong	Orectolobidae	SW Pacific and Australia	125cm
Orectolobus ornatus	Ornate wobbegong	Orectolobidae	W Pacific and Australia	288cm
Chiloscyllium plagiosum	Whitespotted bambooshark	Hemiscylliidae	Indo-W Pacific	95cm
Chiloscyllium punctatum	Brownbanded bambooshark	Hemiscylliidae	Indo-W Pacific	104cm
Hemiscyllium ocellatum	Epaulette shark	Hemiscylliidae	SW Pacific and Australia	107cm
Ginglymostoma cirratum	Nurse shark	Ginglyostomatidae	Atlantic and E Pacific	304cm
Mustelus canis	Dusky smoothhound	Triakidae	W Atlantic	150cm
Triakis semifasciata	Leopard shark	Triakidae	NE Pacific	180cm
Carcharhinus melanopterus	Blacktip reef shark	Carcharhinidae	Indo-W Pacific	180cm
Negaprion brevirostris	Lemon shark	Carcharhinidae	Atlantic and E Pacific	340cm

Source: Fenner (1996), with additional data from Compagno (1984) and Last and Stevens (1994).

aquarists as juveniles or eggcases. If they lived long in captivity most would outgrow all but the largest tanks. However, the difficulties associated with keeping such animals in domestic aquariums are such that most sharks survive for less than one month (Fenner 1996). Despite these losses, the growth of interest in elasmobranchs among the large aquarium hobbyist fraternity is creating a constituency of people who are aware of their conservation requirements.

The demand for living elasmobranchs from the aquarium trade is small compared to the demand for other elasmobranch fishery products. The impact of most aquarium fisheries on wild populations is therefore thought to be insignificant (Sabalones 1995). However, this might not be the case where wild populations are particularly small or already under threat from other causes. For example, there is trade in live freshwater stingrays and sawfish species, including species from Malaysia (Rose 1996), which may further endanger some threatened local populations.

Conclusions

Recreational utilisation is an increasingly important component of the overall utilisation of many elasmobranch resources. The growth of sport diving, the expansion of recreational elasmobranch fishing and the changing of attitudes among its practitioners, and the development of new aquarium displays are all helping to create a vast constituency of people with an interest in elasmobranch conservation. Furthermore, these people have considerable spending power, and this economic influence can be used to forward elasmobranch conservation.

Many elasmobranch species have no recreational value and, even for those that do, promotion of recreational utilisation over commercial fishing is unlikely to provide a cure for all problems. Nevertheless, elasmobranch resource managers, researchers and conservationists need to be aware of the challenges and take advantage of the opportunities presented by the increasing recreational utilisation of elasmobranch resources.

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Review of the Biodiversity of Sharks and Chimaeras in the South China Sea and Adjacent Areas

L.J.V. Compagno
Shark Research Center, Division of Life Sciences, South African Museum, 25 Queen Victoria Street, P.O. Box 61, Cape Town 8000, South Africa

The South China Sea and adjacent areas have a rich shark fauna and undiverse chimaeroid fauna, with at least 136 species of sharks and four species of chimaeras. The region is diverse hydrographically, and includes a broad continental shelf with continuity of inshore fauna between the countries fronting it, an ocean basin, and extensive and largely unexplored continental slopes. The low diversity of chimaeroids in the region may be partly explained by sampling error and limited exploration of the local slopes. The shark fauna is peculiar in having relatively low diversity of catsharks (Scyliorhinidae) and deep-slope squaloids, which may also reflect sampling errors such as better representation of important commercial species in the faunal list and poor representation of deep-slope species. The shark fauna has a wide habitat range and has rich oceanic, slope, and shelf components as well as species that bridge two or more of these broad habitat categories. Zoogeographically, the fauna has few regional endemics (17%), and is primarily composed of wide-ranging species (59%) and Western Pacific species (24%). Most of the ecomorphotypes ascribed to sharks occur in the region, which indicates the high diversity of habitats and life history styles of the regional fauna. A working checklist of sharks and chimaeras of the South China Sea is provided.

Introduction

This paper is an immediate extension of research by the author, for a workshop on diversity of fishes of the South China Sea held at the National University of Singapore in May 1997. This includes compilation of a checklist of cartilaginous fishes of the South China Sea, for use at the workshop. The checklist in turn embodies parts of a previous checklist of chondrichthyans compiled by L.J.V. Compagno, P. Last, B. Seret and V. Niem for the forthcoming FAO species sheets on cartilaginous fishes of the West-Central Pacific (Compagno *et al.* 1997), as well as checklists of Borneo Chondrichthyes included in a report on structuring the Sabah biodiversity project (Cook and Compagno 1996) and a series of regional checklists and distributional datafiles in the author's CHONDTAXON database. The work also contributes to a revision of the FAO shark catalogue (Compagno 1984) soon to be published in three volumes (Compagno 2000, in prep., a,b). The South China Sea checklist of chondrichthyans will be separately published as part of a checklist of fishes of the region (J.E. Randall pers. comm.).

Data sources

Sources for the paper include field surveys by Sid Cook and the author in Thailand in 1993 and in Singapore, Thailand, Peninsular Malaysia, and Sabah in 1996, field and lab work by the author in the Philippines in 1995 during the FAO Western Central Pacific workshop, a re-examination of virtually the entire elasmobranch collection in the Zoological Reference Collection of the National University of Singapore in 1996 and more limited examination of elasmobranchs at Kasetsart University, Bangkok, Thailand in 1996.

Primary literature sources for this paper include Bessednov (1968), Bigelow and Schroeder (1948), Chen (1963), Chu (1963), Chu, Meng, Hu and Li (1981), Chu, Meng and Liu (1981), Chu *et al.* (1982, 1983, 1984, 1986), Compagno (1984, 1988, 1990a), Compagno and Cook (1995), Compagno *et al.* (1994), Compagno *et al.* (1997), Cook and Compagno (1996), Deng *et al.* (1981, 1983, 1985), Dingerkus and DeFino (1983), Fowler (1905,1941), Garman (1913), Garrick (1982, 1985), Herre (1923, 1925, 1929,1930,1953), Last and Stevens (1994), Mongkolprasit (1977, 1984), Shen *et al.* (1995), and Teng (1958, 1959a,b,c,d,e, 1962).

The "Region" as defined here includes the tropical waters of the South China Sea and adjacent waters (Figure 1), with those countries fronting the South China Sea (including freshwater habitats): Thailand (Gulf of Thailand), Malaysia (Peninsular Malaysia, Sarawak and Sabah) Singapore, Kampuchea (Cambodia), Vietnam, China, Taiwan, Philippines, Indonesia (Kalimantan) and Brunei. This paper restricts itself to a discussion of biodiversity of sharks and chimaeroids in the Region, with the batoids discussed elsewhere by Last and Compagno (this volume).

Hydrography

The hydrography of the Region indicates some of the features important in influencing the diversity and

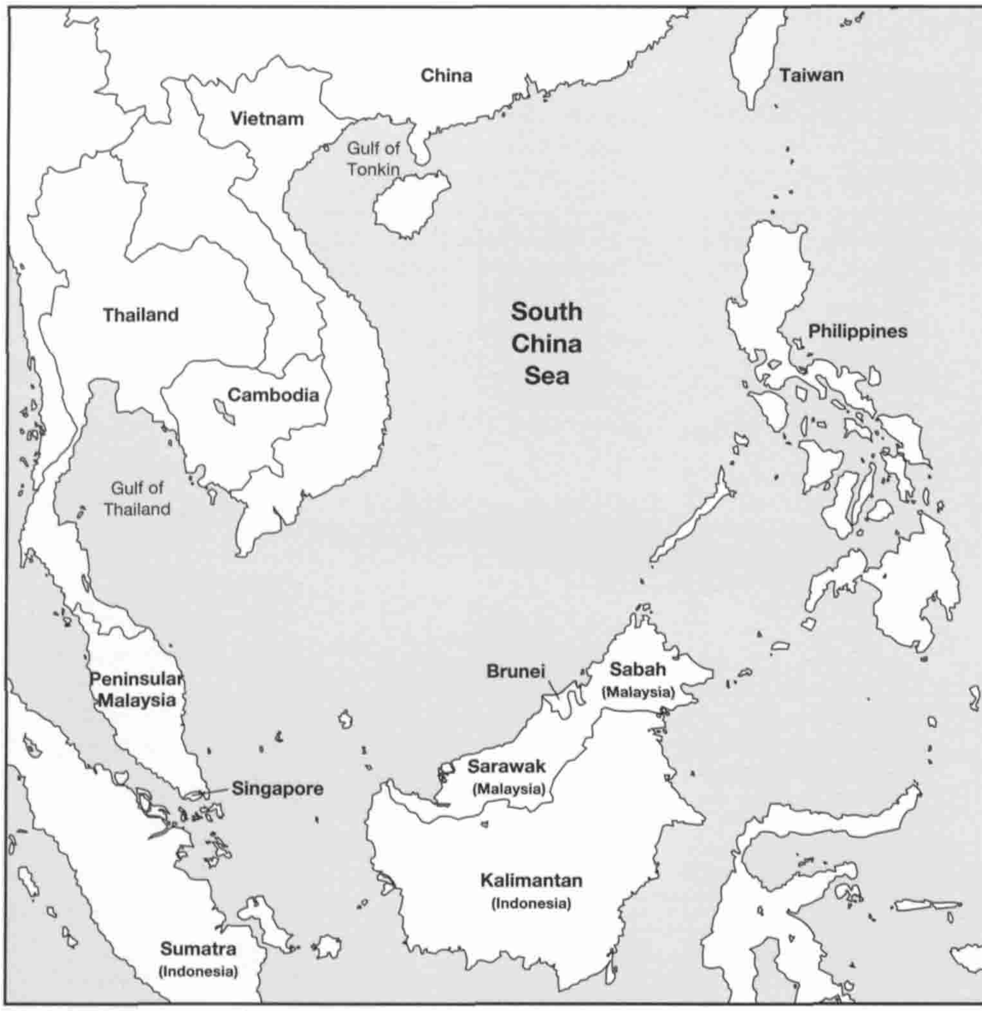


Figure 1. The South China Sea and adjacent waters.

commonality of cartilaginous fish faunas from various localities in the Region. Of considerable importance is the broad continental shelf with water 0-200m deep in the south-western part of the Region. This extends into the Gulf of Thailand and between Malaysia, Singapore, Sumatra, Kalimantan and Sarawak. Many (but not all) species of inshore elasmobranchs are common to parts of this broad shelf. The shelf narrows abruptly along the south of Vietnam, and broadens northwards in the Gulf of Tonkin and on the south coast of China around Hainan Island and northwards beyond Hong Kong to Taiwan. It also narrows abruptly off Brunei and Sabah, and is relatively narrow around the Philippines. The continuity of shelf in the Region might serve as corridors for local movements of shelf species in the area, or have served as corridors for dispersal of wide-ranging inshore species within the Region. Differences within the shelf fauna, including those seen between the relatively well-known Gulf of Thailand fauna and those off Singapore, Sabah and Philippines, for example, suggest localised development of inshore endemics and isolation of Western Central Pacific species within a broad pattern of continuity and dispersion of wide-ranging inshore species.

The continental slopes between 200 and 2,000m deep are prominent in the north-eastern part of the Region, and front a large ocean basin connected by the Luzon Strait to the Western Pacific. The slopes are extensive around Philippines, and in the Sulu and Sulawesi Seas. The north-west slopes off China and the Philippine slopes apparently have considerable endemicity of deepwater elasmobranchs but are not well-explored, and the slopes in other parts of the Region, including Sabah, are poorly known at best. Exploratory deep bottom trawling by the Taiwanese research vessel *Fisheries Explorer 1* off north-eastern Luzon during the FAO West-Central Pacific workshop in Manila in October 1995 revealed many new records of deepwater chondrichthyans, including undescribed species, and suggested that much remains to be learned of the local deep-slope fauna in the Region.

The extensive epipelagic zone around the slopes and the ocean basins allows egress and provides habitat for oceanic and semi-oceanic wide-ranging elasmobranchs, and accounts for the relative richness of oceanic species in the Region. Sampling of epipelagic sharks is very good due to intense oceanic fisheries in the Region.

Biodiversity of chimaeroids and sharks in the Region

The Region of the South China Sea and adjacent waters has a rich chondrichthyan fauna, indicative of a diverse range of tropical surface habitats as well as varied deepwater habitats and also northern incursions of temperate species from the western North Pacific. At least 136 species of sharks and four species of chimaeroids occur in the Region. These species are classified by taxonomic diversity, habitat type, distribution pattern and ecomorphotypes (listed as codes in Table 1), and each of these categories is discussed separately.

Table 1. Species of sharks and chimaeroids in the South China Sea, with habitat, ecomorphotype, and distributional codes. Listing of taxonomic codes given below; habitat, ecomorphotype and distributional codes are listed in Tables 4-6.

Scientific name	Common name	Habitat code	Ecomorphotype code	Distributional code
CHLAMYDOSELACHIDAE				
Chlamydoselachus anguineus	Frilled shark	SHS	BAN	WRAN
HEXANCHIDAE				
Heptranchias perlo	Sharpnose sevengill shark	SHS	LSH	WRAN
Hexanchus griseus	Bluntnose sevengill shark	SHS	LEU	WRAN
Hexanchus nakamurai	Bigeye sixgill shark	SLO	LSH	WRAN
Notorynchus cepedianus	Broadnose sevengill shark	SHL	LEU	WRAN
ECHINORHINIDAE				
Echinorhinus cookei	Prickly shark	SHS	BAT	WRAN
SQUALIDAE				
Cirrhigaleus barbifer	Mandarin dogfish	SLO	BAT	WPAE
Squalus blainvillei	Longnose spurdog	SHS	LSH	WPAE
Squalus brevirostris	Japanese shortnose spurdog	SHS	LSH	WNPE
Squalus japonicus	Japanese spurdog	SHS	LSH	WNPE
Squalus megalops	Shortnose spurdog	SHS	LSH	WPAE
Squalus mitsukurii	Shortpine spurdog	SHS	LSH	WRAN
CENTROPHORIDAE				
Centrophorus acus	Needle dogfish	SLO	BAT	WNPE
Centrophorus atromarginatus	Dwarf gulper shark	SHS	BAT	IWPE
Centrophorus granulosus	Gulper shark	SLO	BAT	WRAN
Centrophorus isodon	Blackfin gulper shark	SLO	BAT	IWPE
Centrophorus lusitanicus	Lowfin gulper shark	SLO	BAT	WRAN
Centrophorus moluccensis	Smallfin gulper shark	SHS	BAT	IWPE
Centrophorus niaukang	Taiwan gulper shark	SLO	BAT	WRAN
Centrophorus squamosus	Leafscale gulper shark	SLO	BAT	WRAN
Deania profundorum	Arrowhead dogfish	SLO	BAT	WRAN
ETMOPTERIDAE				
Etmopterus brachyurus	Shorttail lanternshark	SLO	BAT	WPAE
Etmopterus decacuspidatus	Combtooth lanternshark	SLO	BAT	SCSE
Etmopterus granulosus'?	Southern lanternshark	SLO	BAT	WRAN?
Etmopterus lucifer	Blackbelly lanternshark	SLO	BAT	WPAE
Etmopterus molten	Slendertail lanternshark	SLO	BAT	IWPE
Etmopterus pusillus	Smooth lanternshark	SOC	BAT	WRAN
Etmopterus splendldus	Splendid lanternshark	SHS	OMI	WPAE
SOMNIOSIDAE				
Centroscymnus coelolepis	Portuguese dogfish	SLO	BAT	WRAN
Zameus squamulosus	Velvet dogfish	SOC	BAT	WRAN
DALATIIDAE				
Dalatlas licha	Kitefin shark	SLO	BAT	WRAN
Isistius brasiliensis	Cookiecutter or cigar shark	OCE	OMI	WRAN
Isistius labialis?	South China cookiecutter shark	OCE	OMI	SCSE?
Squaliolus aliae	Smalleye pigmy shark	OCE	OMI	WNPE
Squaliolus laticaudus	Spined pygmy shark	OCE	OMI	WRAN
PRISTIOPHORIDAE				
Pristiophorus japonicus	Japanese sawshark	SHS	BPT	WNPE
Pristiophorus sp.		SLO	BPT	PHIE
SQUATINIDAE				
Squatina formosa	Taiwan angelshark	SHS	BSQ	CHTE
Squatina japonica	Japanese angelshark	SHL	BSQ	WNPE
Squatina nebulosa	Clouded angelshark	SHL	BSQ	WNPE
Squatina tergocellatoides	Ocellated angelshark	SHL	BSQ	CHTE

Table 1 ... continued.

Scientific name	Common name	Habitat code	Ecomorphotype code	Distributional code
HETERODONTIDAE				
Heterodontusjaponicus	Japanese bullhead shark	SHL	BPR	WNPE
Heterodontuszebra	Zebra bullhead shark	SHL	BPR	WPAE
PARASCYLLIDAE				
Cirrhoscylliumexpolitum	Barbelthroat carpetshark	SHL	BLE	SCSE?
Cirrhoscylliumformosanum	Taiwan saddled carpetshark	SHL	BLE	CHTE
ORECTOLOBIDAE				
Orectolobusjaponicus	Japanese wobbegong	SHL	BSQ	WNPE
Orectolobus maculatusl	Spotted wobbegong	SHL	BSQ	WPAE?
HEMISCYLLIDAE				
Chiloscylliumgriseum	Gray bambooshark	SHL	BLE	IWPE
Chiloscylliumhasselti	Indonesian bambooshark	SHL	BLE	WCPE
Chiloscylliumindicum	Slender bambooshark	SHL	BLE	IWPE
Chiloscylliumplagiosum	Whitespotted bambooshark	SHL	BLE	IWPE
Chiloscylliumpunctatum	Brownbanded bambooshark	SHL	BLE	IWPE
GINGLYMOSTOMATIDAE				
Nebriusferrugineus	Tawny nurse shark	SHL	LSH	IWPE
STEGOSTOMATIDAE				
Stegostomafasciatum	Zebra shark	SHL	BPR	IWPE
RHINCODONTIDAE				
Rhincodontypus	Whale shark	SHO	OMA-F	WRAN
ODONTASPIDIDAE				
Carchariastaurus	Sand tiger shark	SHL	LSH	WRAN
PSEUDOCARCHARIIDAE				
Pseudocarchariaskamoharai	Crocodile shark	OCE	OMI	WRAN
MITSUKURINIDAE				
Mitsukurinaowstoni	Goblin shark	SLO	BAR	WRAN
ALOPIIDAE				
Alopiaspelagicus	Pelagic thresher	SHO	OMA	WRAN
Alopiassuperciliosus	Bigeye thresher	WRH	OMA	WRAN
Alopiasvulpinus	Thresher shark	SHO	OMA	WRAN
CETORHINIDAE				
Cetorhinusmaximus	Basking shark	SHL	PTA-F	WRAN
LAMNIDAE				
Carcharodoncarcharias	Great white shark	WRH	PAR	WRAN
Isurusoxyrinchus	Shortfin mako	SHO	PTA	WRAN
Isuruspaucus	Longfin mako	OCE	PTA?	WRAN
SCYLIORHINIDAE				
Apristurusacanutus	Flatnose catshark	SLO	BAR	SCSE
Apristurusgibbosus	Humpback catshark	SLO	BAR	SCSE
Apristurusherklotsi	Longfin catshark	SLO	BAR	WPAE
Apristurusmacrorhynchus	Flathead catshark	SLO	BAR	WNPE
Apristurusmacrostomus	Broadmouth catshark	SLO	BAR	SCSE
Apristurusmicropterygeus	Smalldorsal catshark	SLO	BAR	SCSE
Apristurussinensis	South China catshark	SLO	BAR	SCSE
Atelomycterusmarmoratus	Coral catshark	SHL	BLE	IWPE
Bythaelurusimmaculatus	Spotless catshark	SLO	BLE	SCSE
Cephaloscylliumfasciatum	Reticulated swellshark	SLO	BPR	WPAE
Cephaloscylliumumbratile	Japanese swellshark	SHS	BPR	WNPE
Cephaloscyllium sp.		SHS	BPR	WPAE
Galeuseastmani	Gecko catshark	SHS	BLE	WNPE
Galeussauteri	Blacktip sawtail catshark	SHL	BLE	WNPE
Galeusschultzi	Dwarf sawtail catshark	SLO	BLE	PHIE
Halaelurusboesemani	Speckled catshark	SHL	BLE	IWPE
Halaelurusbuergeri	Darkspot catshark	SHL	BLE	WNPE
Parmaturusmelanobranchius	Blackgill catshark	SLO	BLE	SCSE
Pentanchusprofundicolus	Onefin catshark	SLO	BAR	PHIE
Scyliorhinusgarmani	Brownspotted catshark	SHL?	BLE	WCPE
Scyliorhinustorazame	Cloudy catshark	SHS	BLE	WNPE
PROSCYLLIIDAE				
Eridacnisradcliffei	Pygmy ribbontail catshark	SHS	BLE	IWPE
Proscylliumhabereri	Graceful catshark	SHS	BLE	WPAE

Table 1 ... continued.

Scientific name	Common name	Habitat code	Ecomorphotype code	Distributional code
PSEUDOTRIAKIDAE				
Pseudotriakis microdon	False catshark	SLO	BAT	WRAN
TRIAKIDAE				
Hemitriakis japanica	Japanese topeshark	SHL	LSH	WNPE
Hemitriakis leucoperiptera	Whitefin topeshark	SHL	LSH	PHIE
Hemitriakis sp.		SHL	LSH	PHIE
Hypogaleus hyugaensis	Blacktip topeshark	SHS	LSH	IWPE
Iago sp.		SHS	LSH	PHIE
Mustelus griseus	Spotless smoothhound	SHL	LCA	WPAE
Mustelus manazo	Starspotted smoothhound	SHS	LCA	IWPE
Triakis scyllium	Banded houndshark	SHL	LSH	WNPE
HEMIGALEIDAE				
Chaenogaleus macrostoma	Hooktooth shark	SHL	LSH	IWPE
Hemigaleus microstoma	Sicklefin weasel shark	SHL	LTE	IWPE
Hemipristis elongatus	Snaggletooth shark	SHL	LSH	IWPE
Paragaleus tengi	Straighttooth weasel shark	SHL	LTE	SCSE
CARCHARHINIDAE				
Carcharhinus albimarginatus	Silvertip shark	SSO	LSH	WRAN
Carcharhinus altimus	Bignose shark	SHS	LSH	WRAN
Carcharhinus amblyrhynchoides	Graceful shark	SHL	LSH	IWPE
Carcharhinus amblyrhynchos	Gray reef shark	SHL	LSH	IWPE
Carcharhinus amboinensis	Pigeye or Java shark	SHL	LEU	WRAN
Carcharhinus borneensis	Borneo shark	SHL	LSH	SCSE
Carcharhinus brachyurus	Bronze whaler	SHL	LSH	WRAN
Carcharhinus brevipinna	Spinner shark	SHL	LSH	WRAN
Carcharhinus dussumieri	Whitecheek shark	SHL	LSH	IWPE
Carcharhinus falciformis	Silky shark	SHO	OMA	WRAN
Carcharhinus hemiodon	Pondicherry shark	SHL	LSH	IWPE
Carcharhinus leucas	Bull shark	SHF	LEU	WRAN
Carcharhinus limbatus	Blacktip shark	SHL	LSH	WRAN
Carcharhinus longimanus	Oceanic whitetip shark	SHO	OMA	WRAN
Carcharhinus macloti	Hardnose shark	SHL	LSH	IWPE
Carcharhinus melanopterus	Blacktip reef shark	SHL	LSH	INPE
Carcharhinus obscurus	Dusky shark	SHS	LSH	WRAN
Carcharhinus plumbeus	Sandbar shark	SHS	LSH	WRAN
Carcharhinus sealei	Blackspot shark	SHL	LSH	IWPE
Carcharhinus sorrah	Spottail shark	SHL	LSH	IWPE
Carcharhinus sp.		SHL	LSH	SCSE
Galeocerdo cuvier	Tiger shark	SSO	LEU	WRAN
Glyphis sp. B	Borneo river shark	SHF?	LSH	SCSE
Lamiopsis temmincki	Broadfin shark	SHL	LSH	IWPE
Loxodon macrorhinus	Sliteye shark	SHL	LSH	IWPE
Negaprion acutidens	Sharptooth lemon shark	SHL	LSH	IWPE
Phonace glauca	Blue shark	SHO	OMA	WRAN
Rhizoprionodon acutus	Milk shark	SHL	LSH	WRAN
Rhizoprionodon oligolinx	Gray sharpnose shark	SHL	LSH	IWPE
Scoliodon laticaudus	Spadenose shark	SHL	LSH	IWPE
Triaenodon obesus	Whitetip reef shark	SHL	LSH	INPE
SPHYRNIDAE				
Eusphyra blochii	Winghead shark	SHL	LSP	IWPE
Sphyrna lewini	Scalloped hammerhead	SSO	LSP	WRAN
Sphyrna mokarran	Great hammerhead	SSO	LSP	WRAN
Sphyrna zygaena	Smooth hammerhead	SSO	LSP	WRAN
RHINOCHIMAERIDAE				
Harriotta raleighana	Longnose chimaera	SLO	BAR	WRAN
Rhinochimaera pacifica	Pacific spookfish	SLO	BAR	WPAE
CHIMAERIDAE				
Chimaera phantasma	Silver chimaera	SHS	BCH	WNPE
Hydrolagus mitsukurii	Mitsukuri's chimaera	SLO	BCH	PHIE

Table 2. Actual and relative numbers of species as percentages of totals in higher groups of sharks and chimaeroids, for the Region and the world, with comparisons of regional species as % of world species.

Higher groups	Region No.	Region % total	World maximum No.	World maximum % total	Regional as% of world
Total species	140	100	529	100	26.5
Chimaeroids	4	2.9	50	9.5	8.0
Hexanchoids	5	3.6	7	1.3	71.4
Echinorhinoids	1	0.7	2	0.4	50.0
Squaloids	29	20.7	115	21.7	25.2
Pristiophoroids	2	1.4	18	3.4	11.1
Squatinoids	4	2.9	9	1.7	44.4
Heterodontoids	2	1.4	9	1.7	22.2
Lamnoids	10	7.1	17	3.2	58.8
Orectoloboids	12	8.6	34	6.4	35.3
Carcharhinoids	71	50.7	268	50.7	26.5
Total sharks	136	97.1	479	90.5	28.4

Table 3. Actual and relative numbers of species as percentages of totals in families of sharks and chimaeroids, for the Region and the world, with comparisons of regional species as % of world species.

Families	Region No.	Region % total	World maximum No.	World maximum % total	Regional as% of world
Total species	140	100	515	100	27.2
Rhinochimaeridae	2	1.4	9	1.7	22.2
Chimaeridae	2	1.4	38	7.4	5.3
Chlamydoselachidae		0.7	2	0.4	50.0
Hexanchidae	4	2.9	5	1.0	80.0
Echinorhinidae	1	0.7	2	0.4	50.0
Squalidae	6	4.3	19	3.7	31.6
Centrophoridae	9	6.4	15	2.9	60.0
Etmopteridae	7	5.0	48	9.3	14.6
Somniosidae	2	1.4	17	3.3	11.8
Dalatiidae	5	3.6	10	1.9	50.0
Pristiophoridae	2	1.4	9	1.7	22.2
Squatinidae	4	2.9	18	3.5	22.2
Heterodontidae	2	1.4	9	1.7	22.2
Parascylliidae	2	1.4	7	1.4	28.6
Orectolobidae	2	1.4	7	1.4	28.6
Hemiscylliidae	5	3.6	13	2.5	38.5
Ginglymostomatidae		0.7	3	0.6	33.3
Stegostomatidae	1	0.7	1	0.2	100.0
Rhincodontidae	1	0.7	1	0.2	100.0
Mitsukurinidae	1	0.7	1	0.2	100.0
Odontaspididae	1	0.7	4	0.8	25.0
Pseudocarchariidae	1	0.7	1	0.2	100.0
Alopiidae	3	2.1	4	0.8	75.0
Cetorhinidae	1	0.7	1	0.2	100.0
Lamnidae	3	2.1	5	1.0	60.0
Scyliorhinidae	21	15.0	140	27.2	15.0
Proscylliidae	2	1.4	5	1.0	40.0
Pseudotriakidae	1	0.7	3	0.6	33.3
Triakidae	7	5.0	46	8.9	15.2
Hemigaleidae	5	3.6	8	1.6	62.5
Carcharhinidae	31	22.1	54	10.5	57.4
Sphyrnidae	4	2.9	10	1.9	40.0
Total sharks	136	97.1	468	90.9	29.1
Mean for families					46.7

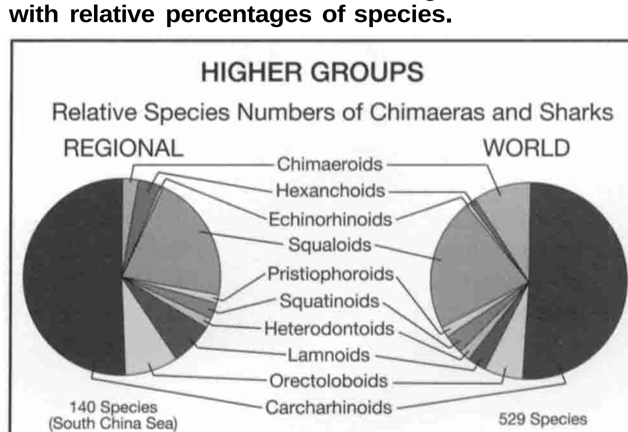
Taxonomic diversity

Table 2 lists the higher groups of sharks and chimaeroids in the Region, with number of species listed and compared with numbers of world species, while Table 3 lists the numbers of species in the families of sharks and chimaeroids in the Region and with comparisons with numbers of world species. It is apparent from these data that the Region has a relatively low representation of chimaeroids compared to the world fauna (possibly due to inadequate and patchy sampling of the deep slope fauna below 600-800m), while hexanchoids, squaloids, lamnoids, orectoloboids, and carcharhinoids are represented in the Region at levels comparable to or higher than world levels.

Consideration of the species composition of the two major shark groups in the Region, squaloids and carcharhinoids, reveal interesting differences from the world fauna. Squaloid sharks (Figure 2) have higher representation of gulper sharks (Family Centrophoridae) and kitefin sharks (Family Dalatiidae) and much lower representation of lantern sharks (Family Etmopteridae) and sleeper sharks (Family Somniosidae) than the world fauna, with dogfish sharks (Family Squalidae) similar regionally and worldwide. These differences may partially reflect the sketchy state of knowledge of deep slope faunas, as well as better sampling of important commercial upper slope species (gulper sharks) and epipelagic species (many dalatiids). but may also reflect real differences from the world fauna.

Carcharhinoid sharks have species of requiem sharks (Carcharhinidae) and weasel sharks (Hemigaleidae) much better represented than in the world fauna, and the catsharks (Scyliorhinidae) and houndsharks (Triakidae) less well represented. The relative abundance of requiem and weasel sharks may represent better sampling of these predominantly shelf families as well as very high species diversity of these groups in the Indo-West Pacific compared

Figure 2. Taxonomic diversity of higher groups of sharks and of chimaeroids in the Region and the world, with relative percentages of species.



to other parts of the world. Catsharks are undiverse on the shelves in the Region and in the entire tropical Indo-West Pacific, which may reflect the presence of small orectoloboids (particularly the genus *Chiloscyllium*) as possible competitors or replacements for them. However, catsharks are most diverse on the continental and insular slopes in the Region and in most of the world (southern Africa being one notable exception, with a rich inshore catshark fauna). Further deepwater exploration in the Region might reveal several additional deepwater scyliorhinids.

Habitat diversity

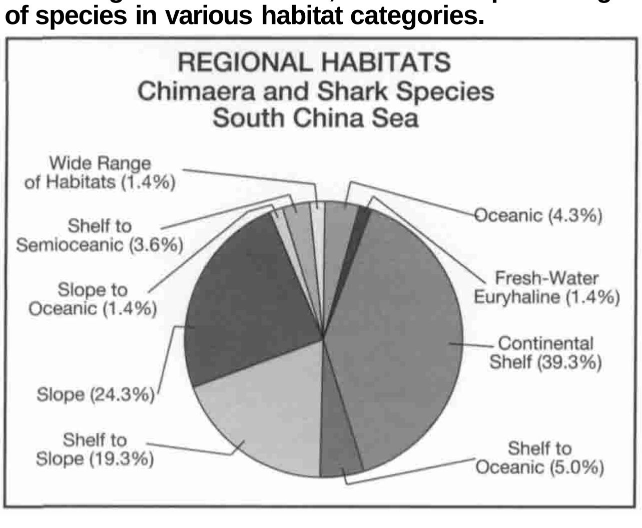
The diverse shark fauna of the Region occupies a variety of habitats (Table 4, Figure 3), while the chimaeroids are confined to deep water and the continental slopes. The three main habitat categories for chondrichthyans are:

- the marine continental and insular *shelves*, with inshore and offshore waters from the intertidal to 200m, and as an extension fresh water in lakes and rivers;
- the continental and insular *slopes* below 200m and extending to 2,000m depth;
- the *oceanic* realm beyond the continental shelves and above the slopes and ocean floor.

Table 4. Habitats occupied by sharks and chimaeroids in the Region, with numbers of species in each habitat and % of total number of species.

Habitat	Code	No.	%total
Obligate freshwater	FWO	0	0.0
Oceanic	OCE	6	4.3
Euryhaline freshwater/shelves	SHF	2	1.4
Continental/insular shelves	SHL	55	39.3
Shelf to oceanic	SHO	7	5.0
Shelf to slope	SHS	27	19.3
Continental/insular slopes	SLO	34	24.3
Slope to oceanic	SOC	2	1.4
Shelf to semi oceanic	SSO	5	3.6
Wide range of habitats	WRH	2	1.4

Figure 3. Habitat diversity of sharks and chimaeroids in the Region and the world, with relative percentages of species in various habitat categories.



Many species of cartilaginous fishes overlap two or more of these categories, and can be placed into the following overlap categories:

- *shelf to slope,* for those species that extend across the shelf-slope boundaries;
- *slope to oceanic,* for those deepwater slope species that range into oceanic waters;
- *shelf to oceanic,* for those oceanic species that regularly penetrate shelf waters;
- *shelf to semi-oceanic,* for those shelf species that regularly range into the open ocean but adjacent to continental waters;
- ***wide** range* of habitats, for those species which can penetrate shelf, slope and oceanic habitats.

Compagno and Cook (1995) classified elasmobranchs in fresh water in four rough habitat categories:

- *obligate freshwater,* for those species confined to fresh water;
- *euryhaline*, for those species that readily penetrated far into fresh water but also regularly occurred in inshore marine waters;
- *brackish-marginal*, for species confined to brackish waters;
- *marginal,* for coastal shelf species that penetrated fresh water in estuaries or river mouths but were not found far from the sea.

There are no known obligate freshwater sharks in the Region, but there are problems with a lack of knowledge of the life-history of the single species of river shark *(Glyphis* sp. B) that is known to occur in the Region (from Borneo) (Compagno, this volume, b). Hence it is tentatively listed as a euryhaline species along with the bull shark *Carcharhinus leucas* until it is proven to be an obligate freshwater species, as may be the case with several whiptailed stingrays (Family Dasyatidae) in the Region.

Oceanic species are comparatively few, as with the world chondrichthyan fauna (Figure 3). The dominant habitat categories are the continental shelves, with nearly 40% of the species, the continental slopes, and the shelf to slope category, mostly for slope species that penetrate the outer continental shelves. Habitat categories with small representation include shelf to oceanic and shelf to semi-oceanic. There are a few species in the region that occupy a wide range of habitats: the great white shark *Curcharodon carcharias* is possibly most common in temperate inshore waters but readily penetrates the tropics, oceanic waters, and the upper slope. The bluntnose sixgill shark *Hexanchus griseus* is a deepwater species common on the slopes, which may reach inshore waters (particularly in temperate areas) but is also known from near the surface in the tropics and may be wide-ranging on seamounts and possibly partly pelagic.

Zoogeographic diversity

The Regional fauna of sharks and chimaeroids can be categorised by their geographic distribution patterns (Table 5) into three major categories:

- *Regional endemics*, comprising about 17% of the total;
- *Western Pacific* species, about 24% of the total;
- *Broad distribution species*, which is the most important category with about 59% of the total.

Table 5. Distribution patterns with coding of sharks and chimaeroids in the Region, with numbers of species in each category and % of total number of species.

Distribution patterns	Code	No.	% total
China/Taiwan Endemic	CHTE	3	2.1
Indo-Pacific endemics	INPE	2	1.4
Indo-West Pacific Endemic	IWPE	31	22.1
Philippine Endemic	PHIE	7	5.0
South China Sea Endemic	SCSE	14	10.0
West Central Pacific Endemic	WCPE	2	1.4
Western North Pacific Endemic	WNPE	18	12.9
Western Pacific Endemic	WPAE	14	10.0
Wide-ranging	WRAN	49	35.0

Endemic sharks and chimaeroids are relatively undiverse in the Region compared to the IUCN subequatorial African region (Compagno *et al.* 1989, 1994) or Australia (Last and Stevens 1994). The Region has only about 17% endemics compared to about 25% of 133 species of sharks and nine species of chimaeroids in subequatorial Africa. Endemism in the Australian fauna is even higher (Last and Stevens 1994), being 48% of the 166 species of sharks and about 50% of the 14 species of chimaeroids.

Many Regional endemics as currently known are slope-dwellers, especially from off the Chinese coast and around the Philippines, with relatively fewer shelf endemics. Regional endemics can be subdivided into

- *China/Taiwan endemics,* from the south-eastern coast of China and southern Taiwan,
- *Philippine endemics,* from around the Philippines,
- *South China Sea endemics,* confined to the Region.

An important component of the Region's shark and chimaeroid fauna occurs in species found in adjacent waters of the Western Pacific Ocean, including those species extending into the tropical *West-Central Pacific* (including Indonesia, Papua New Guinea and tropical Australia), a considerable number of species that extend into the *Western North Pacific* (including many temperate-water species that just reach the Region and which extend northwards to Japan and the Koreas), and those *Western Pacific* species that range north and south of the Region in the Western North and Western South Pacific. Species with *broad distributions* comprise the majority of species in the Region and include a few *Indo-Pacific species* with broad ranges from the Western Indian Ocean to the Eastern Pacific. Most of these species are either *Indo-West Pacific* in distribution, as part of the broad continuity of Indo-West Pacific fauna from the Western Indian Ocean to the Western Pacific (some of which range only to the northern Indian Ocean), or are *wide-ranging* and occur circumglobally or partly outside the Indo-Pacific region. The high percentages of wide-ranging species and relatively lowendemicity of Regional sharks and chimaeras(particularly on the continental shelves) suggest the zoogeographic role of the Region, particularly the inshore shelves, as more of a distributional crossroads to other areas of greater endemicity rather than a centre or series of centres of diversification or endemicity. This does not necessarily apply to the relatively poorly known continental slopes (compared to other parts of the world such as the North Atlantic, Japan and southern Africa), which have considerable endemicity, or for that matter the poorly known offshore benthic faunas of the outer shelves of the Region.

Ecomorphotype diversity

Compagno (1990a) proposed a series of habitus types or *ecomorphotypes*, characteristic patterns of morphology, habitat, and activity that can be used to classify cartilaginous fishes and to subdivide them ecologically. The very varied ecomorphotypes of sharksand chimaeroids in the Region (Table 6) indicate the wide taxonomic and

Table 6. Ecomorphotype coding of sharks and chimaeroids in the Region, with numbers of species in each category and % of total number of species.

Ecomorphotypes	Code	No.	% total
Anguilliform bathic	BAN	1	0.7
Anoxybathic (sharks)	BAO	0	0.0
Rhynchobathic	BAR	11	7.9
Bathic (sharks)	BAT	21	15.0
Chimaerobenthic (chimaeroids)	BCH	2	1.4
Leptobenthic (sharks)	BLE	19	13.6
Probenthic (sharks)	BPR	6	4.3
Pristobenthic	BPT	2	1.4
Squatinobenthic (sharks)	BSQ	6	4.3
Littoral cancritroph (sharks)	LCA	2	1.4
Littoral eurytroph (sharks)	LEU	5	3.6
Littoral (sharks)	LSH	42	30.0
Littoral sphyrnid (sharks)	LSP	4	2.9
Littoral teuthotroph (sharks)	LTE	2	1.4
Macroceanic (sharks)	OMA	6	4.3
Macroceanic filter feeder	OMA-F	1	0.7
Microceanic (sharks)	OMI	6	4.3
Archipelagic (sharks)	PAR	1	0.7
Tachypelagic (shark)	PTA	2	1.4
Tachypelagic filter feeder	PTA-F	1	0.7

ecological variety of sharks and chimaeroids in the area. Of these, the variants on the primitive active *littoral* body form of shelf-dwelling sharks, including macropredatory (*littoral eurytroph*), specialist cephalopod (*teuthitroph*) and crustacean *(cancritroph)* feeders, and the hammerheads (*littoral sphyrnids*), are the most important. A large component of bottom-dwelling shelf sharks and chimaeras with various *benthic* morphotypes also occur in the area, including compressed chimaerids (*chimaerobenthics*), generalised bottom-dwellers (*probenthics*), elongated bottom-dwellers *(leptobenthics)*, sawfish-like forms (*pristobenthics*, for sawsharks), and flattened angel-shark like forms (*squatinobenthics*). Deep-slope morphotypes among sharks include elongated eel-like forms (*anguilliform bathics*, for the frilled shark *Chlamydoselachus anguineus*), generalised deepwater 'floaters' (*bathics*, for many slope squaloids and deepwater lamnoids), and long-nosed deepwater forms (*rhynchobathics*, including the goblin shark *Mitsukurina owstoni*).

There are morphotypes in the Region for specialised *oceanic* sharks, including large *macroceanic* sharks (lamnoids and carcharhinids, plus the possibly macroceanic filter-feeding whale shark *Rhincodon typus*) and dwarf *microceanic* sharks (primarily dalatiid squaloids, also the crocodile shark *Pseudocarcharias kamoharai*). Adaptations for sustained cruising and high speed are seen in the few *tachypelagic* sharks in the area and worldwide, including the shortfin mako *Isurus oxyrinchus* and its essentially macroceanic-converted relative the longfin mako *I. paucus*, with the marginally (Taiwan) distributed basking shark *Cetorhinus maximus* a tachypelagic morphotype converted to slow but steady filter-feeding on small crustaceans. The *archipelagic* morphotype is only represented by the great white shark, which shows tachypelagic characteristics combined with adaptations for predation on large marine vertebrates.

Discussion

The Region has a rich tropical chondrichthyan fauna which is best known from the broad shelves, which support a wide variety of artesanal and commercial fisheries as well as small to huge fish markets in the various countries. As has been known by systematic ichthyologists since the last century (most notably from Pieter Bleeker's work in Indonesia and elsewhere in the tropical Indo-West Pacific in the last century), fish markets in the Region are excellent places for obtaining a broad sample of the local inshore and increasingly offshore and oceanic ichthyofauna, including rare and unusual species. Cartilaginous fishes are mostly caught as bycatch of other fisheries (including high-technology oceanic fisheries) driven by more fecund bony fishes and other fisheries species (Compagno 1990b). The markedly increasing value of shark fins in general and large species in particular during the last decade (including the fins of sharkfin guitarfishes and sawfishes) encourages development and expansion of specialist fisheries targeting large sharks in the Region for fins and for local consumption of their meat, as well as removal of fins from small bycatch sharks during processing of their carcasses for human consumption or other uses.

An important feature of tropical inshore fisheries for sharks is the bycatch of the young of large, more slow-growing species such as tiger sharks, as well as young and adults of small and medium-sized sharks. Many species of sharks use inshore waters as nursery grounds, and small to large scale fisheries in the Region impact these directly. It is suspected that some of the larger species may have declined in the Region due to increased mortality of the young from expanding coastal fisheries, as well as targeted fisheries. Targeted fisheries for large and medium-sized coastal sharks cut down recruitment of young by decreasing the number of breeding adults (Holden's model, 1974), while massive bycatch fisheries that land small sharks, as well as small-boat fishers that target small sharks or collect them as bycatch, catch the young of the larger species and cut down the recruitment of adults.

Fishing methods in the Region are traditionally varied and increasingly modern and intensive. They include poison and explosive-fishing, use of SCUBA gear, and high-technology local and international fishing vessels and gear to augment traditional fishing methodology, artisanal fisheries, and low-tech commercial fisheries (including inshore bottom trawling fisheries with locally manufactured moderate-sized boats and gear) without replacing them. Unlike selective fisheries and markets in North American and some European countries, cartilaginous fishes are generally landed and utilised in tropical markets in the Region and in most parts of the world as part of traditional 'catch-everything fisheries' in which marginal and sometimes useless and toxic species are landed as well as species that are readily utilised for human consumption. Offshore high-technology international fisheries with long-range fleets may ditch finned sharks or bring them in, but the fins are utilised regardless. Cartilaginous fishes form less than 1% of world fisheries landings according to FAO statistics. Non-selective, expanding fisheries are essentially driven by increasing markets for fisheries products and sustained by more fecund and fishable species than chondrichthyans, including teleosts, cephalopods and crustaceans. Declining chondrichthyan catches in such non-targeted fisheries have little influence on the continuance of the fisheries. In such fisheries chondrichthyans and other K-selected vertebrates may be caught in the screws of an r-selected meatgrinder, so to speak, and with inadequate monitoring can disappear locally while the fisheries continue at high levels.

Market sampling can be an extremely valuable tool for estimating the biodiversity of sharks and other chondrichthyans in the Region, including determining the relative abundance of various fisheries species over time as the burgeoning fisheries take their toll. It should be noted, however, that market sampling cannot substitute for wide-ranging faunal surveys of the Region, as the markets often reflect the activities of local fishers who can be relatively conservative and selective in optimising the best catches on well-known inshore grounds. Markets in the Region are, for the most part, not being monitored in detail for species-specific data on chondrichthyan catches, including intraspecific composition by sex, size and age class, and this is reflected by the datasets on cartilaginous fishes provided to the United Nations Food and Agriculture Organization (FAO), with most countries in the Region combining chondrichthyan catches for various species or providing separate statistics for sharks and rays. There are no statistics available for chondrichthyan catches off Vietnam, Brunei, and Cambodia.

The Sabah project is one of the first attempts in the Region to provide intensive species-specific monitoring of tropical markets that land primarily inshore elasmobranchs (as well as actively searching for freshwater elasmobranchs), but it faces problems of continuity, funding, and trained personnel to do the intensive and often laborious and unpleasant field work. What is necessary is long-term and broad-based species-specific monitoring of chondrichthyan catches, which is properly a function of fisheries agencies in cooperation with systematists and universities, but which is not occurring in most of the world. Systematics is the essential basis of biological research, including fisheries biology, yet systematists in general, and chondrichthyan systematists in particular, are relatively few and declining in numbers, while the need for systematic research including alpha taxonomy has increased markedly over the past few decades with the expanding human population and commensurate impact on terrestrial and marine environments. Systematics has become unfashionable in many universities; well-established university systematics institutions such as the Division of Systematic Biology at Stanford have disappeared, and recruitment of new systematists and employment of young postdoctoral systematists is not tracking the increased need for such researchers. There is often no incentive for the present generation of established systematic researchers to train replacements in the form of graduate students, and no incentives for graduate students to become systematists if they face an uncertain career.

There is evidence from ichthyological sampling in the 1960s by the George Vanderbilt Foundation and more recent market surveys in Thailand in 1993 and 1995, that certain groups of inshore chondrichthyans, including sawfish (Pristidae), possibly electric rays (Narcinidae and Narkidae), and eagle rays (Myliobatidae), have markedly declined in the Gulf of Thailand, while shark diversity and landings have decreased and whiptailed stingrays (Dasyatidae) and sharkfin guitarfishes (Rhinidae) are increasingly dominating the declining catches. Declining inshore elasmobranch catches off the Philippines and Thailand as recorded by FAO fisheries statistics (FAO 1996) are worrying, as are increasingly massive and probably unsustainable catches of elasmobranchs off Indonesia; these reached 93,000 metric tonnes in 1994 (the highest in the world). The region includes several countries that have major elasmobranch landings (over 10,000t per year), including Malaysia, Indonesia, Taiwan and China, and formerly Thailand and the Philippines.

The shelf shark fauna of the Region is best known from off China and Taiwan, the Gulf of Thailand, Singapore and Philippines. Surveys in the Gulf of Thailand and off Sabah reveal a number of new records of sharks and other elasmobranchs, and suggest that even the inshore elasmobranch fauna of the Region is imperfectly known and needs more survey work to improve our knowledge of it. There is a danger that offshore benthic shelf chondrichthyan faunas may be adversely impacted as fisheries expand into areas that are poorly known by systematists and fisheries biologists.

The oceanic chondrichthyan fauna of the epipelagic zone in the Region is well-known due to extensive collecting as part of fisheries investigations, but is relatively undiverse and unspeciose as elsewhere in the world. The slope fauna is best known off Taiwan (where deepwater sharks are routinely landed in the local fisheries), southern China and the Philippines, but is poorly known elsewhere. With the rush to exploit deepwater teleosts elsewhere in the world (particularly in the North Atlantic but increasingly in the southern hemisphere), it is quite likely that deepwater fisheries will expand in the Region and will have a negative impact on a little-known chondrichthyan fauna including deep-slope sharks, skates and chimaeroids.

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Review of the Biodiversity of Rays in the South China Sea and Adjacent Areas

P. R. Last
CSIRO, Division of Fisheries Research, G.P.O. Box 1538, Hobart, Tasmania 7001, Australia
L.J.V. Compagno
Shark Research Center, Division of Life Sciences, South African Museum, 25 Queen Victoria Street, P.O. Box 61, Cape Town 8000, South Africa

The South China Sea and adjacent areas have a rich ray fauna of at least 103 species, or about a fifth of the world's fauna. The region is physically diverse with extensive and largely unexplored continental slopes. The fauna is in need of further study. Knowledge of the species, some of which may be vulnerable to exploitation, is difficult in the absence of an adequate identification tool. The low diversity of rajoids in the region may be partly due to the limited exploration of the local slopes. The ray fauna is typical of other parts of the Indo-West Pacific where the myliobatoid groups, the stingrays (Dasyatidae), eagle rays (Myliobatidae) and the devilrays (Mobulidae) are particularly diverse. The ray fauna has a wide habitat range including freshwater, oceanic, and continental shelf and slope components, as well as species that bridge two or more of these broad habitat categories. Biogeographically, the fauna is similar to the shark fauna in having few regional endemics (17%), and is primarily composed of wide-ranging species (54%) and Western Pacific species (29%). However, unlike sharks, the proportion of Indo-West Pacific endemics (45%) greatly exceeds the proportion of very widespread species (10%). Most of the ecomorphotypes ascribed to rays occur in the region, indicating a high diversity of habitats and life history styles of the regional fauna. More than half the species are rajabenthic.

Introduction

The ray fauna of the Indo-West Pacific is the most diverse on earth. Our understanding of its composition and distribution is seriously impaired by a lack of focused research. The inshore component of the fauna is reasonably well known, although many of the species need more critical examination and comparison across the region, as the levels of sibling speciation are high. Offshore on the continental slope and deep trenches the fauna is much less well known. With the possible exceptions of the seas off Taiwan and Japan to the north, and Australia to the east, few areas of the Indo-West Pacific have been adequately surveyed. Hence, in the absence of robust data, the present study must be considered to be preliminary.

This paper is a companion paper to that on sharks and chimaeras (Compagno, this volume), and is based on literature, regional checklists and databases referred to therein. Its format closely follows this shark paper and features described relating to the hydrography, bathymetry and biomic structure, as well as primary literature sources cited, apply equally to rays. Both authors have had a long involvement in researching the ray fauna of the Region through field surveys, museum holdings, regional fish markets and reviewing literature on these fishes. Data acquired will contribute to planned volumes of an FAO catalogue on world batoids.

The Region, defined as the tropical South China Sea and adjacent waters, includes those countries fronting the South China Sea (including freshwater habitats): Thailand (Gulf of Thailand), Malaysia (Peninsular Malaysia, Sarawak and Sabah, Borneo) Singapore, Kampuchea (Cambodia), Vietnam, China, Taiwan, Philippines, Indonesia (Kalimantan) and Brunei (*sensu* Compagno, this volume).

Biodiversity of rays in the region

The rich chondrichthyan fauna of the South China Sea and adjacent waters is likely to be a product of high habitat diversity and faunal mixing from two major ocean basins. At least 103 species of rays occur in the Region. These species are classified by taxonomic grouping, habitat type, distribution pattern, and their ecomorphotypes (listed as codes) in Table 1. Each of these categories is discussed separately as follows.

Taxonomic diversity

Table 2 lists the higher groups (suborders) of rays in the Region, with number of species listed and compared with numbers of world species. Table 3 lists the numbers of species in the families of rays in the Region, with comparisons of numbers of world species. Like sharks, the Region has a relatively high representation across higher batoid groups (i.e. pristoids, rhinobatoids, torpedinoids, rajoids, and myliobatoids) with about a fifth to a half of the world's diversity represented. The comparatively low level representation of the rajoids, which is evident from

Table 1. Species of rays in the South China Sea, with habitat, ecomorphotype and distributional codes. Listings of codes below in Tables 4-6.

Scientific name	Common name	Habitat code	Ecomorphotype code	Distributional code
PRISTIDAE				
Anoxypristis cuspidata	Knifetooth sawfish	SHL	BPT	IWPE
Pristis microdon	Greattooth sawfish	SHF	BPT	IWPE
?Pristis pectinata	Smalltooth sawfish	SHL	BPT	WRAN
Pristis zijsron	Green sawfish	SHL	BPT	IWPE
RHINIDAE				
Rhina ancylostoma	Bowmouth guitarfish	SHL	BRH	IWPE
RHYNCHOBATIDAE				
Rhynchobatus australiae	Whitespotted shovelnose ray	SHL	BRH	WCPE
Rhynchobatus laevis	Smoothnose wedgefish	SHL	BRH	IWPE
Rhynchobatus sp.	Broadnose wedgefish	SHL	BRH	WCPE
Rhynchobatus sp.	Roughnose wedgefish	SHL	BRH	WCPE
RHINOBATIDAE				
Rhinobatos formosensis	Taiwan guitarfish	SHL	BRH	CHTE
Rhinobatos granulatus	Sharpnose guitarfish	SHL	BRH	IWPE
?Rhinobatos halavi	Halavi guitarfish	SHL	BRH	IWPE
Rhinobatos hynnicephalus	Ringstraked guitarfish	SHL	BRH	WNPE
Rhinobatos microphthalmus	Smalleyed guitarfish	SHL	BRH	WNPE
Rhinobatos schlegelii	Brown guitarfish	SHL	BRH	WPAE
Rhinobatos thouin	Clubnose guitarfish	SHL	BRH	IWPE
Rhinobatos typus	Giant shovelnose ray	SHL	BRH	WPAE
PLATYRHINIDAE				
Platyrhina limboonkengi	Amoy fanray	SHL	BRH	WNPE
Piatyrhina sinensis	Fanray	SHL	BRH	WPAE
NARCINIDAE				
Benthobatis sp.	Narrow blindray	SLO	BTO	IWPE
Narcine brevilabiata	Shortlip electric ray	SHL	BTO	CHTE
?Narcine brunnea	Brown electric ray	SHL	BTO	IWPE
Narcine lingula	Rough electric ray	SHL	BTO	CHTE
Narcine maculata	Darkspotted electric ray	SHL	BTO	CHTE
Narcine prodorsalis	Tonkin electric ray	SHL	BTO	IWPE
Narcine timlei	Blackspotted electric ray	SHL	BTO	IWPE
?Narcine sp.	Indian electric ray	SHL	BTO	WPAE
NARKIDAE				
Crassinarke dormitor	Sleeper torpedo	SHL	BTO	WNPE
Narke dipterygia	Spottail electric ray	SHL	BTO	IWPE
Narke japonica	Japanese spotted torpedo	SHL	BTO	IWPE
Narke sp.	Dwarf sleeper ray	SHL	BTO	SCSE
Temera hardwickii	Finless electric ray	SHL	BTO	IWPE
TORPEDINIDAE				
Torpedo cf. *nobiliana*	Taiwan black torpedo	SHL	BTO	WRAN
Torpedo tokionis	Trapezoid torpedo	SHL	BTO	WNPE
Torpedo sp.	Philippine torpedo	SHL	BTO	PHIE
ARHYNCHOBATIDAE				
Notoraja subtilispinosa	Velvet skate	SLO	BRA	SCSE
RAJIDAE				
Dipturus gigas	Giant skate	SLO	BRA	WNPE
Dipturus kwangtungensis	Kwangtung skate	SHS	BRA	WNPE
Dipturus macrocaudus	Bigtail skate	SLO	BRA	WNPE
Dipturus tengu	Acutenose skate	SHL	BRA	WNPE
Okamejei acutispina	Sharpspine skate	SHL	BRA	WNPE
Okamejei boesemani	Black sand skate	SHL	BRA	IWPE
Okamejei hollandi	Yellow-spotted skate	SHL	BRA	CHTE
Okamejei kenojei	Spiny rasp skate	SHS	BRA	WNPE
Okamejei meerdervoorti	Bigeye skate	SHL	BRA	WNPE
ANACANTHOBATIDAE				
Anacanthobatis borneensis	Borneo legskate	SLO	BRA	CHTE
Anacanthobatis melanosoma	Blackbodied legskate	SLO	BRA	WPAE
PLESIOBATIDAE				
Plesiobatis daviesi	Giant stingaree	SLO	BRA	IWPE
UROLOPHIDAE				
Urolophus aurantiacus	Sepia stingray	SHL	BRA	WNPE

Table 1 ... continued.

Scientific name	Common name	Habitat code	Ecomorphotype code	Distributional code
HEXATRYGONIDAE				
Hexatrygon bickelli	Sixgill stingray	SLO	BRA	WRAN
POTAMOTRYGONIDAE				
Taeniura lymma	Ribbontailed stingray	SHL	BRA	IWPE
Taeniura meyeni	Fantail stingray	SHL	BRA	IWPE
DASYATIDAE				
Dasyatis akajei	Red stingray	SHL	BRA	WNPE
Dasyatis bennetti	Bennett's cowtail stingray	SHL	BRA	IWPE
Dasyatis kuhlii	Bluespotted maskray	SHL	BRA	IWPE
Dasyatis laevigata	Yantai stingray	SHL	BRA	WNPE
Dasyatis laosensis	Mekong freshwater stingray	FWO	BRA	SCSE
Dasyatis microps	Thickspine giant stingray	SHL	BRA	IWPE
Dasyatis navarrae	Blackish stingray	SHL	BRA	CHTE
Dasyatis zugei	Pale-edged stingray	SHL	BRA	IWPE
Himantura bleekeri	Whiptail stingray	SHL	BRA	IWPE
Himantura chaophraya	Giant freshwater stingray	SHF	BRA	WPAE
Himantura fai	Pink whipray	SHL	BRA	IWPE
Himantura gerrardi	Sharpnose whipray (Species complex, 2 spp.)	SHL	BRA	IWPE
Himantura granulata	Mangrove whipray	SHL	BRA	IWPE
Himantura imbricata	Scaly whipray	SHL	BRA	IWPE
Himantura jenkinsii	Golden whipray	SHL	BRA	IWPE
Himantura krempfi	Marbled freshwater whipray	SHF	BRA	SCSE
Himantura marginata	Blackedge whipray	SHL	BRA	IWPE
Himantura microphthalma	Smalleye whipray	SHL	BRA	WNPE
Himantura oxyrhyncha	Longnose marbled whipray	SHF	BRA	SCSE
Himantura pastinacoides	Round whipray	SHL	BRA	SCSE
Himantura signifer	White-edge freshwater whipray	FWO	BRA	SCSE
Himantura uarnacoides	Whitenose whipray	SHL	BRA	IWPE
Himantura uarnak	Honeycomb whipray (Species complex, 2+ spp?)	SHL	BRA	IWPE
Himantura undulata	Leopard whipray [? = *H. fava*]	SHL	BRA	WPAE
Himantura walga	Dwarf whipray	SHL	BRA	WCPE
Himantura sp. cf. *signifer*	Darktailed freshwater whipray	SHF	BRA	SCSE
Pastinachus sp.		SHL	BRA	SCSE
Pastinachus sephen	Feathertail stingray (Species complex, 2+ spp.)	SHL	BRA	IWPE
Pteroplatytrygon violacea	Pelagic stingray	OCE	ORA	WRAN
Urogymnus asperrimus	Porcupine ray	SHL	BRA	WRAN
GYMNURIDAE				
Aetoplatea zonura	Zonetail butterfly ray	SHL	BRA	IWPE
Gymnura bimaculata	Twinspot butterfly ray	SHL	BRA	WNPE
Gymnura japonica	Japanese butterfly ray	SHL	BRA	WNPE
Gymnura sp. cf. *micrura*		SHL	BRA	IWPE
Gymnura poecilura	Longtail butterfly ray	SHL	BRA	IWPE
MYLIOBATIDAE				
Aetobatus flagellum	Longheaded eagle ray	SHL	PAQ	IWPE
Aetobatus narinari	Spotted eagle ray	SHL	PAQ	WRAN
?Aetobatus guttatus	Indian eagle ray	SHL	PAQ	IWPE
Aetomylaeus maculatus	Mottled eagle ray	SHL	PAQ	IWPE
Aetomylaeus milvus	Ocellate eagle ray	SHL	PAQ	IWPE
Aetomylaeus nichofii	Banded eagle ray	SHL	PAQ	IWPE
Aetomylaeus vespertilio	Ornate eagle ray	SHL	PAQ	IWPE
Myliobatis tobijei	Kite ray	SHL	PAQ	WNPE
RHINOPTERIDAE				
IRhinoptera adspersa	Rough cownose ray	SHL	PAQ	IWPE
Rhinoptera javanica	Flapnose ray	SHL	PAQ	IWPE
MOBULIDAE				
Manta birostris	Manta	SHO	PAQ	WRAN
Mobula eregoodootenkee	Pygmy devilray	SHO	PAQ	IWPE
Mobula japanica	Spinetail devilray	SHO	PAQ	WRAN
IMobula kuhlii	Shorthorn devilray	SHO	PAQ	IWPE
Mobula tarapacana	Sicklefin devilray	SHO	PAQ	WRAN
Mobula thurstoni	Bentfin devilray	SHO	PAQ	WRAN

The nomenclature used in this table has been edited to concur with the latest world checklist on chondrichthyan fish (Compagno and Didier, in press). When this manuscript was submitted in 1998, *Rhynchobatus australiae, R. laevis* and the two R spp. were part of the Rhinidae. They are now in Rhynchobatidae. Similarly *Dipturusgigas, D. kwangtungensis, D. macrocaudus, D. tengu, Okamejeiacutispina, O. boesemani, O. hollandi, O. kenojei*and *O. meerdervooti* were part of Arhynchobatidae. They are now in Rajidae. Finally, *Taeniura lymna* and *T. meyeni* were part of Dasyatidae and are now in Potamotrygonidae. See Appendix 1.

Table 2. Actual and relative numbers of species as percentages of totals in higher groups of rays, for the Region and the world, with comparisons of regional species as percentages of world species.

Higher groups	Region No.	Region % total	World maximum No.	World maximum % total	Regional as% of world
Pristoids	4	3.9	7	1.2	57.1
Rhinobatoids	15	14.6	54	8.9	27.8
Torpedinoids	16	15.5	74	12.3	21.6
Rajoids	12	11.7	281	46.5	4.3
Myliobatoids	56	54.4	188	31.1	29.8
Total rays	103	100.0	604	100.0	17.1

Table 3. Actual and relative numbers of species as percentages of totals in families of rays, for the Region and the world, with comparisons of regional species as percentages of world species.

Families	Region No.	Region % total	World maximum No.	World maximum % total	Regional as% of world
Pristidae	4	3.9	7	1.2	57.1
Rhinidae	5	4.9	7	1.2	71.4
Rhinobatidae	8	7.8	43	7.1	18.6
Platyrhinidae	2	1.9	4	0.7	50.0
Narcinidae	8	7.8	29	4.8	27.6
Narkidae	5	4.9	15	2.5	33.3
Torpedinidae	3	2.9	29	4.8	10.3
Hypnidae	0	0.0	1	0.2	0.0
Arnynchobatidae	1	1.0	95	15.7	1.1
Rajidae	11	10.7	186	30.8	5.9
Plesiobatidae	1	1.0	1	0.2	100.0
Urolophidae	1	1.0	42	7.0	2.4
Hexatrygonidae	1	1.0	1	0.2	100.0
Potamotrygonidae	0	0.0	22	3.6	0.0
Dasyatidae	32	31.1	67	11.1	47.8
Gymnuridae	5	4.9	12	2.0	41.7
Myliobatidae	8	7.8	22	3.6	36.4
Rhinopteridae	2	1.9	11	1.8	18.2
Mobuiidae	6	5.8	10	1.7	60.0
Total rays	103	100.0	604	100.0	17.1

Please note the calculations in this table were based on the previous nomenclature and classification, at the time the manuscript was submitted.

the relatively low diversity in both families compared to the rest of the world, is likely to reflect the relative poor sampling coverage of much of the continental slope. Consideration of the species composition within families of rhinobatoids, torpedinoids and myliobatoids, reveal interesting differences from the world fauna. Rhinobatoid rays have a higher representation of sharkfin guitarfishes (Family Rhinidae). Similarly torpedinoid rays are rich in both numbfishes (Family Narcinidae) and sleeper rays (Family Narkidae) but relatively poor in torpedo rays (Family Torpedinidae). The myliobatoid rays are highly diverse here and throughout the Indo-West Pacific region. Major groups, which include stingrays (Family Dasyatidae), eagle rays (Family Myliobatidae) and devil rays (Family Mobuiidae) are all very well represented with about a third to two-thirds of the world's fauna found in the Region. In comparison, stingarees (Family Urolophidae) are relatively poorly represented with less than 5% of the total ray diversity.

Habitat diversity

Rays occupy a wide variety of habitats that are indicative of their diversity within the Region (Table 4). Most species are strongly adapted to a benthic life style, so their preference for bottom habitats is unsurprising. Consequently, the range of habitats occupied is simpler than for sharks. The *marine continental and insular shelves* biome (with inshore and offshore waters from the intertidal to 200m) is by far the most species rich (more than three-quarters of the species). The proportion of demersal species known from the *continental and insular slopes,* below 200m and extending to 2,000m depth and beyond (i.e. about 8%), is significantly lower than for sharks (i.e. about 24%). Only 11 skates are known from this region compared to 17 off eastern Indonesia, 21 off both tropical eastern and western Australia and 16 off New Caledonia (Last and Seret, 1999). Once again, this possibly reflects the poor level of collecting in deepwater carried out in the region rather than being representative of biodiversity levels. Only one species, *Pteroplatytrygon violacea*, occurs exclusively in the *oceanic* biome, beyond the continental shelves and above the slopes and ocean floor. This species, although yet to be collected in the Region, has been collected nearby and is considered to be circumtropical in tropical seas (Masuda *et al.* 1984). Two species of *Himantura* rays (i.e. *H. signifer* and *H. laosensis)* are considered to be primary inhabitants of freshwater but may venture into estuaries. A few species overlap two or more of these biomes (i.e. about 9%) but at a lower level than for sharks (i.e. about 30%). For example, two skates occur demersally on both the *shelf and slope.* Similarly, the six devil rays are *oceanic* species that regularly penetrate shelf waters or vice versa. Rays were not taken from habitats defined as *shelf to semioceanic* or *slope to oceanic* or a wide range of habitats covering several of the above (i.e. those species that frequent a combination of shelf, slope and oceanic habitats).

Table 4. Habitats occupied by rays in the Region, with numbers of species in each habitat and % of total number of species.

Habitat	Code	No.	% total
Obligate fresh-water	FWO	2	1.9
Oceanic	OCE	1	1.0
Euryhaline fresh-water/shelves	SHF	5	4.9
Continental/insular shelves	SHL	79	76.7
Shelf to oceanic	SHO	6	5.8
Shelf to slope	SHS	2	1.9
Continental/insular slopes	SLO	8	7.8

Zoogeographic diversity

The Region's ray fauna can be categorised by their geographic distribution patterns (Table 5) into three major categories:

- *Regional endemics,* comprising about 17% of the total;
- *Western Pacific* species, about 29% of the total; and
- *Broadly distributed* species, with about 54% of the total.

The level of endemism within the Region is similar to other parts of the Indo-West Pacific. Last and Seret (1999) found that levels of local endemism across eastern Indonesia and tropical Australia varied between 12 and 18%, but were higher off New Caledonia (i.e. about 30%). Endemism in the broader Australian fauna is even higher (Last and Stevens, 1994), being 67% of the 117 species of rays. However, these elevated levels of endemism are biased, due to the influence of uniquely endemic temperate Australian fauna. About half (54%) of these endemics are temperate species. Many *regional endemics* as currently known are slope-dwellers (especially from off the Chinese coast and around the Philippines) with relatively fewer shelf endemics. Regional endemics are defined as *China/ Taiwan endemics,* from the south-eastern coast of China and southern Taiwan, *Philippine endemics* from around the Philippines, and *South China Sea endemics.* Of these the endemic Philippine component is minimal. An important component of the Region's ray fauna occurs in species found in adjacent waters of the Western Pacific Ocean. This includes species extending into the tropical *West-Central Pacific* (including Indonesia, Papua New Guinea and tropical Australia), a considerable number of species that extend into the *Western North Pacific* (including many temperate-water species that just reach the Region and which extend northwards to Japan and the Koreas), and those *Western Pacific* species that range north and south of the Region in the Western North and Western South Pacific. This component is dominated by a large suite of Western North Pacific species (18.4%). Species with *broad distributions* are dominant in the Region (44.7%) and include a small suite of *Indo-Pacific species*

Table 5. Distribution patterns with coding of rays in the Region, with numbers of species in each category and % of total number of species.

Distribution patterns	Code	No.	% total
China/Taiwan Endemic	CHTE	7	6.8
Indo-West Pacific Endemic	IWPE	46	44.7
South China Sea Endemic	SCSE	1	1.0
Philippine Endemic	PHIE	9	8.7
West Central Pacific Endemic	WCPE	4	3.9
Western North Pacific Endemic	WNPE	19	18.4
Western Pacific Endemic	WPAE	7	6.8
Wide-ranging	WRAN	10	9.7

Table 6. Ecomorphotype coding of rays in the Region, with numbers of species in each category and % of total number of species.

Ecomorphotypes	Code	No.	% total
Pristobenthic	BPT	4	3.9
Rajabenthic	BRA	51	49.5
Rhinobenthic	BRH	15	14.6
Torpedobenthic	BTO	16	15.5
Rajaoceanic	ORA	1	1.0
Aquilopelagic	PAQ	16	15.5

with broad ranges from the Western Indian Ocean to the Eastern Pacific. Most of the broadly ranging species have *Indo- West Pacific* distributions, from the Western Indian Ocean to the Western Pacific. Only a small suite of species (9.7%) occurs circumglobally or partly outside the Indo-Pacific region.

Ecomorphotype diversity

Compagno (1990) proposed a classification of ecomorphotypes of cartilaginous fishes. This scheme includes 20 groups of which six apply to rays. All of these are represented in the Region. The ecomorphotypic structure of the Region's batoids (Table 6) is less varied than for sharks. Rays are classified as either aquilopelagic (forms with wing-like discs), rhinobenthic (shark-like rays), torpedobenthic (resembling rhinobenthic but with expanded discs containing electric organs), rajabenthic (rays with greatly flattened discs), rajaoceanic (rays with flattened discs adapted to a pelagic existence), or pristobenthic (sawfish-like forms). About half of the rays of the Region are rajabenthic forms. About equal ratios of rhinobenthic, torpedobenthic and aquilobenthic rays occur. Only one rajaoceanic species, the pelagic stingray *Pteroplatytrygon violacea* occurs in the region.

Discussion

The elasmobranch fauna of this Region is rich in species and has supported a variety of artisanal and commercial fisheries (Compagno, this volume). Whereas concerns over the conservation of sharks have been raised widely within the past few decades, only recently has the plight of their cousins, the rays, been identified. Their large average size has posed problems for collection managers and taxonomists alike, and our knowledge of the alpha-taxonomy of most groups is far from complete. Unlike sharks, for which a comprehensive guide to the world's fauna was prepared 15 years ago (Compagno, 1984) and is now being revised, no equivalent treatise on rays presently exists. The inability to identify many of the species of ray remains an impediment to the study and assessment of their populations for both conservation and fisheries purposes. Some Indo-Pacific species have very narrow distributional ranges. Some of these may be threatened even before their ranges have been identified. Others, once thought to be widespread, have recently been found to consist of regional species complexes. A world guide to the identification of rays is needed as a basic biodiversity management tool, and is currently in the early stages of compilation, though funding is still required.

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New Records of Elasmobranch Species from Sabah

Bernadette Mabel Manjaji
Borneo Marine Research Institute, Universiti Malaysia Sabah, Locked Bag 2073, 88999 Kota Kinabalu, Sabah, Malaysia

This paper presents an annotated checklist of new records of elasmobranch species from Sabah (including both marine and freshwater species); the result of the 18-month elasmobranch biodiversity project funded by the UK Darwin Initiative for the Survival of Species. The high number recorded (34 species of shark, 35 species of ray), with 25 new records for the region (14 shark and 11 ray species), and a record of at least one undescribed species of shark, reflects the rich fish biodiversity in this part of the world. Furthermore, this number does not include several records that have only been determined to level of genus. New records were made throughout the study period, with several species seen only during the last few months of the project. In addition, surveys carried out during the study have provided additional information and added to the knowledge of scientists studying some of the elasmobranchs. These results have indicated that there is considerable scope for more detailed work in the area. Other papers in this volume present information on species recorded from rivers and estuaries and on elasmobranch fisheries in Sabah.

Introduction

The information presented in this paper represents part of the results of the 18-month project (January 1996-June 1997) on shark and ray biodiversity entitled *"Elasmobranch Conservation and Management in Sabah"*, which covered both marine (including coastal estuarine) and freshwater habitats (Fowler, this volume). Prior to this study there had not been a detailed investigation of elasmobranchs and their fishery in the state, and only anecdotal information was available (Mohsin and Ambak 1996; Biusing *et al*. 1995; Biusing 1992,1991; Chua and Mathias 1978), although additional records of the fauna were made by European scientists early this century (Cook and Compagno 1996). The earliest published record on the occurrence of marine elasmobranchs in Sabah (then *North Borneo)* is possibly an article dated 1948, which mentions sightings of whale sharks and devil rays (Tubb 1948). Freshwater elasmobranchs in Sabah are even less well known and have not previously been studied in any detail. Much of the information was obtained through interviews with local people living along the river system, particularly the Kinabatangan and Labuk rivers, both located on the east coast, and from visiting coastal fish markets.

Objectives

This study was initiated because of concerns over the threats faced by elasmobranchs worldwide, particularly freshwater species which are particularly vulnerable to overexploitation compared to their marine counterparts, and which are still inadequately known. A proposal was therefore submitted to help address this problem (Fowler, 1995). The objectives of this study were broadly as follows:

1. Biodiversity assessment
2. Fisheries impact study
3. Conservation issues
4. Education and training for local people.

Methods

Biodiversity study

To prepare a checklist of elasmobranch species, frequent visual market surveys in all the major fish markets of Sabah were conducted. In addition, fish markets in other states of Borneo Island (northern Sarawak, East Kalimantan and Brunei Darussalam) were all visited once, and elasmobranch species recorded. Specimens (complete or partial) were saved whenever possible, while larger ones were photographed, and their basic taxonomic and biological characteristics noted. The specimens now make up a reference collection in the Sabah State Museum. Elasmobranchs were also recorded from trips with the Sabah Department of Fisheries during their marine inshore surveys (two trips), on fishing boats with local fishermen (a commercial trawler in Sandakan and a 'jongkong' off Mabul Island, which lies offshore from Semporna, south-east Sabah), and from photographs sent to us by various sources.

During the second half of the project, species abundance was also recorded using a log, rapid estimate of abundance (see Table 1), and tissue samples taken for genetic analysis. The project has benefited greatly from the assistance of several experts in this field, particularly with taxonomy.

Table 1. Logarithmic abundance categories used to estimate abundance of numerically dominant species.

Log_3 Abundance Category	Number of fishes
1	1
2	2-3
3	4-9
4	10-27
5	28-81

Specimens of freshwater elasmobranchs were more difficult to obtain. During the initial survey period (two weeks in January 1996), which included visits to the major coastal fish markets in Sabah, with A. Wong (Sabah Fisheries Department officer), S. Fowler (project manager), F. Dipper (UK marine biologist), L. Compagno and S. Cook (elasmobranch research expert advisors), and the author (appointed as the local project officer), only dried bull shark fins, river rays tails and rostrums or saws of sawfishes) were seen, and anecdotal information was provided by villagers. Later on, river sampling using longlines and gill nets was carried out by the research team, in addition to seeking assistance from villagers. Cylindrical HDPE (high density polyethylene) lockable tanks filled with formalin (diluted to ~10% using river water) were left in three villages (kampongs) along the Kinabatangan, i.e. Kampong Abai on the lower Kinabatangan approximately 10km from sea, Kampong Bukit Garam located around the mid-portion of the Kinabatangan approximately 137km from sea and Kampong Desa Permai, Kuamut on the upper Kinabatangan approximately 217km from the sea (see Map 1 in the other paper by Manjaji, this volume, b). Villagers were asked to keep any sharks and rays they caught from the river, and store them in these tanks. The kampongs were visited at regular intervals, and the current market price was paid for each specimen saved. During the last few months of the project (March-June 1997), members of the Darwin team were able to accompany villagers on their fishing trips on the river.

Fisheries impact study

For this objective, the team surveyed two coastal fishing villages on the east coast of Sabah. The study involved assessing fisheries and trade activity, including quantification of the socio-economic and cultural importance of elasmobranchs for traditional subsistence fishing communities, and their value to the eco-tourism industry. Two survey questionnaires were used to compile socio-economic information during interviews and to record market prices offish. A full report of these findings is presented in a separate paper (Almada-Villela, this volume). Another trip was also made to an offshore island (one of the villages visited in August the previous year), Pulau Mabul, where the elasmobranch fishery was observed (Cavanagh and Mycock, 1997).

Addressing conservation issues

Through the field surveys, it was hoped to identify as far as possible, freshwater, estuarine and near-shore marine areas critical for species conservation and sustainable use by subsistence fishing communities; and to recommend management strategies for these critical areas through fisheries and protected areas legislation or changes in river catchment/land use policies. It is also hoped that the results from this study will serve as a catalyst to future studies in the region.

Promote education and awareness for local people

An important aspect of interviews conducted with local people was the two-way exchange of information. The intention was that when members of the research team communicated informally with villagers, they could at the same time instil a better awareness of various environmental aspects and the importance of the current study. Team members Scott Mycock and Rachel Cavanagh also prepared and produced posters and leaflets, which were distributed (with the assistance from the Department of Fisheries and WWF personnel) to communities living along the Kinabatangan River. The posters and leaflets contained illustrations of 'rare' animals (aquatic and terrestrial) found in the Kinabatangan area, with a particular message for the awareness of elasmobranch conservation. The positive feedback received from the locals is encouraging.

Results and discussion

Biodiversity of sharks and rays

The system of classification for sharks and rays follows that of Nelson (1994) and Compagno (1984). New records were ascertained by comparison with Compagno's Preliminary Checklist of Borneo Chondrichthyes (in Cook and Compagno, 1996). Most of the specimens seen were easily determined up to species level using the available keys, but problems were sometimes encountered with the identification of species in fish markets. Large specimens were usually quickly cut up and sharks were usually finned before being put on sale. It was particularly difficult to identify large carcharinids to species level when only a head or a photograph of a finned shark carcass was available for reference. Large numbers of newborn specimens were often seen; some of these, and the discarded

Table 2. Checklist of Elasmobranch recorded from Sabah and elsewhere in Borneo.

1. Recorded from Sabah during project survey period (January 1996-June 1997)
2. First record from Sabah
3. Recorded elsewhere in Borneo, not yet recorded from Sabah (Cook and Compagno, 1996)

3a. Miri, northern Sarawak (July 1996) (p: photo only)
3b. Samarinda, east Kalimantan (November 1996) (s: specimen saved; p: photo only)
3c. Bandar Seri Begawan, Brunei (January 1997) (s: specimen saved)

4. Occurs off Borneo, status off Sabah uncertain (Cook and Compagno, 1996)
5. DOF-Sabah unpublished record (Biusing, 1992; Biusing, 1991)

Note: Eight carcharhinids were collected with only the heads or photos available as records, these were not identified to species level. Several species names (e.g. *Himantura pastinacoides, H. uarnacoides)* used in this list are resurrected names based on concurrent studies by Last, Compagno and Manjaji. In addition, several others *(H. gerrardi, H. uarnak, Pastinacoides sephen)* appear to form species complexes which will need to be resolved in the future.

Scientific name	Common name	Notes
CENTROPHORIDAE		
Centrophorus moluccensis	Smallfin gulper shark	1,2
HETERODONTIDAE		
Heterodontus zebra	Zebra bullhead shark	1,2,5
ORECTOLOBIDAE		
Orectolobus sp.	Borneo wobbegong	1,2
HEMISCYLLIIDAE		
Chiloscyllium hasselti	Indonesian bambooshark	3
Chiloscyllium plagiosum	Whitespotted bambooshark	1,2
Chiloscyllium punctatum	Brownbanded bambooshark	1
STEGOSTOMATIDAE		
Stegostoma fasciatum	Zebra shark	1
RHINCODONTIDAE		
Rhincodon typus	Whale shark	1,5
SCYLIORHINIDAE		
Apristurus sibogae	Pale catshark	3
Apristurus verweyi	Borneo catshark	3,4
Atelomycterus marmoratus	Coral catshark	1,2
TRIAKIDAE		
Mustelus sp.1	Sabah white-spotted smoothhound	1,2
Mustelus sp.2	Grey smoothhound	1,2
HEMIGALEIDAE		
Chaenogaleus macrostoma	Hooktooth shark	1
Hemigaleus microstoma	Sicklefin weasel shark	1
Hemipristis elongata	Snaggletooth shark	1
CARCHARHINIDAE		
Carcharhinus amblyrhynchoides	Graceful shark	1
Carcharhinus amblyrhynchos	Gray reef shark	1,2
Carcharhinus borneensis	Borneo shark	3,4
Carcharhinus brevipinna	Spinner shark	1
Carcharhinus dussumieri	Whitecheek shark	1
Carcharhinus falciformis	Silky shark	1,2
Carcharhinus leucas	Bull shark	1
Carcharhinus limbatus	Blacktip shark	1
Carcharhinus melanopterus	Blacktip reef shark	1
Carcharhinus plumbeus	Sandbar shark	1
Carcharhinus sealei	Blackspot shark	1
Carcharhinus sorrah	Spot-tail shark	1
Carcharhinus sp.	False smalltail shark	3
Galeocerdo cuvier	Tiger shark	1
Glyphis sp. B	Borneo river shark	1,2 - pending confirmation (see Compagno, this volume, b)
Lamiopsis temmincki	Broadfin shark	3,4
Loxodon macrorhinus	Sliteye shark	1,2
Rhizoprionodon acutus	Milk shark	1
Rhizoprionodon oligolinx	Gray sharpnose shark	1,2
Scoliodon laticaudus	Spadenose shark	1,3a
Triaenodon obesus	Whitetip reef shark	1

Table 2 ... continued. Checklist of Elasmobranch recorded from Sabah and elsewhere in Borneo.

Scientific name	Common name	Notes
SPHYRNIDAE		
Eusphyrablochii	Winghead shark	1,2
Sphyrnalewini	Scalloped hammerhead	1
Sphyrnamokarran	Great hammerhead	1,2
PRISTIDAE		
Anoxypristiscuspidatus	Narrow sawfish	1,2 - photo of fresh dorsal and caudal fins from Sandakan fish market
Pristis microdon	Greattooth or freshwater sawfish	1, found in freshwater
Pristiszijsron	Green sawfish	1, found in freshwater
RHINIDAE		
Rhinaancyclostoma	Sharkray	1,2
RHYNCHOBATIDAE		
Rhynchobatus sp. 2	Broadnose wedgefish	1
Rhynchobatusaustraliae	Whitespotted shovelnose ray (WPHC)	1
RHINOBATIDAE		
Rhinobatosgranulatus	Sharpnose guitarfish	3,4
Rhinobatosthouin	Clubnose guitarfish	3b: s
Rhinobatostypus	Giant shovelnose ray	1, found in freshwater in Sabah
NARKIDAE		
Narkedipterygia	Spottail electric ray	3,4
ANACANTHOBATIDAE		
Anacanthobatisborneensis	Borneo legskate	3
POTAMOTRYGONIDAE		
Taeniuralymma	Bluespotted fantail ray	1
Taeniurameyeni	Fantail stingray	1,2
DASYATIDAE		
Dasyatiskuhlii	Bluespotted maskray	1
Dasyatismicrops	Thickspine giant stingray	1,2
Dasyatiszugei	Pale-edged stingray	1
Himanturachaophraya	Giant freshwater stingray	1,2
Himanturafai	Pink whipray	1,2
Himanturafava	Ocellate whipray	1,2
Himanturagerrardi	Sharpnose stingray/Whitespot whipray	1
Himanturajenkinsii	Jenkins whipray/Golden whipray	1
Himanturapastinacoides	Round whipray	1
Himanturasignifer	White-edge freshwater whipray	3
Himanturauarnacoides	Whitenose whipray	1
Himanturauarnak	Reticulate whipray	1
Himanturaundulata	Leopard whipray	1,2
Himanturawalga	Dwarf whipray	1
Pastinachussephen	Cowtail stingray	1
Pastinachus sp.	Roughnose stingray	1,3c
Urogymnusasperrimus	Porcupine ray	1,3b
GYMNURIDAE		
Aetoplateazonura	Zonetail butterfly ray	1
Gymnurapoecilura	Longtail butterfly ray	1
MYLIOBATIDAE		
Aetobatusnarinari	Spotted eagle ray	1
Aetomylaeusmaculatus	Mottled eagle ray	1
Aetomylaeusnichofii	Banded eagle ray	1
Aetomylaeusvespertilio	Ornate eagle ray	1,2
RHINOPTERIDAE		
Rhinopterajavanica	Javanese cownose ray	1
MOBULIDAE		
Mantabirostris	Manta	3,4
Mobulaeregoodootenkee	Pygmy devilray	1
Mobulajapanica	Spinetail devilray	1,2
Mobulathurstoni	Bentfin devilray	1,2
CHIMAERIDAE		
Chimaera sp.	Borneo chimaera	3,4

foetuses whose fins and teeth were not fully developed, were also difficult to identify. However, these were identified with considerable confidence, at least to genus level.

The complete checklist of elasmobranchs is provided in Table 2. From the total number of species recorded (34 shark species and 35 ray species), 25 are new records for Sabah (14 species of shark and 11 species of rays), and at least one is a previously undescribed species of shark (caught from the Kinabatangan River). The number of species does not include several records that have only been determined to genus level (eight *Carcharhinus* sp., and three batoids with more than one morphological form).

Species composition

The sharks comprised 11 families from four orders, including one family (Heterodontidae) recorded previously but not during this project. They included both inshore and oceanic species, as well as one deepwater species. The family Carcharhinidae (requiem sharks) was the most diverse with 22 species, followed by Hemigaleidae (weasel sharks), Scyliorhinidae (cat sharks), Sphyrnidae (hammerheads) and Hemiscyllidae all with three species each, and Triakidae (hound sharks) with only two species of *Mustelus* spp.

The *Mustelus* spp. could not be determined up to species level, mainly because the whole genus itself is currently being revised (Compagno, pers. comm.). Information provided by P. Heemstra (pers. comm.) has helped the author to narrow the problem by providing suggestions of the species most likely to occur in the Sabah region (Table 4). Comparison of morphometric characteristics between several *Mustelus* specimens recorded from here and of several species known to occur in the region, is shown in Tables 3 and 4.

The only deepwater species recorded was a dogfish (*Centrophorus moluccensis*), from Tawau fish market, south-east Sabah. It might have been caught by offshore purse-seiners, while making diel vertical migrations, as there are no known (registered) deepwater fishing vessels operating in the area, although the ocean depth off this area reaches 2,000m.

As for rays, they consist of 10 families from six orders, including two families from two orders recorded previously but not during this project, i.e. Rajiformes and Torpediniformes. The rays exhibit a much wider range of habitat than the sharks, with representatives recorded from marine habitats 2,000m deep, up to freshwater habitats of more than 200km upriver (e.g. Last and Stevens, 1994). The occurrence of elasmobranchs in the rivers and estuaries of Sabah is further elaborated in a separate paper in this volume by the same author. Dasyatidae (whiptail stingrays) of the order Myliobatiformes are the most diverse family with 24 species, followed by Myliobatidae (eagle rays) five species and Mobulidae (devilrays) four species. Members of the genera *Himantunt* and *Pastinachus* from the family Dasyatidae and *Rhynchobatus* cf. *australiae* from the family Rhinidae (order Rhiniformes) show the most varied morphological forms. Chimaeras are known from the South China Sea but were not observed in any of the market surveys. This is to be expected since there are no known deepwater fishing vessels operating in Sabah.

Distribution and abundance

The distribution of elasmobranchs indicates the location on the coasts of Sabah where each have been observed (see Map 1, Manjaji, this volume, b). Their abundance was

Table 3. Comparisons of morphometric of *Mustelus* spp. from Sabah.

	***Mustelus* sp.1** KPU-BKK 1 9196	***Mustelus* sp.2** BKK 30 15496	***Mustelus* sp.2** BKK 32 15497	***Mustelus* sp.2** BKK 7 6397	***Mustelus* sp.2** BKK 30 2497	***Mustelus* sp.2** BKK 40 2497
Total length	940mm	490mm	468mm	490mm	440mm	387mm
Eye length	24mm	10mm	9mm	9mm	14mm	13mm
Preorbital/snout length	55mm	33mm	32mm	32mm	30mm	25mm
Interdorsal space	270mm	110mm	95mm	98mm	~80mm	68mm
Interorbital space	55mm	31mm	31mm	33mm	28mm	25mm
Internarial space	23mm	14mm	14mm	14mm	13mm	12mm
Pectoral posterior margin	95mm	38mm	38mm	39mm	34mm	26mm
Mouth width	49mm	25mm	25mm	25mm	21mm	19mm
Mouth length	24mm	14mm	13mm	13mm	13mm	10mm
Vertebral numbers	Not radio-graphed	137	137	139	138	134
Coloration	Fins plain, black tipped	Upper caudal lobe tip black	D2, C tip black/dusky	D2, C tip black/dusky	D2, C tip black/dusky	D2, C tip black/dusky

Table 4. Comparisons of morphometric of *Mustelus manazo, M. antarcticus,* and *M.*sp.A			
	Mustelusmanazo **(Compagno, 1984)**	***Mustelusantarcticus*** **(Compagno, 1984)**	***Mustelus* sp. A (Last and Stevens, 1994)**
Eye length	Large, 1.7-2.5 times preorbital length and 2.4-4.1% of total length	Fairly large, 1.6-3.2 times preorbital length and 2.4-4.2% of total length	Eyes oval, dorsolateral on head
Preorbital/snout length	6-7.8% of total length; preoral snout 5.7-7.5% of total length; snout moderately long and bluntly angularin lateral view	5.8-7.8% of total length; preoral snout 5.7-7.4% of total length; snout moderately long and bluntly angular in lateral view	Relatively long (preoral length 6-6.3% of total length), tip relatively narrow and pointed
Interdorsal space	19-23% of total length	19-23% of total length	Interdorsal ridge present
Interorbital space	Narrow, 3.7-4.5% of total length	Fairly broad, 3.7-5.1% of total length	Relatively narrow, 5.6-6.0% of total length
Intemarial space	Fairly narrow, 2-2.9% of total length	Broad, 2.6-3.2% of total length	2.4-2.7% of total length
Pectoral margin	Anterior margins 11-15% of total length, width of posterior margin 7.5-14% of total length	Anterior margins 12-16% of total length, width of posterior margins 8-13% of total length	N.a.
Mouth width/length	Mouth fairly short, approx. equal to eye length and 2.5-3.7% of total length	Mouth short: length subequal to eye length and 3-3.6% of total length	Mouth relatively narrow length 1.1-1.3 of width
Labial furrows	Uppers considerably longer than lowers and 1.9-2.5% of total length	Uppers considerably longer than lowers and 2-2.8% of total length	Uppers 0.8-1.1% of total length, shorter than lowers
Vertebral numbers	Precaudal centra 71-91; monospondylous centra 33-41; diplospondylous centra 35-54	Precaudal centra 76-86; monospondylous centra 35-38; diplospondylous centra 39-50	Total: 138-146; precaudal centra 90-92; monospondylous centra 34-37
Denticle morphology	Molariform and asymmetric with cusp reduced to a low point	Molariform and asymmetric with cusp reduced to a low point	Cusp rather high, teeth in both jaws flattened, arranged in a pavement-like pattern
Buccal denticle pattern	Buccopharyngeal denticles covering almost entire palate and floor of mouth	Buccopharyngeal denticles confined to tongue and anteriormost part of palate	Buccopharyngeal denticles confined to anterior end of mouth
Fin shape	Pectoral and pelvic fins relatively small; trailing edges of dorsal fins denticulate, without bare ceratotrichia; first dorsal broadly triangular, with posteroventrally sloping posterior margin; ventral caudal lobe not falcate in adults	Pectoral and pelvic fins relatively small; trailing edges of dorsal fins denticulate, without bare ceratotrichia; ventral caudal lobe more or less falcate in adults	Second dorsal fin considerably larger than anal fin; pectoral fins moderately broad, weakly falcate; apices pointed. Caudal fin with deep subterminal notch
Coloration	Uniform grey or grey-brown above, light below, usually with numerous white spots but no dark spots or dark bars	Grey or grey-brown above, light below, usually with numerous small white spots but without dark spots or dark bars	Uniformly bronze or greyish-brown dorsally, pale ventrally (lacking white spots on the body). Second dorsal and upper caudal-fin tips usually with dark margins; pectoral and caudal fins with pale posterior margins.

N.a: not available

estimated using a log, rapid estimate of abundance (Table 1). This numerical procedure, was only initiated in February 1997 and continued up to the end of the project period (June 1997). The results presented in the following are the average of the five months when such data are available. It was intended that each market would be visited at least once a week, to obtain comparable data between markets. However, this proved to be logistically unrealistic for some markets.

Analysis of the data suggests that the species are evenly distributed around Sabah. However, this may be an over-simplification and a more detailed analysis taking into account all available data may later show up subtle variations. Indeed, some preliminary analysis by Mycock and Cavanagh (pers. comm.) has shown indications that the east coast species may be more diverse. The three shark species showing the highest abundance (average per month, class 3 of the log_3 estimate) were whitecheek shark *Carcharhinus dussumieri*, milk shark *Rhizoprionodon acutus*, and scalloped hammerhead *Sphyrna lewini.* The rest showed an average of class 2 per month of the log_3 estimate. These were *C. amblyrhyncoides, C. amblyrhynchos, C. brevipinna, C. limbatus, C. sorrah,* all of the family Carcharhinidae; *Chaenogaleus macrostoma* and *Hemigaleus microstoma* of the family Hemigaleidae, and *Mustelus* sp. of the family Triakidae. *Mustelus* showed a possible seasonality pattern and were only observed in markets during the beginning of the year (February-May in 1996 and 1997). Further research to collect more data is needed to support these observations.

For rays, higher abundances were recorded, (average per month was class 4 of the log_3 estimate), particularly for the bluespotted maskray *Dasyatis kuhlii* and whitespot whipray *Himantura gerrardi.* The latter abounds throughout the year, and mature adults were observed for the duration of the project. Other rays were observed at abundance estimate class 2 *(Himantura uarnacoides*, *Taeniura lymma* of the family Dasyatidae; *Aetobatus narinari* family Myliobatidae; *Rhinoptera javanica* family Rhinopteridae; and *Rhynchobatus* cf. *australiae* family Rhinidae).

Interestingly, new records were made throughout the study period, with several more species seen only in the last few months of the project work. For example, the river shark *Glyphis* recorded from the Kinabatangan River, and the oceanic silky shark *Carcharhinus falciformis*, recorded only from the island of Mabul, off the south-eastern tip of mainland Sabah.

Conclusion

The elasmobranch biodiversity in Sabah is far richer than previously thought (Compagno, Last, pers. comm.) and the species occurring in this area are now well documented. Findings from the project surveys have also added to the current knowledge level of the species concerned. The results will contribute to improvements in the systematics of some species, particularly the rays, *H. uarnak* and *Pastinachus* species complexes, which are currently still poorly known. Information gathered on the basic reproductive patterns and abundance of several species may be useful in preparing guidelines on the issuance of number of fishing gear per season/year, as an immediate action in shark and ray management strategy in Sabah. Further analysis of seasonality patterns may also prove useful. This project has collected a great deal of the baseline data that is essential for conservation and management strategies. Future work on the shark and ray resource should be directed towards more specific objectives, now that the elasmobranch biodiversity status has begun to be addressed.

Acknowledgements

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Importance of Biological Collections for Future Taxonomic Research in the Indo-West Pacific

P.R. Last
CSIRO, Division of Fisheries Research, G.P.O. Box 1538, Hobart, Tasmania 7001, Australia

The Indo-West Pacific has the richest fish fauna of any of the world's major faunal regions. It is extremely complex biogeographically, with several genera being represented by pairs of sister species, often sympatric, from the Pacific and Indian Oceans. Much of the region is faunally unexplored, and the extent of new deepwater taxa is likely to be large. Well organised and maintained regional specimen collections and strategic collecting of reference specimens are essential if we are to adequately define the composition and structure of this fauna. The various benefits of such collections, and recommended procedures for their establishment, are discussed in the light of Australian experiences.

Need for strategic regional collection strategy

The known elasmobranch fauna of the Indo-West Pacific, with more than 330 species, is the richest of any region. This megadiversity extends to both chondrichthyans and teleosts, and faunal lists are likely to expand as material is obtained from presently unexplored parts of the region.

The marine environment, which is extremely complex from both geomorphological and palaeohistorical standpoints, is defined by deep seas and isolated trenches wedged between islands and continental shelves. The inshore fauna is not well known across the region and most of the offshore continental slopes remain unexplored. Basic research to date supports the terrestrial scenario, indicating that the biogeographic structure of the region is complex with high levels of sibling speciation. These species are very similar in general appearance, and often cannot be distinguished unless specimens are compared side by side. To further complicate matters, the slope faunas of nearby Western Australia are represented by discrete assemblages stratified by depth (Williams, unpublished data). Consequently, to describe the fauna it is necessary to broadly sample the region both geographically and across depth intervals.

Existing international collections of fishes from the region are inadequate for solving the difficult taxonomic problems created by complex sibling speciation. These collections were never assembled with the aim of solving broad regional problems. To achieve this goal, local reference collections, built through targeted collecting, are needed. The fish collections that are accessible within the region are neither extensive nor focused on biodiversity. The Darwin Initiative-funded collection of elasmobranchs has grown from nothing to possibly the largest chondrichthyan collection in the region within two years. Regional neighbours (e.g. Indonesia, Singapore, Taiwan, Thailand) have small, but important, collections. These are somewhat limited in regional and familial coverage of elasmobranchs in their present form.

Plans are afoot to survey deep trawl grounds offshore. Such surveys are costly to run, and the research output must be maximised to meet these costs. A key outcome of such surveys is to define the biological resources of each nation's fishing zone. In unfished areas, with essentially undiscovered faunas, taxonomic material must be retained for initial identification and future validation. The catch composition needs to be identified carefully, as poor identification will lead to the collection of useless biological data and ultimately wasted resources. This baseline is also critical for defining community structure of virgin stocks in order to subsequently monitor changes if fisheries are established in the region. Baseline data are needed before a fishery commences, rather than after it has altered stock structures. Unfortunately, few world fisheries have been developed strategically, or against systematic baseline data.

Typical collection uses

Collections should not be viewed as inaccessible repositories of dead biological material. They are dynamic resources that must be managed as biological libraries, helping define the structure and distribution of the region's fauna. Collections have multiple uses, most of which have particular relevance in this region:

- Establish biodiversity baselines – they can be used to compile faunal checklists for a region, define community composition, and provide concrete evidence for the local existence of species.
- Provide validatable geographical point information for species that can be used in biogeographic studies, to define the ranges of species, or in the rediscovery of rare or endangered species.
- Construction of reference guides - they provide the basis of species descriptions for the preparation of

regional identification guides and are a source of validating information within these guides.

- Essential to resolve sibling speciation – multiple specimen lots are needed to determine levels of intraspecific variation and to assess the usefulness of diagnostic characters for distinguishing closely related species. To resolve taxonomic problems of rare or inaccessible species, specimens often need to be acquired over comparatively long time frames.
- Fisheries tool - too often, fishery studies have been undertaken on 'single species' only to find later that the species was a species complex rendering the work wholly or partly useless. Adequate reference collections must be available for study to resolve these problems quickly and efficiently.
- Training of local ichthyologists - text descriptions of species are informative but students learn more by handling real specimens. Fish collections provide a repository of biological forms for study in many fields including anatomy, morphology, parasitology, evolutionary biology and biogeography.
- The cost of maintaining preserved biological collections is much cheaper than searching for fresh material every time it is needed.

Strategic collecting procedures

In the last century, most museum acquisitions consisted of small collections of species, each represented by one or two individuals. The contemporary approach is to place a greater emphasis on strategic collecting of material, in order to make better use of often crowded storage facilities, help resolve taxonomic problems, and provide better biodiversity coverage. These objectives can be achieved by:

- Systematically sampling within all 'likely' or 'known' biogeographic provinces to maximise the biodiversity coverage.
- Targeting collecting within different biotopes (or habitats) from each biogeographic province, to account for subtle patterns of habitat dependency.
- Querying of collection databases to reduce overcollecting of some taxa, and increasing representation of others.
- Using all available collecting methods within biotopes to maximise representation of their communities.
- Retaining small multiple lots (5-10 specimens from each sample rather than single specimens) to get an understanding of intraspecific character variation.
- Including within specimen lots, when necessary, a range of sexual and ontogenetic morphotypes.
- Taking colour transparencies of fresh specimens to record natural colour patterns and tones. These are usually fully, or partially, lost in preservative. Colour patterns are essential for identifying some species, and can be useful for highlighting sibling speciation and population differences.
  Collecting genetic tissue samples, either frozen removed from fresh, or frozen whole specimens, or in ethanol as whole fish or tissues. Samples should not be placed in formalin.
  Taking cartilage samples (i.e. claspers, crania, shoulder and pelvic girdles) to identify sibling species, or to provide material for phylogenetic studies.

Collection methodology

The quality and quantity of biological material in museums varies greatly from institution to institution, depending on the type of specimen, method of collection, transportation, preservative, storage method, and curatorial rigour. However, there are some general rules:

- Select collection specimens carefully, given a choice. Dehydrated, decomposing, bent, twisted or badly damaged specimens are obviously less useful than those preserved in good condition.
- Handle carefully to avoid damaging those that have been selected, and transfer them quickly into a freezer or 10% formalin. Specimens collected from tropical climates will dry out and commence decomposition quickly in the heat. Fixative stored outside in drums and tanks is usually warm. The thick skins and belly flaps of many elasmobranchs are less permeable to fixative than the skins of most teleosts. The body cavity should be injected with formalin to arrest decomposition.
- Use appropriately sized drums and jars. Cramping of sharks and rays will result in twisted specimens that are difficult to store, X-ray and measure. If possible, sharks should be laid out straight and rays laid out flat.
- Label specimens properly. Key collection information (such as locality, depth, date and collector) must either be included with each specimen or with each specimen lot. Labels can be placed in jars, tethered to the outside of bags, or placed in the gill or mouth of large specimens. Nylon clothing tags do not denature in preservative and can be attached with needle guns through the side or tail of specimens. Care must be taken, when attaching labels externally, to avoid damaging the specimen and to ensure that the tag is properly attached. It is preferable to use an untearable, waterproof paper label such as Polypaper.
- High quality, photo transparencies should be obtained for each species to construct field guides and keys, and to assist in distinguishing species surveyed. A label with a provisional identification and a station code, and a measuring device (preferably in cm increments) should be visible in transparencies to link the photograph back to a specimen.

Field guides and taxonomic references should be used to identify specimens when available. However, deepwater habitats of the Indo-Pacific remain largely unexplored and many species are undescribed. Consequently, specimens from the initial surveys of a region will need careful taxonomic scrutiny and a hard-copy or electronic field guide should be compiled for each survey. Specimens should be photographed using a digital or polaroid camera, so that these guides can be continuously updated with new species during the survey, enabling reasonable catch composition data to be obtained for each sample.

Responsibility for long-term management

Biological collections are both important regional resources and repositories for research material needed by the wider international scientific community. They require a substantial commitment of resources, are usually assembled over long time frames and, as such, must be managed responsibly.

There are several essential functions of collections:

- Collections act as an extended international reference facility representing part of the world's biodiversity and should be available for broad scientific study.
- Specimens should be stored adequately in the correct preservatives, using acceptable fixation/preservation protocols. Storage containers should be replenished periodically to prevent drying out and subsequent loss of material.
- Collections should be maintained by trained collection staff, because some curatorial procedures are complex requiring specialist skills and knowledge.
- Nomenclatural type specimens such as paratypes and holotypes are irreplaceable. They have international importance, and are not the property of individuals or institutional custodians. If they are held in collections, then the custodians must accept full responsibility for their welfare, and dedicate necessary resources to their protection, or pass them to an institution with the capacity to afford such protection. Non-type specimens referred to in the taxonomic literature are less important, but need to be safeguarded similarly.
- Collections need to be accessible to users so they must be stored in an ordered, efficient and retrievable fashion. Most museums use a family based, phylogenetic arrangement to locate species on shelves that is usually outdated, but acts as a convenient cataloguing order.

Other important features of collections that need consideration include:

- Types and other voucher specimens–are often retained in special areas within collections. There are unfortunate examples of where types have been lost, misplaced or ruined through poor collection practices.

Registration database - enables faster access to collection registration and cataloguing information, provision of listings of specific holdings, access to loans information, and electronic generation of labels.

Loan facility - enables collection material to be more accurately identified by taxonomic specialists, improving the quality of identifications in the collection

A photographic index can be compiled for a region, based on transparencies taken from acquired material. Linking a collection specimen to an indexed photograph provides a capability that is usually unavailable for field photographs of live specimens.

Other sub-collections, such as genetic, skeletal and embryo collections are important adjuncts to the main adult collections.

Radiographic facilities are needed to obtain meristic data (fin-ray and vertebral counts) and for skeletal investigations when studying the phylogeny of groups.

Specific consideration and requirements for sharks and rays

The taxonomy of large elasmobranchs (as well as large bony fishes) is dependent on many factors that are a function more of logistics than of inherent difficulties within the groups in question:

- Taxonomic problems can only be resolved if adequate research material is available. Elasmobranch collections are typically poor, both in numbers of species and their replicates. Due to their large relative size, elasmobranchs will never be held in adequate numbers in American or European museums. Soaring costs, and more stringent freight regulations, have made it increasingly difficult to transport these fishes over long distances. Space limitations in many museums means that the willingness of curators to keep large specimens has diminished.
- The condition of elasmobranchs in tropical markets is often poor. Some are partly processed at sea, or finned when landed. Space limitations in the holds of boats means that fish are sometimes left on deck for several days before being landed, or kept in holds without ice. Partly decomposing specimens make poor museum specimens.
- When large specimens cannot be retained, photographs or subsamples (e.g. skeletal parts, tissue sample in ethanol) may be enough to enable identification.
- Less common elasmobranch species are usually collected opportunistically. In such instances, the assistance of local fishermen and villagers is invaluable. Temporary storage, including drums and formalin, left on site has provided material that is unlikely to have been collected otherwise (e.g. Manjaji, this volume).

Regional collections - 2000 and beyond

Few regional collections in the Indo-Pacific meet the above criteria, in terms of their capacity and commitment to elasmobranch biodiversity. New local collections are needed to fill a collection void within the region. These must be managed strategically, and adequately funded, to be fully effective. Similarly, with the likely establishment of new commercial fishing operations along the continental slopes of the region, adequate resources will need to be allocated to accommodate the wealth of biological material that is likely to emanate from these surveys. Unless these resources are provided, governments will be unable to accurately evaluate the marine resources of their region.

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An Annotated Checklist of Elasmobranchs of the South China Sea, with some Global Statistics on Elasmobranch Biodiversity, and an Offer to Taxonomists

R. Froese
Institut für Meereskunde, Düsternbrooker Weg 20, 24105 Kiel, Germany
C.V. Garilao
ICLARM, MC P.O. Box 2631, 0718 Makati City, Philippines

An annotated checklist of the sharks and rays of the South China Sea is described, together with some global statistics on the status and use of elasmobranchs. For each of the 156 recorded species, the checklist contains scientific names, synonyms, common names, global distribution, distribution in the area, status of threat, human uses, key references on taxonomy, identification, reproduction, population dynamics, and a list of people who have contributed information. The checklist is a direct printout from FishBase, a global database on finfish, developed at ICLARM in collaboration with FAO, the California Academy of Sciences, and many other partners, and supported by the European Commission (see www.fishbase.org). The goal of FishBase is to further the conservation and sustainable use of fish by bringing together the knowledge of taxonomists, fisheries experts, and conservationists, providing tools for analysing and updating this knowledge, and making it available to concerned people. How a closer link between FishBase, taxonomists and country experts can benefit the specialists, as well as elasmobranch conservation, is discussed.

Introduction

The rapid decline of elasmobranch populations due to overfishing and bycatch mortality is widely recognised (Bonfil 1994). In this paper we present some global statistics on the use and status of elasmobranchs, we describe an annotated checklist of elasmobranchs for the South China Sea, one of the areas of high concern, and we discuss how a global database such as FishBase (Froese and Pauly 1997)can assist conservation efforts. See www.fishbase.org for latest information and to search Fish Base.

Some global statistics on elasmobranchs

Elasmobranchs consist of about 359 sharks and 456 rays (Nelson 1994). Their size ranges from about 16cm total length (TL) in the cat shark *Parmaturus campechiensis* to 13.7m in the whale shark *Rhincodon typus,* with a median length of 86cm TL. The centres of shark biodiversity are the Indian Ocean and the Western Central Pacific with more than 220 species. Temperate oceans have less than 100 species, and the Arctic and the Southern Ocean have

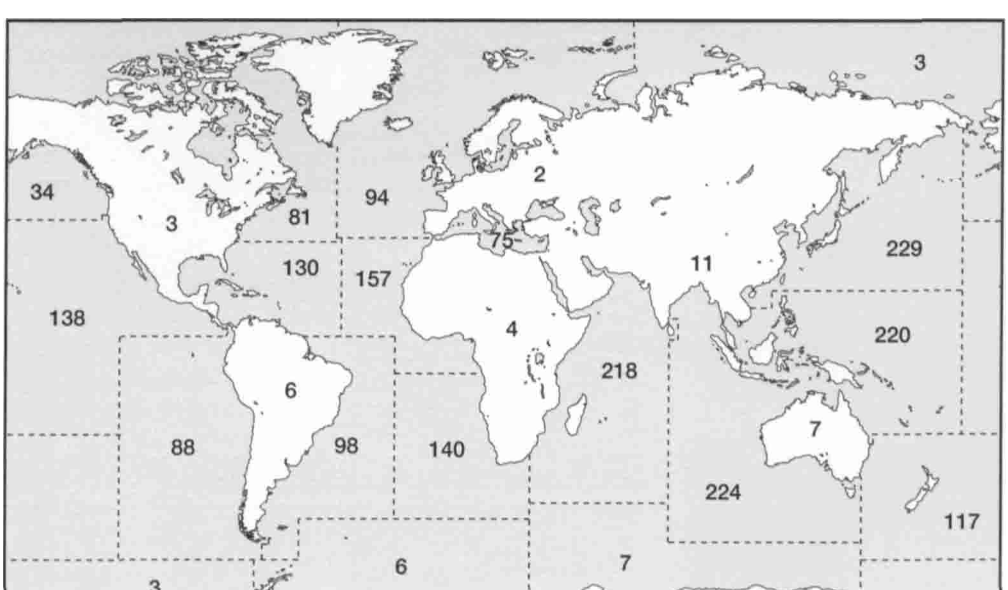


Figure 1. Approximate number of elasmobranch species by FAO statistical area, based on FishBase '97. Note that the number (229) for the Northwest Pacific is too high because it includes many species of the Western Central Pacific that extend to southern Taiwan. Also, the number (6) for inland South America is too low, because these species had not yet been entered in FishBase.

less than 10 species (Figure 1). About a third of elasmobranchs have limited distributional ranges, i.e. they occur in only one of the FAO areas shown in Figure 1. About 100 species are wide-ranging or cosmopolitan and occur in five or more FAO areas. Half of the elasmobranchs are demersal, about 20% are deep-sea species, about 100 are pelagic or benthopelagic, and about 60 species regularly occur in or around coral reefs. More than 13 species regularly enter freshwaters, and more than 12 are restricted to freshwaters. Because of their low fecundity, these species are even more vulnerable than freshwater fishes in general to habitat destruction, pollution and fisheries.

Based on references compiled in FishBase (Froese and Pauly 1997), 40% of the 815 elasmobranch species (Nelson 1994) are reported to be used in fisheries, 11% are considered game fishes, and five species regularly enter the aquarium trade. Of the commercial species, seven are considered highly commercial, 123 are commercial, 138 are of minor commercial importance, and 55 are consumed locally. Most of the commercial species are demersal (60%), 13% are reef-associated, and 8% are pelagic. Only

Figure 2. FAO nominal catch statistics for *Lamna nasus* from 1950 to 1994. Note that unsustainable high catches in 1964 in the Northwest Atlantic led to a collapse of the fishery, which has not recovered 30 years later.

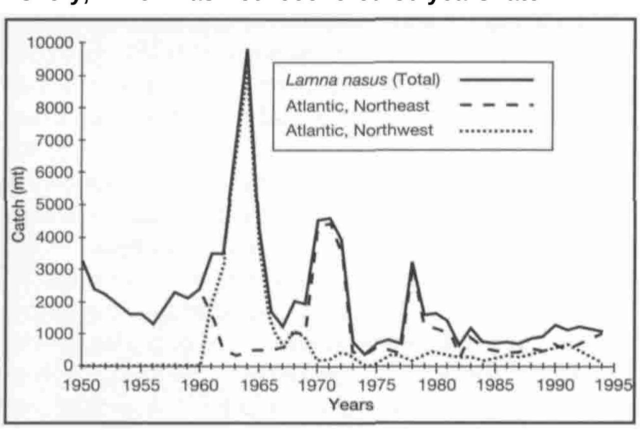
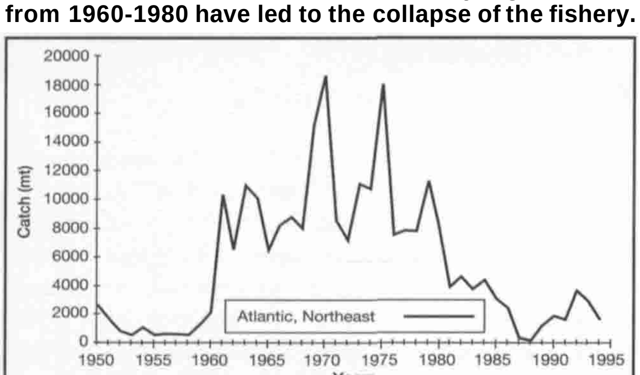


Figure 3. FAO nominal catches for *Cetorhinus maximus* in the Northeast Atlantic. Unsustainably high catches from 1960-1980 have led to the collapse of the fishery.



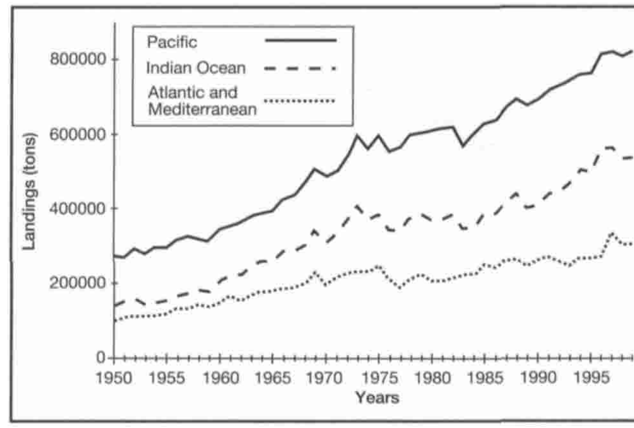


Figure 4. FAO nominal catches for elasmobranchs by selected FAO statistical areas. A continuous decline in catches in the Northwest Pacific is compensated by increased catches in the Western Central Pacific.

88 elasmobranch species (11%) have been reported to be involved in biting accidents with humans, most of which were provoked by divers or fishers harassing, handling or otherwise provoking the animals. Thirty-six species, mostly stingrays of the genera *Dasyatis* and *Gymnura,* are venomous; and 28 species, mostly electric rays of the genera *Torpedo* and *Narcine,* can provide electric shocks.

The IUCN Red List (IUCN 1996) listed 16 elasmobranch species as threatened by extinction, in the following categories: Critically Endangered - one ***Gfyphis*** *gangeticus***,** six Endangered and seven Vulnerable. The whale shark *Rhincodon typusand* the deep-sea ray *Bathyraja* ***abyssicola*** were listed as Data Deficient. The porbeagle *Lamna nasus* and the basking shark *Cetorhinus maximus.* are two commercially exploited species reported in FAO catch statistics. Their time series show the typical pattern of overfishing: a rapid increase of catches to unsustainable levels, followed by the inevitable decline (Figures 2 and 3). [Editor's note: See www.redlist.org for the most recent threatened species assessments for a much larger number of species.]

FAO catch statistics for all elasmobranchs (FAO 1996) show an increase in reported landings from 1950 to 1994 (Figure 4). Most landings are reported from the Northwest Pacific, where catches are steadily declining. This downward trend is presently being more than compensated for by increasing catches in other areas, particularly the Indian Ocean and Western North Pacific, but it cannot be expected that this will last. For a more detailed analysis of shark fisheries see Bonfil (1994 and this volume).

An annotated checklist of elasmobranchs of the South China Sea

The checklist information held on FishBase is organised in five sections: species account, literature section, common names section, synonyms section, and collaborators section.

- The species account lists species in phylogenetic order following Eschmeyer (1990). Families are listed alphabetically within orders and species are listed alphabetically within families. Provision is made for each Family chapter to be authored by an expert.
- The literature section gives full citations for all references used, sorted by the reference numbers given in the species accounts.
- The common names section lists vernacular names used in the area with language, country and current scientific name and Family. Also, English FishBase names are listed. These are identical with FAO names or names suggested by the American Fisheries Society or, if neither of these exist, other published English names that are not already used for other species.
- The Synonyms section lists synonyms and common misspellings, sorted by genera and species, with the current name and Family.
- The collaborators' section contains names, addresses and email of colleagues who have contributed to the checklist. It is sorted by the collaborators' number that is shown in the list of Families and in the species accounts.

For each species the current checklist contains the following (see Box 1 for an example):

- Current name and author.
- English common name.
- Salinity (M = marine, Br = brackish, Fr = freshwater).
- Habitat (Dmrsl = demersal, Plgc = pelagic, BnthPlgc = benthopelagic, BthPlgc = bathypelagic, BthDmrsl = bathydemersal. Reef = reef-associated).
- Human uses (Fi = fishery, Aq = aquaculture, Or = ornamental, Sp = sport, Bait = used as bait).

Box 1. Example of a species account as contained in the annotated Checklist.

Heterodontiformes (bullhead and horn sharks)
Heterodontidae (bullhead, horn, or Port Jackson sharks) by….
Heterodontus zebra Zebra bullhead shark, (M Dmrsl Fi DngTrm), Ref. 9705
(Gray 1831) Max. 125cm TL. Depth range: - 50m.
Found on the continental and insular shelves at moderate depths down to at least 50m. Inhabits trawling grounds. Probably feeds on bottom invertebrates and small fishes (Ref. 6871). Oviparous. Males mature at about 84cm (Ref. 6871).
Distribution: Western Pacific: Japan, Korea, China, Vietnam, Indonesia (Sulawesi, Ambon), and northern Western Australia (Ref. 6871). Also in the Philippines (Ref. 2334).
Countries in area: CHN [247], IDN [247], PHL [2334], TWN [247], VNM [9705].
B/W picture.
Collaborators: 01, 14, 23

- Danger to humans (Psn = poisonous, Cig = ciguatera, Vnm = venomous, Trm = traumatogenic).
- Main reference used.
- Maximum length.
- Depth range.
- One or two sentences on biology.
- Global distribution.
- Countries of occurrence in the area, with reference.
- Availability of a b/w drawing and/or colour photo in FishBase.
- Available references on morphology, growth, food, diet, reproduction, or spawning.
- Collaborators that contributed, compiled or verified information for the species.

We would like to stress that the suggested format can be easily changed to accommodate more or less information, or to present information differently. Also, the information currently included is preliminary and has not yet been critically reviewed. We are aware that species are missing from the list, that assignments to countries are incomplete, and that more information on the species (reproduction, growth, diet etc.) may be available. However, we believe that this preliminary checklist will already help colleagues working on South China Sea elasmobranchs to find available information, and to identify missing information that can be sent to the FishBase Team for inclusion in the next annual updates. The annotated checklist is not appended to this paper due to space limitations, but was distributed at the workshop to interested participants. The authors will mail additional copies on request.

The FishBase Project is an example of a cumulative approach, i.e. information that is entered once will stay, until it is shown to be wrong. Due to the availability of this information we hope that new projects on the conservation and sustainability of fishes, rather than starting with a time-consuming literature search or maybe repeating work that has already been done, will build on existing knowledge and immediately address the task at hand, hopefully with better results. The new knowledge they create, if added to the system, might enable future projects to do an even better job.

An offer to taxonomists

Keeping track of the status of 25,000 fish species in 470 families is not something that the FishBase Team can do alone. Thus, we would like taxonomists to volunteer to become Taxonomic Coordinators in FishBase for their families of expertise, similar to the approach used in large checklists, such as Daget *et al.* (1984), Quéro *at al.* (1990) or Smith and Heemstra (1986). We realise that taxonomists are already overburdened with numerous tasks and may not be keen to take on yet another responsibility. We have therefore thought hard about what we can offer to make such collaboration more attractive, and we can:

- Provide three copies of FishBase per annual release.
- Provide printouts (text files) in any required format, from checklist to field guide (database publishing).
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Please contact the authors if you are interested in becoming a FishBase Coordinator for your country, island, or ecosystem. We will send you an annotated checklist with the information we have compiled so far. The details for the Taxonomic Cooridinator with regard to editing and reprints also apply here.

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Elasmobranch Fisheries in Peninsular Malaysia

Abu Talib Ahmad
Fisheries Research Institute, Department of Fisheries - Malaysia,11960 Batu Maung,
Pulau Pinang, Malaysia

This paper presents information on the status of elasmobranch fisheries on the east and west coasts of Peninsular Malaysia. Approximately 19 species of shark and 20 species of ray have been reported in the waters off the east coast, and fewer are reported in the waters off the west coast of Peninsular Malaysia. Information on the biology and habitats of these species is limited. Landings data from 1982 to 1994 indicate that more sharks were caught on the east coast, but rays were found to be more abundant on the west coast. Both sharks and rays were caught mainly by bottom trawl nets. Demersal resource surveys conducted by fisheries research vessels using bottom trawl nets indicated that catch rates of sharks were higher in water deeper than 30m, while catch rates of rays were higher in water of less than 30m.

Introduction

The marine fisheries sector plays an important and significant role in the economy of Malaysia. Fisheries are viewed as an important source of food, employment and foreign exchange. With a current per capita consumption of about 39.5kg per annum, the demand for fish is expected to increase progressively in the future. In 1994 the total fish landings from marine fisheries reached 1,065,585 tonnes (t) with a value of RM2.59 billion. This contributed 1.4% to the Gross Domestic Product. At the same time, there were about 79,802 people employed in this sector constituting 1.1% of total employment. During this period Malaysia exported 218,163t of fish and fish products, valued at RM847.2 million. This contributed about 0.6% of the total exports. Malaysia also imported 288,1811 of fish and fish products, valued at RM760.9 million, giving a net gain in foreign exchange of RM86.3 million.

The marine fisheries consist of inshore fisheries and deep-sea fisheries. In 1994 the production from inshore fisheries in Peninsular Malaysia was 687,203t, which made up 64.5% of the total marine landings of the country. Deep-sea fisheries of this area contributed 9.2% of the total marine landings at 97,876t. The west coast of Peninsular Malaysia is the most important area for inshore fisheries and contributed 62.9% of the landings in Peninsular Malaysia, or 46.4% of the landings for Malaysia as a whole. The east coast of Peninsular Malaysia contributed 71.0% of the deep-sea landings for Peninsular Malaysia, or 51.3% of landings for the whole country. However, analyses of the catches from research trawl surveys in the coastal water of the west coast of Peninsular Malaysia show a persistent drop in catch per unit effort from 141.7kg/hr in 1971 (Mohammed Shaari *et al.* 1974) to 46.75kg/hr in 1988 (Ahmad Adnan, in press a). A similar trend was also observed in the coastal waters of the east coast of Peninsular Malaysia. The catch rate decreased from 254.8kg/hr in 1972 (Lam *et al.* 1975) to 69.9kg/hr in 1991 (Ahmad Adnan, in press b). The declaration in 1980 of the Exclusive Economic Zone of Malaysia accelerated the development of offshore or deep-sea fisheries. A deep-sea resource survey conducted in 1987 over an area of more than 30 nautical miles from the coastline, indicated a potential yield of 1 l,300t of demersal fish on the west coast and 82,200t on the east coast. The potential yield for pelagic fish was estimated to be 16,950t and 54,600t for the west and east coast of Peninsular Malaysia, respectively (Anon. 1987). A second resource survey in these waters seems necessary in order to assess the potential and the current status of the resources.

Sharks and rays are considered as human food throughout the world. There are very few studies and publications dealing with elasmobranch fishes in Malaysia. Cantor (1849) published a catalogue of 292 species of Malaysian fishes, of which 28 species were sharks and rays. Scott (1959) described 294 species, of which 25 were sharks and rays. Mohammed Shaari (1971) identified six species of sharks and rays in trawl catches from waters off Penang. Mohsin *et al.* (unpublished) described the cartilaginous fishes of the east coast of Peninsular Malaysia and produced a taxonomic key to 39 species of sharks and rays. Recently, Mansor *et al.* (in press) produced a field guide to commercial marine fishes of the South China Sea area and described eight species of sharks and eight species of rays. There is limited information for the biological parameters of sharks and rays required for stock assessment in this region. Therefore, the aim of this paper is to give a general overview of the current status of elasmobranch fisheries in Peninsular Malaysia, based on information from commercial landings and trawl surveys.

Landings from commercial vessels

Landings of sharks and rays in 1994 were 12,238t, contributing only 1.5% of the total fish landings in

Table 1. Landings of sharks and rays by state in Peninsular Malaysia.

Year		Perils	Kedah	Penang	Perak	Selangor	Negeri Sembilan	Malacca	West Johor	Sub-Total	Kelantan	Trengganu	Pahang	East Johor	Sub-total	Grand total	Total Landing
		West Coast									East Coast						
1982	Sharks	61	296	12	287	338	16	46	92	1,148	1	48	357	311	717	1,865	567,323
	Rays	103	673	53	850	651	47	146	541	3.064	14	94	555	101	764	3,828	
1983	Sharks	48	233	15	228	135	1	10	12	682	1	716	964	213	1,894	2,576	609,056
	Rays	166	755	92	1.009	511	45	297	458	3.333	32	185	818	210	1,245	4,578	
1984	Sharks		269	119	461	267	—	8	74	1,198	—	1.486	231	330	2,047	3,245	481.640
	Rays	220	421	320	1,232	794	26	254	610	3,877	3	591	310	231	1.140	5,017	
1985	Sharks	22	202	102	627	223	—	21	67	1,264	—	1,092	84	378	1.554	2,818	462,862
	Rays	172	370	315	1,560	428	51	468	429	3.793	6	567	247	329	1.149	4,942	
1986	Sharks	22	82	55	764	519	—	8	33	1.483	1	780	257	515	1.553	3,036	446,376
	Rays	279	280	305	1,983	1,231	25	323	551	4.977	30	324	717	685	1.756	6,733	
1987	Sharks	8	91	34	491	241	—	24	17	906	—	286	365	317	968	1,874	740,565
	Rays	109	436	143	2,430	979	16	219	340	4.672	18	1.502	1,103	898	3,521	8,193	
1988	Sharks	54	234	20	691	313		28	19	1,359		217	334	560	1,111	2,470	694,449
	Rays	151	479	63	2,301	2,425	12	244	451	6,126	41	347	805	1,110	2.303	8.429	
1989	Sharks	15	200	19	546	193		25	17	1,015	8	217	223	498	946	1.961	746,884
	Rays	276	535	113	1,787	925	9	289	457	4,391	324	313	485	1.146	2.268	6.659	
1990	Sharks	65	62	16	421	160	2	21	12	759	11	303	546	578	1.438	2,197	819,902
	Rays	365	527	129	1,809	926	43	401	472	4,672	429	745	1,778	1,628	4,580	9,252	
1991	Sharks	71	47	49	418	160	3	17	11	776	48	272	572	400	1,292	2,068	709,587
	Rays	180	430	195	1,890	1,220	16	173	497	4,601	189	843	1.713	1,120	3,865	8,466	
1992	Sharks	110	59	85	341	134	1	26	13	769	28	731	724	602	2,085	2,854	767,532
	Rays	567	458	192	2.525	1.147	12	185	344	5.430	165	1.159	1.901	1.347	4,572	10,002	
1993	Sharks	17	54	76	303	175	4	53	12	694	51	450	584	400	1,485	2,179	791,618
	Rays	361	456	458	2,580	1,060	40	285	368	5,608	833	1,371	1.637	1,399	5,240	10,848	
1994	Sharks	24	51	83	361	190	4	35	21	769	101	421	485	390	1.397	2.166	788,079
	Rays	190	563	384	2,489	1,019	16	88	355	5,104	875	1,102	1,301	1,690	4,968	10,072	

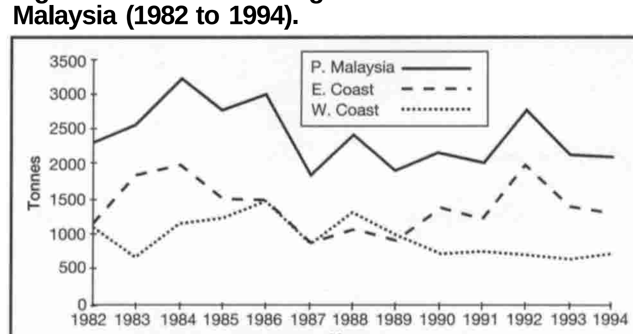
Source: Annual Fisheries Statistics 1982-1994, Department of Fisheries Malaysia

Peninsular Malaysia. On the west coast, 769t of sharks and 5,104t of rays were landed, equivalent to 1.3% of the total fish landings in this region. The percentage was slightly higher on the east coast (1.9%), due to the higher landings of sharks at l,397t and rays at 4,968t (Table 1).

Shark and ray landings

Shark landings in Peninsular Malaysia between 1982-1994 fluctuated between 3,246t (1984) and l,874t (1987) (Figure 1). Throughout this period, more sharks were landed on the east coast than on the west coast, except for 1988 and 1989. In 1994, landings of sharks on the east coast were almost double the amount on the west coast. More than 70% of shark landings on the west coast came from Perak and Selangor states. Yearly landings from other states on this coast were mostly less than l00t, especially after 1990. On the east coast, the landings were contributed to roughly equally by all states except Kelantan. Terengganu was the main contributor of sharks in the mid-1980s (Table 1). Shark trawl catches in 1994 contributed 77% and 65% of the shark landings of the west coast and east coast, respectively. Landings by drift nets were also substantial on the east coast of Peninsular Malaysia and amounted to 22% (Figure 2 and Table 2).

Figure 1. Annual landings of sharks in Peninsular Malaysia (1982 to 1994).



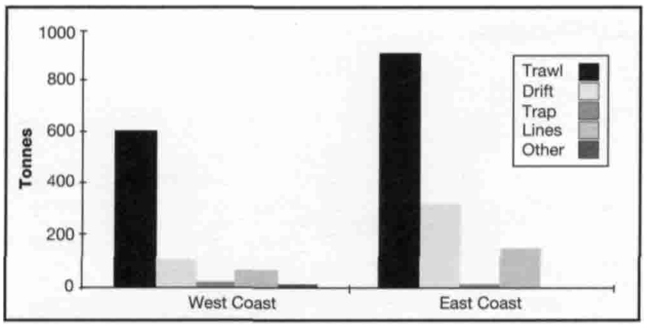


Figure 2. Landings of sharks by types of gear in Peninsular Malaysia, 1994.

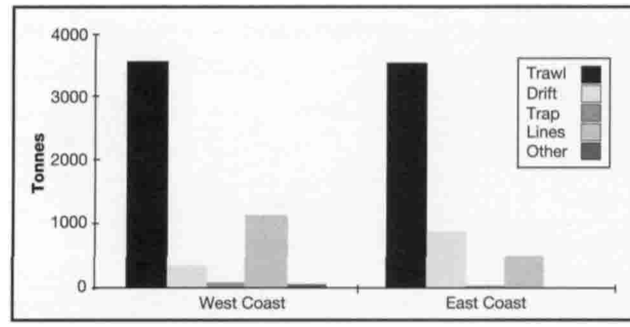


Figure 4. Landings of rays by types of gear in Peninsular Malaysia, 1994.

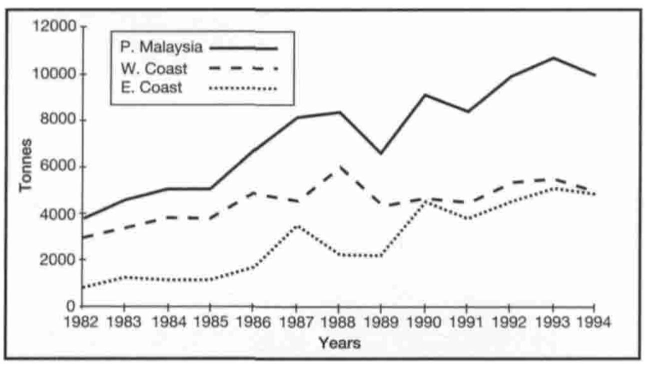


Figure 3. Annual landings of rays in Peninsular Malaysia (1982 to 1994).

Ray landings in Peninsular Malaysia increased from 1982 to 1994 (Figure 3). The trend was more prominent on the east coast, increasing from 763t in 1982 to 4,968t in 1994. On the west coast, the highest landing was recorded at 6,125t in 1988. The trend in landings on the east coast changed the landing ratio between the east and west coasts from 1:4 in 1982 to 1:1 in 1994. By 1994 landings on both coasts were around 5,000t.

The waters off Perak and Selangor are productive for both rays and sharks, contributing 69% of the ray landings on the west coast. The southern region is the main ground for rays. Landings from the northern part of the east coast, especially Kelantan, have been increasing.

Table 2. Landings of sharks and rays (tonnes) by types of gear in Peninsular Malaysia.

		West Coast					East Coast				
Year		Tawl	Drift/Gill	Trap	Lines	Others	Tawl	Drift/Gill	Trap	Lines	Others
1982	Sharks	683	95	—	295	74	123	697	3	325	1
	Rays	1,615	160	18	1,081	100	454	110	7	186	6
1983	Sharks	456	73	—	143	12	195	1,369	7	322	—
	Rays										
1984	Sharks	Data were not separated by coast									
	Rays										
1985	Sharks	Data were not separated by coast									
	Rays										
1986	Sharks	931	166	—	383	3	313	972	—	265	2
	Rays	3,056	280	56	1,567	16	1,332	174	8	231	11
1987	Sharks	666	89	1	150	—	589	253	—	122	3
	Rays	3,517	158	30	944	22	2,041	1,233	2	228	17
1988	Sharks	854	385	—	118	1	786	216	9	97	3
	Rays	4,881	231	50	957	6	2,146	114	21	13	9
1989	Sharks	796	146	—	73	—	674	166	4	99	3
	Rays	3,135	238	36	857	125	2,177	46	8	29	8
1990	Sharks	642	75	3	38	1	1,085	219	4	128	2
	Rays	3,362	625	44	589	525	4,217	196	9	155	3
1991	Sharks	683	30	4	52	7	982	176	8	126	—
	Rays	3,298	462	54	781	66	3,586	158	25	91	5
1992	Sharks	658	56	—	55	—	1,396	522	7	157	3
	Rays	3,869	523	30	976	32	4,269	144	20	135	4
1993	Sharks	539	90	3	62	—	958	365	12	150	1
	Rays	3,910	429	80	1,176	131	3,610	861	36	730	3
1994	Sharks	594	98	12	64	1	914	324	9	150	—
	Rays	3,565	333	51	1,120	35	3,536	898	23	509	2

Source: Annual Fisheries Statistics 1982-1994, Department of Fisheries Malaysia

Table 3: Average catch rates (kg/hr) of sharks and rays by depth strata on the easi and west coast of Peninsular Malaysia from trawl resource survey.

	West Coast						East Coast					
Depth(m)	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**>60**	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**>60**
Sharks												
1970							5.68	7.38	2.02	11.92	3.18	—
1971	0.05	0.09	0.67	0.69	7.64	—	1.88	3.89	4.49	2.89	2.61	—
1972	0.47	1.75	0.33	0.47	0.73	—	—	2.4	3.8	2.09	3.64	—
1974	—	0.29	0.78	3.34	0.33	—	5.15	2.28	1.38	7.67	0.74	—
1978	0.07	0.84	1.00	0.34	0.11	—						
1980	—	0.22	0.52	2.94	0.05	—						
1981	—	—	0.04	0.13	1.47	—	—	1.39	—	0.39	0.59	—
1983							0.41	0.68	8.8	1.24	0.12	—
1984		0.06	0.22	0.5	—		0.5	—	1.94	2.02	0.9	—
1986	0.08	—	0.19	0.15	—	—						
1988	—	—	4.51	1.1	0.29	—	—	0.16	0.5	0.33	1.31	—
1990							8.04	0.74	1.14	4.38	6.32	—
1990/91	0.01	—	1.25	0.02	—	—						
1991/92							—	0.07	1.8	0.81	0.33	—
1992/93	—	—	0.38	—	—	—						
1995							—	0.15	0.284	—	0.15	—
Rays												
1970							17.21	1.85	4.87	12.35	5.01	—
1971	1.9	4.53	15.32	6.03	0.09	—	5.86	8.46	17.12	6.23	0.74	—
1972			1.11	0.91	0.3	—	2.76	8.65	10.33	6.64	7.59	—
1974	6.08	0.57	0.57	4.13	4.93	—	31	4.5	8.55	0.64	1.3	—
1978	0.19	0.38	0.97	1.96	4.3	—						
1980	0.56	1.22	1.58	1.36	2.39	—						
1981	0.57	0.31	0.66	1.06	2.37	—	7.22	18.09	0.87	1.2	2.83	—
1983							22.76	5.92	21.19	1.49	0.05	—
1984	0.36	1.77	0.93	2.09	—	—	9.89	14.09	1.85	10.37	1.02	—
1986	4.2	10.31	0.84	1.82	5.82	—						
1988	0.29	0.75	3.57	21.03	0.84	—	—	36.2	—	—	6.42	—
1990							2.01	7.49	22.66	16.74	0.84	—
1990/91	1.98	1.07	0.46	3.29	1.07	—						
1991/92							0.98	2.86	3.48	4.37	1.53	—
1992/93	1.19	0.24	0.72	—	—	—						
1995							1.802	2.215	0.341	0.245	0.618	—

Source: Data obtained from catches of research vessel at systematic randam sampling stations

Trawl landings constituted about 70% of the total ray landings. Drift nets and hooks and lines were also important gears for this fishery (Figure 4).

Catch rates from trawl surveys

Trawl resource surveys in the coastal waters off the coasts of Peninsular Malaysia have been carried out periodically to monitor the status of fishery resources. The first of 11 surveys on the east coast wasconducted in 1970 (Pathansali *et al.* 1974) and the most recent was in 1995. The first of 11 surveys off the west coast took place in 1971 (Mohammed Shaari *et al.* 1974). The latest was conducted in 1992/93. Surveys conducted off the west coast include an area in the northern part of the Straits of Malacca. The 1973 survey was the only survey to include the southern part, which is untrawlable due to uneven rocky ground and coral bed (Mohammed Shaari *et al.* 1976). So far, only one deep-sea or offshore resource survey has been conducted off Peninsular Malaysia (Anon. 1987).

The coastal area (less than 30 nautical miles [nm] from the coast)

The average catch rates of sharks and rays by depth stratum during the resource surveys are given in Table 3.

Sharks were mostly caught at a rate of less than 10kg/hr in all depth strata, but occasionally higher landings were recorded. This was due to the landing of single large specimens in certain depth strata. Pathansali *et al.* (1974) reported that the most common species caught was *Rhizoprionodon acutus*, a small species of the family Carcharinidae. The slender bambooshark *Chiloscyllhan indicum*, a larger species of the family Orectolobidae, did not appear often and was never caught in large numbers. Based on data from the 11 surveys of both coasts, catch rates were higher in depths greater than 20m. The highest catch on the west coast was recorded in 1971 at 7.64kg/hr in the depth stratum 51-60m. On the east coast, a catch rate of 11.92kg/hr was recorded in the water depth stratum 5l-60m during 1970.

The Trygonidae were the most common rays caught during the surveys on both coasts. The dominant species were *Dasyatis zugei, D. walga, Gymnura poecilura, Aetomylaeus nichofii* and *Rhynchobatus djiddensis* (Pathansali *el al.* 1974, Mohammed Shaari *et al.* 1974, Jothy *et al.* 1975). These were caught in waters between 10-20m stratum, and to a lesser extent in deeper water. The honeycomb whipray *Himantura* uamak**,** a large species which weighs over 50kg, was occasionally caught in the 41-60m stratum. Average catch rates in all depth strata for all surveys conducted on the north-west coast were much lower than those off the south-west coast in 1973, suggesting that the southern region of the Straits of Malacca is richer in ray resources.

Rays were most abundant at depths below 40m on the east coast. The overall catch rate for the whole surveyed area declining trend from 9.19kg/hr during the survey in 1971, to 6.49kg/hr in 1981, and 0.88kg/hr in 1995.

Deep-sea or offshore area

The catch rates of sharks and rays in deeper water beyond 30 nautical miles (nm) off the coastline on the west coast and beyond 12nm off the east coast are shown in Table 4. Sharks were caught in very few hauls off the west coast. The catch rates in depths 56-91 m in the waters off Penang/ north Perak ranged from 0.1 to 5.0kg/hr. The highest average catch rate was 14.0kg/hr in water of 56-91 m deep off south Selangor (Table 4). On the east coast, sharks were rarely caught in the northern part off Kelantan. The highest catch rate from individual hauls was attained at l4.0kg/hr in waters 56-91 m off Terengganu. Over the rest of the area, the catch rates ranged from less than 0.1 kg/hr to 15.0kg/hr, with the highest mean catch per stratum recorded at 7.0kg/hr in water between 56 and 91m off Pahang (Table 4).

Table 4. Catch rates (kg/hr) of sharks and rays from the trawl survey in the offshore (>30nm from coast) off the west and east coast of Peninsular Malaysia.

West Coast

	Kedah			Nouth Perak	South Perak North Selangor	South Selangor	
Depth(m)	**18-55**	**46-91**	**92-183**	**56-91**	**56-91**	**18-55**	**56-91**
Rays	—	—	0.4	5.6	—	14.0	—
Sharks	—	—	—	0.4		—	14.0

East Coast

	North Kelantan		Kelantan North Trengganu	Trengganu	Pahang	Johore	
Depth(m)	**18-55**	**56-91**	**92-183**	**56-91**	**56-91**	**18-55**	**56-91**
Rays	—	0.2	—	1.0		2.9	6.8
Sharks	—	0.1	—	2.4	1.7	7.0	0.8

Source: Data obtained from catches of research vessel at stratified random sampling stations

The highest ray catch rate was in the 18-55m depth stratum off south Selangor, at 14.0kg/hr. This was due to a single successful haul. Two hauls in the 56-9lm stratum off Perak yielded even higher catch rates of between 30.1 and 60.0kg/hr, but the absence of rays in other hauls caused the average catch rate to decrease to 5.6kg/hr. On the east coast, rays were occasionally caught. The highest incidental catches ranged from 15.1 to 30.0kg/hr and were caught within the southern half of the region.

Percentage of sharks and rays in the total catch

The percentage of sharks and rays within the total fish catch was compared for all trawl surveys conducted by the Fisheries Research Institute, off both coasts of Peninsular Malaysia (Table 5).

The percentage of sharks within the total west coast fish catch varied throughout the period surveyed (Table 5). These varied between 0.50% and 3.02% and were much lower than rays. Sharks formed less than 1% of the total catch except in the 1980 and 1988 surveys. Percentages were highest in depth strata exceeding 30m. Off the north-east coast (Table 5), sharks appeared in all depth strata. It appears that the overall high catch composition of sharks in 1990 was the result of a relatively high catch composition of sharks in each of the depth strata.

Off the north-west coast (Table 5), the percentage of rays within the total fish catch increased from 0.4% in 1972 to 13.5% in 1988. However, they declined in the 1990/91 and 1992/93 surveys to 4.0% and 2.4%, respectively. The percentage of rays to the total catch off the south-west coast was even higher at 14.3% in 1973. The percentage of rays in the total catch off the east coast (Table 5) increased from 1.5% in 1970 to 10.3 % in 1990, but appeared to be declining in the surveys carried out in 1991(4.7%) and 1995 (1.9%).

Rays appear predominantly in shallower strata up to 50m. The percentage of rays in total catches in the 10-30m depth zone off the east coast increased from 1.1% in 1974 to 17.4% in 1988 (Table 5). In subsequent surveys, in 1990, 1991 and 1995, their contribution dropped to between 3.8% and 5.3%. The waters of the 31-50m depth strata appeared to be the next most important stratum for rays off the east coast with a contribution to the total catch of 18.4% in 1990. However, off the north-west coast (Table

Table 5. Percentage of catch by weight of sharks and rays by depth strata from trawl survey on northwest and east coasts of Peninsular Malaysia.

	West Coast			East Coast		
Depth(m)	10-29	30-49	50-70	10-29	30-49	50-70
Sharks						
1970				0.92	1.61	1.28
1971	0.14	1.36	7.64	2.23	1.87	2.15
1972	1.62	0.48	0.97	0.77	1.04	1.91
1974	0.29	4.12	0.33	1.18	1.78	0.33
1978	0.17	1.83	0.26			
1980	0.35	5.21	0.14			
1981	—	0.35	0.83	0.68	0.11	0.48
1983				0.36	3.38	0.15
1984	0.18	1.39	—	0.21	2.02	0.93
1986	0.15	0.51	—			
1988	—	9.00	1.17	2.62	2.09	0.95
1990				3.74	2.77	4.83
1991				0.08	1.36	0.69
1990/91	0.03	3.64	—			
1991/92						
1992/93	—	1.44	—			
1995				0.22	0.72	0.45
Rays						
1970				1.21	2.11	2.02
1971	6.43	21.35	0.09	5.48	5.95	0.61
1972	—	1.26	0.4	2.92	2.98	2.68
1974	6.65	4.7	4.93	1.05	3.21	0.57
1978	0.8	3.81	1.61			
1980	2.91	4.43	6.51			
1981	2.21	3.71	2.51	10.85	2.72	2.01
1983				8.1	7.58	0.08
1984	8.55	5.8	—	13.48	6.15	1.49
1986	20.09	4.13	7.92			
1988	3.13	43.27	3.34	17.39	2.97	3.51
1990				5.33	18.42	0.64
1991				3.75	5.09	3.18
1990/91	10.22	11.14	2.32			
1991/92						
1992/93	5.38	2.75	—			
1995				4.49	1.05	2.56

Source: Data obtained from catches of research vessel at systematic randam sampling stations

5), depth stratum 41 -50m had the most consistent catches, with a peak of 37.7% in 1988. The south-west coast also recorded high levels of rays in depth strata 31-40m and 41-50m. Overall, on the west coast the ray percentage of 15.4% was much higher in the southern region than the maximum of 8.6% in the northern region.

Exploitation of elasmobranchs

Alias (unpublished report) applied Fox's Surplus Production Model to the west coast annual statistics from 1969 to 1991 and provided yield-effort curves for every species including sharks and rays. The Maximum Sustainable Yield (MSY) estimated for sharks on the west coast was l,274t for a total effort of 538,753 of trawler horsepower (hp). The MSY and fMSY values for rays were estimated at 4,240t and 1,325,3 l0hp, respectively. This indicates that landings on the west coast of Peninsular Malaysia of sharks and rays have been exceeding the MSY value since 1985 and 1986, respectively. The status of these resources on the east coast has not been assessed so far. However, considering the extension of the area and the expansion of deep-sea trawl fishing, this resource may have already been fully exploited or be close to it.

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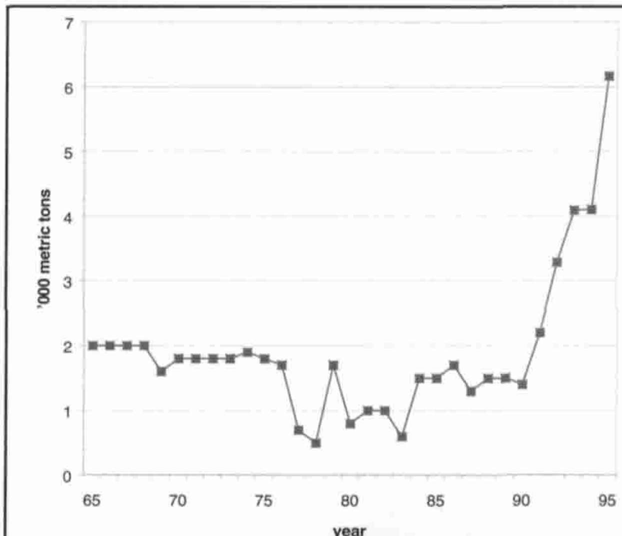
Status and Trends of the Elasmobranch Fishery in Sabah, Malaysia: A Brief Overview

Mr E. Rooney Biusing
Department of Fisheries, Menara Khidmat, 88628 Kota Kinabalu, Sabah, Malaysia

During the 1991-1994 period, elasmobranch fisheries contributed a total of 2.4%(13,370t) by volume and 1.0% (RM13.5 million) by wholesale value of the total marine fish landings in Sabah. The total elasmobranch landings in 1995 was estimated at about 6,170t, an increase by 50% and 180% over the previous year (4,1 10t) and the 1991 period (2,200t) respectively (Figure 1). A total of 19,020t of elasmobranchs were landed during the 1991 1995 period, with sharks contributing about 58% (10,930t) of the landings. During this period, most of the shark production came from the upper east coast zone (440-1,150t or 31-46% of their annual landings). The lower east coast zone contributed the largest portion of the ray landings (230-1,660t or 29-65% of their annual landings).

Figure 2 illustrates the important fishing grounds of Sabah. The annual CPUE trend by gear type for the elasmobranch fishery is shown in Figure 3. Commercial gears (particularly trawl nets, some gillnets and hook and line tuna fisheries) formed the backbone of the fishery, contributing about 70% and 67% respectively of the cumulative shark and ray landings. In general, it is believed that some of the elasmobranch landings, particularly from traditional gear types, were not recorded in the



(* year 1965-1978 - sharks and rays are pooled in the landing statistics. Two sampling methods were used in the estimation of landing statistics: 1965-1990 – market sampling only, 1991-onwards – gear sampling with wider sampling coverage)

Figure 1. Elasmobranch landings in Sabah (East Malaysia). (Source: Department of Fisheries Sabah annual statistics for 1965-1995.)

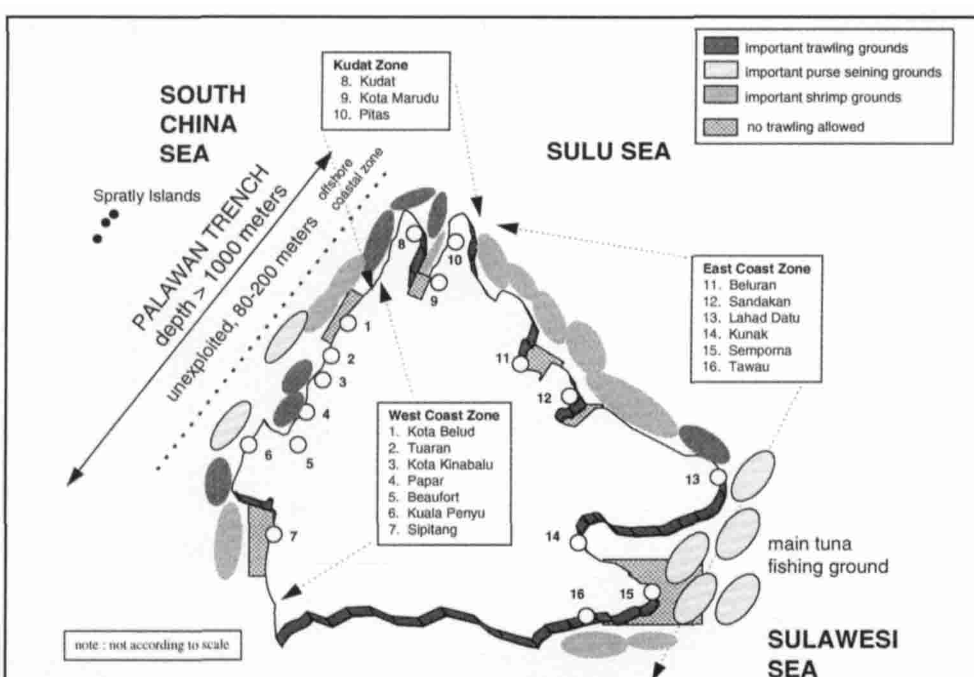


Figure 2. Fishing grounds of Sabah (East Malaysia).

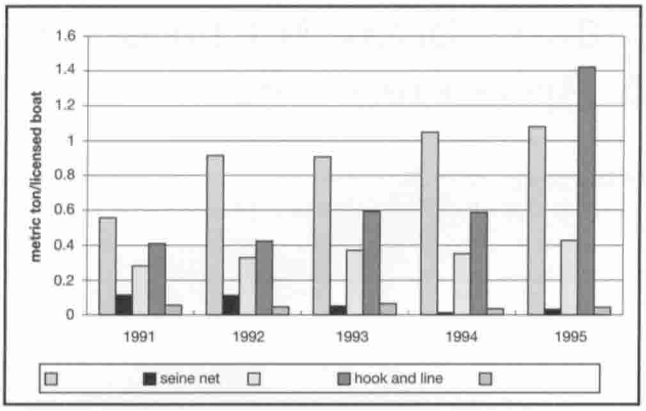


Figure 3. Annual CPUE (mt/boat) of the elasmobranch fishery, Sabah (East Malaysia). (Source: Department of Fisheries Sabah annual statistics for 1991-1995.)

present statistics-sampling program. Freshwater elasmobranch landings were not recorded although it is generally believed that their contribution is not significant to the overall elasmobranch landings. Most of these landings occurred in the east coast zone, particularly along the Kinabatangan river.

Elasmobranchs are either sold fresh or processed into dried and salted products. The meat is mainly for local consumption, while processed shark fins are for both local and international markets. During the 1991-1995 period, the cumulative export and import volume of processed shark fins were reported respectively at about 20.06t (value: RM4.07million)and l0.46t(value:RM0.74million) (Figure 4), with Peninsular Malaysia as the main trading partner (94% and 76% of total export and import volume). About 15% of the imports came from Hong Kong (8%) and Indonesia (7%), and about 5.5% of exports were for Sarawak (2.9%) and Brunei (2.6%) (Figure 5). During this period, the average prices of exported and imported processed shark fins were estimated respectively to be approximately RM204/kg and RM71/kg.

Information on the distribution of elasmobranchs in Sabah is thus far limited to the study carried out under the recently completed Darwin Project. Studies on their biology and stock assessments are urgently needed to provide an important basis for the formulation of appropriate management and regulatory measures for sustainable exploitation.

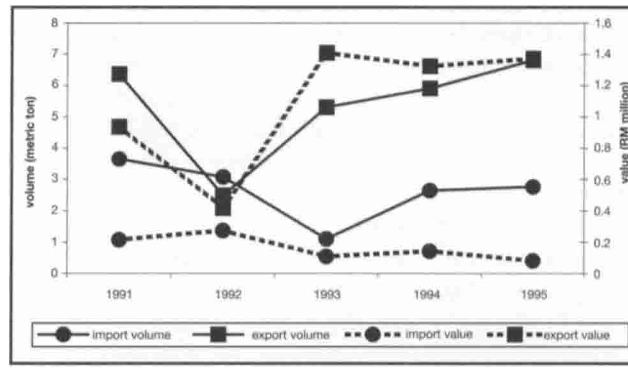


Figure 4. Shark fin trade, Sabah (East Malaysia). (Source: Department of Fisheries Sabah annual statistics for 1991-1995.)

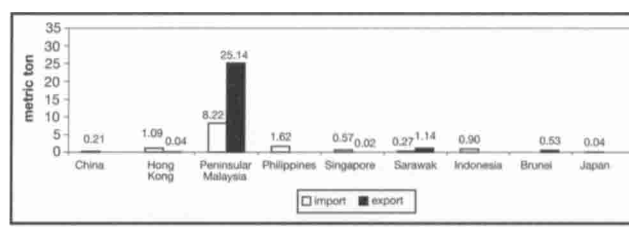


Figure 5. Import and export of shark fins, Sabah (East Malaysia). (Source: Department of Fisheries Sabah annual statistics for 1991-1995.)

Taiwan's Shark Fishery - An Overview

Che-Tsung Chen
National Kaohsiung Institute of Marine Technology, 142 Haichuan Road, Nantzu, Kaohsiung, Taiwan
Kwang-Ming Liu, Shoou-Jeng Joung
National Taiwan Ocean University, 2 Pei-Ning Road, Keelung 20224, Taiwan
Marcus J. Phipps
TRAFFIC East Asia, 2001 Double Building, 22 Stanley Street, Central Hong Kong

Between 1985 and 1995 the annual landing of sharks in Taiwan ranged from 39,000 to 74,000t, some 7.3% of the world's total shark catch. Of Taiwan's shark landings 85% are from deep-sea fisheries, caught on the high seas or in other countries' Exclusive Economic Zones. Three major fishing grounds are the waters around Papua New Guinea, Indonesia and Mozambique. In addition, the bulk of Taiwan's remaining shark catch was bycatch from tuna longliners and trawlers. The major species landed are silky shark, oceanic whitetip shark, shortfin mako, thresher sharks, hammerhead sharks, blue shark and silvertip shark. Two major bases for coastal and offshore shark fishery in Taiwan, Chengkaung and Nanfang Ao, together landed 4,518t of shark (85% of Taiwan's total coastal and offshore shark landings). The dominant shark species are bigeye thresher, pelagic thresher, scalloped hammerhead, smooth hammerhead, sandbar shark, oceanic whitetip shark, silky shark, dusky shark, spinner shark, blue shark, shortfin mako and tiger shark. The major fishing methods are bottom longline and drift net. The price of sharks caught in coastal waters ranged from US$0.7/kg for blue shark to US$7/kg for whale shark. The sharks were utilised completely, i.e. meat, skin, stomach, intestine and fins for food, and liver and cartilage for medicinal use.

Introduction

Sharks are used worldwide for their meat, skins, fins, cartilage, jaws and livers (Bonfil 1994). There is increasing concern that heavy, largely unregulated trade in shark species is contributing to a decline in global shark stocks. Efforts by the IUCN/SSC Shark Specialist Group and relevant national and international authorities to gauge the current level of threat are hindered by a lack of data, including data on trade in shark products, and its effects on individual species.

The Class Chondrichthyes - the cartilaginous fishes - is divided into sharks, skates, rays and chimaeras. They are sub-divided into two sub-classes - the Elasmobranchii, sharks, skates and rays, and the Holocephali, rat-fishes (chimaeras), rabbit-fishes and elephant fish (Anon. 1990). Taiwan's waters are home to eight orders, 25 families, 52 genera and 91 species of shark, as well as three orders, 16 families, 24 genera and 55 species of skate and ray (Shen 1993).

Taiwan utilises many shark products, including: fins, shark meat, skin, intestines, cartilage and teeth. Over the period 1985-1995, Taiwan's combined coastal and distant-water shark catch has averaged between 39,000t and 74,000t, accounting for roughly 7.25% of the world catch in 1993 (FAO 1995, Taiwan Fisheries Bureau 1993).

Eighty-five percent of Taiwan's shark landings come from outside Taiwan's own waters (Taiwan Fisheries Bureau 1994). Despite the large quantities of sharks caught, the low price of shark meat has meant that they continue to be predominantly bycatch species. As non-target species, detailed information on shark catch, effort, and fishing grounds has not been collected for inclusion in Taiwan's Fisheries Yearbook. Such information is a prerequisite for any fishery management decisions.

The objective of this study is to document which species of shark are utilised in Taiwan, the quantity harvested, the areas being fished, and the methods and gear employed.

Methods and materials

Historical information on Taiwan's fisheries was adapted from a literature review. Information on the current status of coastal and offshore fisheries was summarised from a questionnaire completed during interviews with 40 local fishers in early 1995. Information on shark yields and prices was gathered from species-specific daily catch and sales data for Nanfang Ao (Suao) and Chengkung fish markets.

Research on distant-water fisheries was conducted between November 1995 and March 1996. Two approaches were used: interviews with fishers and sales data collection and analysis. Captains of fishing vessels were interviewed in Kaohsiung and Tongkang. Interviews of those captains engaged in directed shark fisheries were more detailed and included: dominant species, catch volumes, fishing grounds, timing of operations and fishing gears. For other fisheries with sharks as bycatch more general information was collected, including the proportion of sharks to total catch and dominant species. Fourteen captains and ten managers of fishing companies were interviewed in Chengchen and three fishers (one captain and two managers) in Tongkang.

Foreign sales records were collected from fishing companies and the foreign base landing records (those fish, mainly bycatch, landed and sold abroad) for Kaohsiung city. Domestic sales data were collected from sales records of Kaohsiung's Chengchen fish market. Annual shark bycatch data were taken from the Annual Catch Statistics of Taiwan's tuna longline fishery (Tuna Research Center 1978-1994). Data for annual landings from distant-water shark fisheries were taken from the Fisheries Yearbook - Taiwan Area (Taiwan Fisheries Bureau 1961-1994).

Results

Historical fisheries 1930-1960s

The first description of Taiwan's shark fishery dates back to the 1930s. Nakamura (1936) mentioned that the average annual yield of the shark fishery was about 6,000t, making it the most important in terms of catch, and third in terms of value in Taiwanese fisheries from 1929 to 1933. The major fishing methods for shark fisheries at that time were longline and bottom trawling.

Longline fishery

The main bases for longline fishery were in Suao, Keelung and Kaohsiung. Sharks were the major target species in Keelung and Suao and were bycatch in Kaohsiung, where tuna was the target species. The fishing vessels in Keelung and Suao were 20-30t and made daily trips to coastal waters. The fishing season was from October to April, with a peak in February. The main catch species were scalloped hammerhead *Sphyrna lewini,* shortfin mako *Isurus oxyrinchus,* pelagic thresher *Alopiaspelagicus,* and requiem sharks Carcharhinidae spp. Scalloped hammerhead, pelagic thresher and sandbar shark *Carcharhinus plumbeus* formed 70% of the catch. Shark fins were used for shark-fin soup and meat was used as an ingredient in minced fish products.

The fishing grounds for tuna longliners based in Kaohsiung extended to the South China Sea. A single voyage took two to three weeks and sharks were primarily bycatch. For economic reasons, the fishers brought back shark fins only. The target species were similar to those of Suao including: blacktip reef shark *Carcharhinus melanopterus,* silvertip shark *C. albimarginatus,* shortfin mako and pelagic thresher.

Bottom trawling fishery

The main base of this multi-species fishery was in Keelung, and sharks (mostly small demersal species) were bycatch. In the 1960s, the annual yield of sharks was about 17,000t, three times that of the 1930s, and it occupied second place in the fisheries. Additional methods were drift longline, bottom trawling and harpoon (Teng 1962). There were 30 trawlers larger than l00t and the remainder were 70-100t. The operations area was in northern Taiwan, the Taiwan Straits and the South China Sea. The major species caught by this multi-species fishery were zebra bullhead shark *Heterodontus zebra,* leopard shark *Triakis semifasciata,* zebra shark *Stegostoma fasciatum,* hardnose shark *Carcharhinus macloti,* spottail shark *Carcharhinus sorrah,* slender bambooshark *Chiloscyllium indicum* and Japanese tope shark *Hemitriakis japanica.* The fishing season was from September to the following June.

Drift longline fishery

By the 1960s, the fishing vessels of Kaohsiung, Keelung, Aoti and Suao had increased to 450 in number and vessels tended to be larger than 30 years earlier. Four hundred vessels of 20-50t had their main fishing grounds in the South China Sea, where an average voyage lasted 7-10 days. Forty tuna longliners of 50-100t had fishing grounds extended to the East Indian Ocean, where an average voyage lasted one month. Four tuna longliners were larger than 350t and their fishing grounds were in the west Indian Ocean, where an average voyage took about two months. The species caught by these vessels were similar to those 30 years earlier.

Bottom longline fishery

The main bases for this fishery were in Nanliao, Tahsi, Suao, Hualien and Tongkang. The kitefm shark *Dalatias licha,* Taiwan gulper shark *Centrophorus niaukang,* red stingray *Dasyatis akajei* and birdbeak dogfish *Deania calcea* were the dominant catch species. The sixgill shark *Hexanchus griseus,* sharpnose sevengill shark *Heptranchias perlo,* shortspine spurdog *Squalus mitsukurii* and silver chimaera *Chimaera phantasma* were caught occasionally.

Harpoon fishery

The main bases of harpoon fishery were Keelung, Suao, Hualien, Chengkung and Henchien. The fishing season matched the trade wind season (October-April). The smooth hammerhead *Sphyrna zygaena,* shortfin mako and especially the spinetail devilray *Mobulajapanica* were the dominant catch species.

Current coastal and offshore fisheries

The major bases for coastal and offshore shark fishery are in Chengkung and Nanfang Ao. According to market data for 1993, these two harbours landed 4,518t of sharks (Tables 1 and 2) accounting for 84.5% of Taiwan's total coastal and offshore shark landings (5,343t; Table 3). In addition, these two ports are home to the only directed

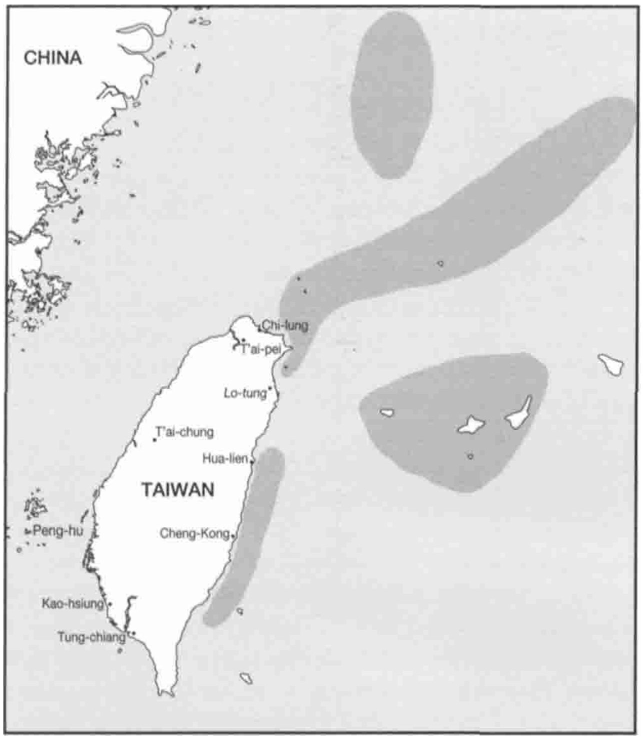


Figure 1. Map of Taiwan showing adjacent shark fishing grounds.

shark fishery vessels in Taiwan, so Nanfang Ao and Chengkung were chosen as focal points for the coastal and offshore section of this study.

There are 20 shark fishing vessels in Nanfang Ao. Most of these vessels target sharks from September-April and shift to other species in the remaining months of the year. The major method used is the bottom longline, fishing at depths between 80-200m. Only three to five fishing vessels target sharks year-round. There are four major fishing grounds for sharks off Suao as follows:

1. the coastal waters from 121°50'E to 122°20'E and 24°30'N to 25°30'N, where the dominant species are bigeye thresher *Alopias superciliosus* and pelagic thresher *Alopias pelagus;*
2. from 122°30'E to 123°30'E and 26°30'N, where the dominant species is the shortfin mako *Isurus oxyrhinchus;*
3. along the 200m isodepth contour line from Peng Jia Yeu through to the Tiaoyutai islands, Huang Wei Yeu, Chih Wei Yeu to 126°E, where the dominant species are smooth hammerhead *Sphyrna zygaena*, scalloped hammerhead *S. lewini*, sandbar shark *Carcharhinus plumbeus*, silky shark *C. falciformis*, oceanic whitetip shark *C. longimanus*, spinner shark *C. brevipinna* and dusky shark *C. obscunis;*

Table 1. Annual landing of sharks at Nanfang Ao fish market (t) 1989-1994.

Species	1989	1990	1991	1992	1993	1994	Overall average
Alopiassuperciliosus	161.7 (9.4%)	197.2 (10.1%)	274.1 (13.4%)	180.3 (11.2%)	202.3 (10.9%)	320.0 (18.0%)	222.6 (12.2%)
Alopiaspelagicus	215.2 (12.5%)	161.3 (8.3%)	190.7 (9.3%)	272.2 (16.9%)	353.2 (19.0%)	140.3 (7.9%)	222.2 (12.2%)
Carcharhinusbrevipinna	92.8 (5.4%)	136.3 (7.0%)	179.9 (8.8%)	57.5 (3.6%)	110.9 (6.0%)	84.7 (4.8%)	110.4 (6.0%)
Carcharhinusfalciformis	31.0 (1.8%)	31.4 (1.6%)	33.9 (1.7%)	51.3 (3.2%)	52.2 (2.8%)	82.3 (4.6%)	47.0 (2.6%)
Carcharhinuslongimanus	27.7 (1.6%)	14.2 (0.7%)	16.6 (0.8%)	31.4 (2.0%)	31.6 (1.7%)	43.5 (2.5%)	27.5 (1.5%)
Carcharhinusobscurus	204.2 (11.8%)	284.1 (14.6%)	339.2 (16.6%)	172.2 (10.7%)	261.9 (14.1%)	193.1 (10.9%)	242.5 (13.3%)
Carcharhinusplumbeus	133.7 (7.7%)	160.4 (8.3%)	139.9 (6.8%)	112.1 (7.0%)	106.5 (5.7%)	95.6 (5.4%)	124.7 (6.8%)
Galeocerdocuvier	12.9 (0.7%)	44.5 (2.3%)	10.6 (0.5%)	61.4 (3.8%)	34.8 (1.9%)	24.4 (1.4%)	31.4 (1.7%)
Isurusoxyrinchus	328.0 (19.0%)	361.0 (18.6%)	412.2 (20.2%)	304.9 (19.0%)	337.9 (18.2%)	417.9 (23.6%)	360.3 (19.7%)
Sphyrnazygaena	65.7 (3.8%)	65.1 (3.3%)	64.4 (3.1%)	57.9 (3.6%)	74.1 (4.0%)	65.7 (3.7%)	65.5 (3.6%)
Sphyrnalewini	450.9 (26.1%0	484.3 (24.9%)	383.1 (18.7%)	304.9 (19.0%)	287.4 (15.5%)	307.0 (17.3%)	369.6 (20.2%)
Others	1.9 (0.1%)	4.4 (0.2%)	0.6 (0.0%)	2.3 (0.1%)	2.8 (0.2%)	0.0 (0.0%)	2.0 (0.1%)
Annual yield	1,725.7	1,944.2	2,045.2	1,608.4	1.855.6	1,774.5	

Note: (% of total) Source: Chen *et al.* 1995.

Table 2. Annual landing of sharks at Chengkung fish market (t) 1989-1994.

Species	1990	1991	1992	1993	1994	Overall average
Alopias superciliosus	52.7 (31.2%)	104.4 (44.9%)	98.2 (40.5%)	85.7 (32.2%)	35.4 (14.5%)	75.3 (32.6%)
Alopias pelagicus	11.8 (7.0%)	29.3 (12.6%)	10.7 (4.4%)	23.4 (8.8%)	44.1 (18.1%)	23.9 (10.3%)
Carcharhinus brevipinna	7.1 (4.2%)	5.5 (2.4%)	2.4 (1.0%)	7.3 (2.8%)	9.8 (4.0%)	6.4 (2.8%)
Carcharhinus falciformis	3 3 (2.0%)	12.3 (5.3%)	4.6 (1.9%)	4.9 (1.8%)	5.6 (2.3%)	6.1 (2.7%)
Carcharhinus longimanus	0.5 (0.3%)	1.8 (0.8%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.5 (0.2%)
Carcharhinus obscurus	4.0 (2.4%)	1.2 (0.5%)	0.01 (0.0%)	0.2 (0.1%)	0.0 (0.0%)	1.1 (0.5%)
Galeocerdo cuvier	1.8 (1.1%)	2.1 (0.9%)	4.0 (1.6%)	4.1 (1.6%)	6.7 (2.8%)	3.7 (1.6%)
Isurus oxyrinchus	31.2 (18.4%)	20.9 (9.0%)	30.3 (12.5%)	52.7 19.8%)	53.3 (21.9%)	37.7 (16.3%)
Prionace glauca	20.8 (12.3%)	22.8 (9.8%)	46.3 (19.1%)	47.6 (17.9%)	48.6 (19.9%)	37.2 (16.3%)
Sphyrna zygaena	0.1 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	4.7 (1.9%)	1.0 (0.4%)
Sphyrna lewini	35.7 (21.1%)	32.0 (13.8%)	45.2 (18.6%)	40.1 (15.1%)	32.9 (13.5%)	37.2 (16.1%)
Others	0.0 (0.0%)	0.5 (0.2%)	0.8 (0.3%)	0.2 (0.1%)	2.8 (1.2%)	0.86 (0.4%)
Annual yield	169.0	232.8	242.6	266.2	243.9	230.9

(% of total)

Table 3. Shark yield in Taiwan fisheries (t) 1981-1995.

Year	Total shark landings in Taiwan	Distant-water: Total landings	Distant-water: Trawl	Distant-water: Tuna longline	Distant-water: others*	Offshore: Total landings	Offshore: Trawl	Offshore: Gill-net	Offshore: Longline and others	Coastal: Total landings	Coastal: Set-net	Coastal: Gill-net	Coastal: Spear	Coastal: others
1981	**40,628**	**25,737**	3,784	18,576	3,377	**14,246**	1,262	2,737	10,247	**646**	129	311	0	186
1982	**44,928**	**27,104**	3,200	17,476	6,428	**17,313**	2,262	3,050	12,001	**511**	56	350	0	105
1983	**41,026**	**24,738**	2,666	16,814	5,258	**1,547**	1,999	2,329	11,142	**818**	382	258	0	178
1984	**45,703**	**31,304**	2,664	19,153	8,487	**13,772**	2,483	2,459	8,830	**627**	162	343	0	122
1985	**53,207**	**40,482**	2,204	20,311	18,327	**11,557**	2,854	2,584	6,119	**808**	96	411	0	301
1986	**44,078**	**33,280**	7,394	11,217	14,669	**10,144**	2,246	1,855	6,043	**654**	173	420	0	61
1987	**48,108**	**39,984**	10,233	11,685	18,066	**7,545**	997	1,569	4,979	**579**	77	467	0	35
1988	**41,426**	**32,839**	12,069	14,322	6,448	**8,058**	986	1,450	5,622	**529**	68	444	0	17
1989	**51,889**	**42,084**	17,548	14,649	9,887	**9,241**	1,262	1,829	6,150	**564**	35	188	209	132
1990	**73,947**	**6,695**	25,769	26,117	15,064	**6,626**	706	1,072	4,848	**372**	86	138	111	37
1991	**68,097**	**60,513**	21,571	24,933	14,009	**7,309**	1,374	1,030	4,905	**275**	49	140	81	5
1992	**64,048**	**57,526**	12,547	36,031	8,948	**5,746**	1,195	534	4,017	**776**	296	120	338	22
1993	**55,407**	**50,064**	9,938	40,126	0	**4,818**	952	617	3,249	**525**	168	244	85	28
1994	**38,924**	**33,530**	7,862	2.401	23,267	**4,934**	1,148	556	3,230	**460**	105	240	86	29
1995	**43,418**	**36,844**	742	8,106	21,309	**5,859**	842	612	4,405	**715**	117	265	39	294

Source: *Fisheries Yearbook Taiwan Area,* 1981 throught 1995 (Taiwan Fisheries Bureau)

*Prior to 1993. the category of "other" included sharks caught in drift-net fishing operations while bottom longline shark catch was reported under tuna longline. Drift-net fishing was prohibited in Taiwan from 1 January 1993 resulting in a "0" entry for "other" in 1993. From 1994, bottom longline catch has been reported under the category of "other".

4. from 122°40'E to 125°E and 24°N to 25°N, where the tiger shark *Galeocerdo cuvier* is the dominant species.

There are three different fishing types in Chengkung: longline, drift-gill net and set-net. Only large-mesh driftnets and mid-water longlines specifically target sharks. The large-mesh driftnet fishery targets bigeye threshers and pelagic threshers. The mid-water longlines target requiem sharks, scalloped hammerhead, blue shark and shortfm mako.

In addition to the above, some other fishing methods (e.g. tuna longline, billfish gillnet and bonito gillnet) catch sharks as bycatch, including: whale shark *Rhincodon typus*, shortfm mako, great white shark *Carcharodon carcharias*, blacktip reef shark *C. melanopterus*, blue shark, Japanese topeshark *Hemitriakisjapanica*, smooth hammerhead and scalloped hammerhead. Whale sharks are also sometimes caught in set-nets as bycatch.

The fishing season and distribution of dominant shark species

The results of interviews conducted with local fishermen in Nanfang Ao (n=20) and Chengkung (n=20) using a questionnaire, are summarised below.

1. **Bigeye thresher *Alopias superciliosus***
   There are two main fishing grounds for this species, one at 24°30'N-25°30'N and west of 122°30'E for Nanfang Ao fishing vessels and the other at 22°40'N -23°20'N and west of 121°40'E for Chengkung shark fishery vessels. January-May and November-December are the major seasons for Chengkung fishing vessels. The fishing methods are longline for Nanfang Ao fishing vessels at depths of more than 50m and large-mesh driftnet at less than 50m for Chengkung fishing vessels.
2. **Pelagic thresher *A. pelagicus***
   Caught year-round, for Nanfang Ao vessels the major seasons are January-April and October-December, and February-April for Chengkung vessels. The fishing grounds and operational depths were similar to those for the bigeye thresher.
3. **Scalloped hammerhead *Sphyma lewini***
   The major fishing ground for Nanfang Ao fishing vessels is along the 200m isobath contour line from Peng Jia Yeu, Huang Wei Yeu, Chih Wei Yeu to 126°E. The major fishing ground is from 22°20'N to 22°40'N and 121°E to 121°20'E for Chengkung fishing vessels. This species is caught by longline vessels at a depth of 40-100m for both sites, with the peak in September-March for Nanfang Ao and November-March for Chengkung.
4. **Smooth hammerhead *S. zygaena***
   The fishing ground in Chengkung is from 121°20'E to 121°40'E and 22°20'N to 22°40'N, otherwise fishing details are similar to those for the scalloped hammerhead.
5. **Sandbar shark *Carcharhinus plumbeus***
   The major season is from September-March. This species is mainly caught from Nanfang Ao, with little from Chengkung. The major fishing ground is from Peng Jia Yeu along the 200m isobath line to Huang Wei Yeu, Chih Wei Yeu waters. This species can be caught at depths of 40-120m.
6. **Oceanic whitetip shark *C. longimanus***
   As with the sandbar shark, this species is mainly caught by Nanfang Ao fishing vessels. The fishing season is from June-August, with fishing grounds in the waters south to the 200m isobath line of north-eastern Taiwan. This species can be caught at a depth of 40-120m.
7. **Silky shark *C. falciformis***
   This species is caught by longliners mostly from Nanfang Ao. The fishing grounds for this species are the same as those for the oceanic whitetip shark. The Nanfang Ao season is from October-December, and January-April in Chengkung.
8. **Dusky shark *C. obscurus***
   All catches came from Nanfang Ao fishing vessels. Although caught year-round, the major season is from October-April. The fishing grounds are identical to those of sandbar shark, oceanic whitetip shark and silky shark but at shallower depths.
9. **Spinner shark *C. brevipinna***
   Most of the catch of spinner sharks is by longliners out of Nanfang Ao. The fishing grounds and season are similar to those for the dusky shark.
10. **Blue shark *Prionace glauca***
    The major fishing season for this species is from May-August and February-May for Nanfang Ao and Chengkung respectively. There are no specific fishing grounds.
11. **Shortfin mako *Isurus oxyrinchus***
    The major season in Chengkung is from January-May and there are no specific fishing grounds. The major fishing season in Nanfang Ao is from November to April and the fishing ground is from 122°30'E to 123°30'E and 26°30'N to 27°30'N.
12. **Tiger shark *Galeocerdo cuvier***
    Caught by longliners, the major fishing season for tigersharks in Chengkung is from February-April in fishing grounds close to the Philippines. The major fishing season in Nanfang Ao is from June-July in waters around Yu Na Kuo Island, Shi Piao Island and Shi Huan Island (122°30'E-124°30'E and 24°N-24°50'N).

Fluctuations in shark yield for coastal and offshore fisheries

Collection of this data is from sales records for a six-year period in Nanfang Ao (1989-1994) and a five-year period in Chengkung (1990-1994) (Table 2).

Nanfang Ao

The annual landing of sharks at Nanfang Ao (1989-1994) ranged from l,608t to 2,045t (mean l,836t, n=6). As a percentage of the total catch, the scalloped hammerhead was commonest (20.2% of all shark landings); followed by shortfin mako (19.7%), dusky shark (13.3%), bigeye thresher (12.3%), pelagic thresher (12.2%), sandbar shark (6.8%) and spinner shark (6.1%). Other species, such as smooth hammerhead, silky shark and oceanic whitetip shark each accounted for less than 5% of the total shark landings.

Although the scalloped hammerhead ranked first in total weight from 1989 to 1993, its yield decreased yearly from 45It in 1989 to 287t in 1993, down by 36.3%. The catch of shortfin mako increased from 328t in 1989 to a peak of 412t in 1991, declined 26% to 305t in 1992 and slightly recovered in 1993 but at a lower level than in 1991. The catches of the bigeye thresher, spinner shark and dusky shark exhibited similar trends to that of the shortfin mako which reached its peak in 1991, declined in 1992 and recovered slightly in 1993 but without regaining 1991 levels.

The catch of pelagic thresher, silky shark and oceanic whitetip shark increased but, with the exception of the pelagic thresher, only occupied a small portion of the total catch. The sandbar shark had the highest catch of 160t in 1990 and declined one-third to 107t in 1993. The catch of smooth hammerhead was steady but it accounted for only 3.5% of the total catch and was not a dominant species.

Although there is considerable variation in the above figures for individual species, the total catch does not show a significant change. There are 11 potential target species of shark, allowing fishermen to compensate when one commercially important species decreases. This may allow individual species an opportunity to recover. In addition, the seasonal switch in fishing effort from sharks to other commercially prized species such as tuna may also allow for recovery of certain shark stocks.

Chengkung fishing port

The shark landings in Chengkung (Table 2) increased yearly from 169t in 1990 to 266t in 1993, before declining to 244t in 1994. The bigeye thresher was most important (37.2% of all shark landings), followed by the shortfin mako (19.9%), scalloped hammerhead (17.1%), blue shark (14.8%) and pelagic thresher (8.2%). Other species accounted for less than 5% of the total shark landings.

The major fishing method for the Chengkung shark fishery was the large-mesh driftnet which specifically targets bigeye and pelagic thresher sharks, hence, the yield of threshers contributed 45% of total shark landings. The bigeye thresher had in fact declined from 1991 in terms of absolute catch and percentage of total.

Fortunately, the fishing season during which large-mesh driftnets are employed is relatively short, limited to a two-month period from late February to early April. Whilst the catch from the large-mesh driftnet has decreased, that from the longline fishery has increased. However, the yield from longline fishing, although increasing, is still a smaller portion of the total than the yield from large-mesh driftnets, some fishing vessels have begun to target sharks year-round.

Catches of spinner shark increased threefold in 1993 and needs to be closely monitored.

The utilisation of sharks from coastal and offshore fisheries

Most of the sharks were utilised completely. After processing, the fins, including dorsal, pectoral, anal and caudal fins, are sold to restaurants for making shark fin soup. The meat is sold both as fresh meat and as mince. The cartilage is sold for medicinal use. The utilisation of shark products in Taiwan is discussed in more detail below.

The price of sharks in fishery markets

The price of sharks varies according to season and freshness, but the range of variation is not as large as that of billfish and tuna. The price of sharks in the winter (December-February) is higher than in the summer. The average landing price for whole specimens of intact sharks at fish markets (US$/kg) were: pelagic thresher, $1.28—$2.56; bigeye thresher, $0.92-$1.83; smooth hammerhead, $1.46-2.20; scalloped hammerhead, $1.83-$2.75; sandbar shark, $1.83; oceanic whitetip shark, $1.83; tiger shark, $1.10; shortfin mako, $1.83-$2.93; silky shark, $1.83-$2.20; spot-tail shark, $2.01; spinner shark, $2.01; dusky shark, $1.10-$1.46; dogfish sharks, $1.10; blue shark, $0.55-$0.73; silvertip shark, $1.83-$2.20; basking shark, $1.10; whale shark, $2.56-$7.0.

Major fishing grounds for sharks

It is difficult to obtain information on specific fishing grounds for sharks caught as bycatch. However, information can be obtained for the shark longline fishery. There are three major shark fishing grounds (Figure 2):

1. Papua New Guinea (FAO fishing ground 71)

There were 40 directed shark fishing vessels in this area in 1995 and several tuna longliners which catch shark as bycatch. Of these vessels, 60% were from Tongkang, 30% from Kaohsiung, and 10% from Suao, ranging in size from 50–100t. Silky sharks make up 60% of the total catch, oceanic whitetip 30%, whilst shortfin mako, thresher

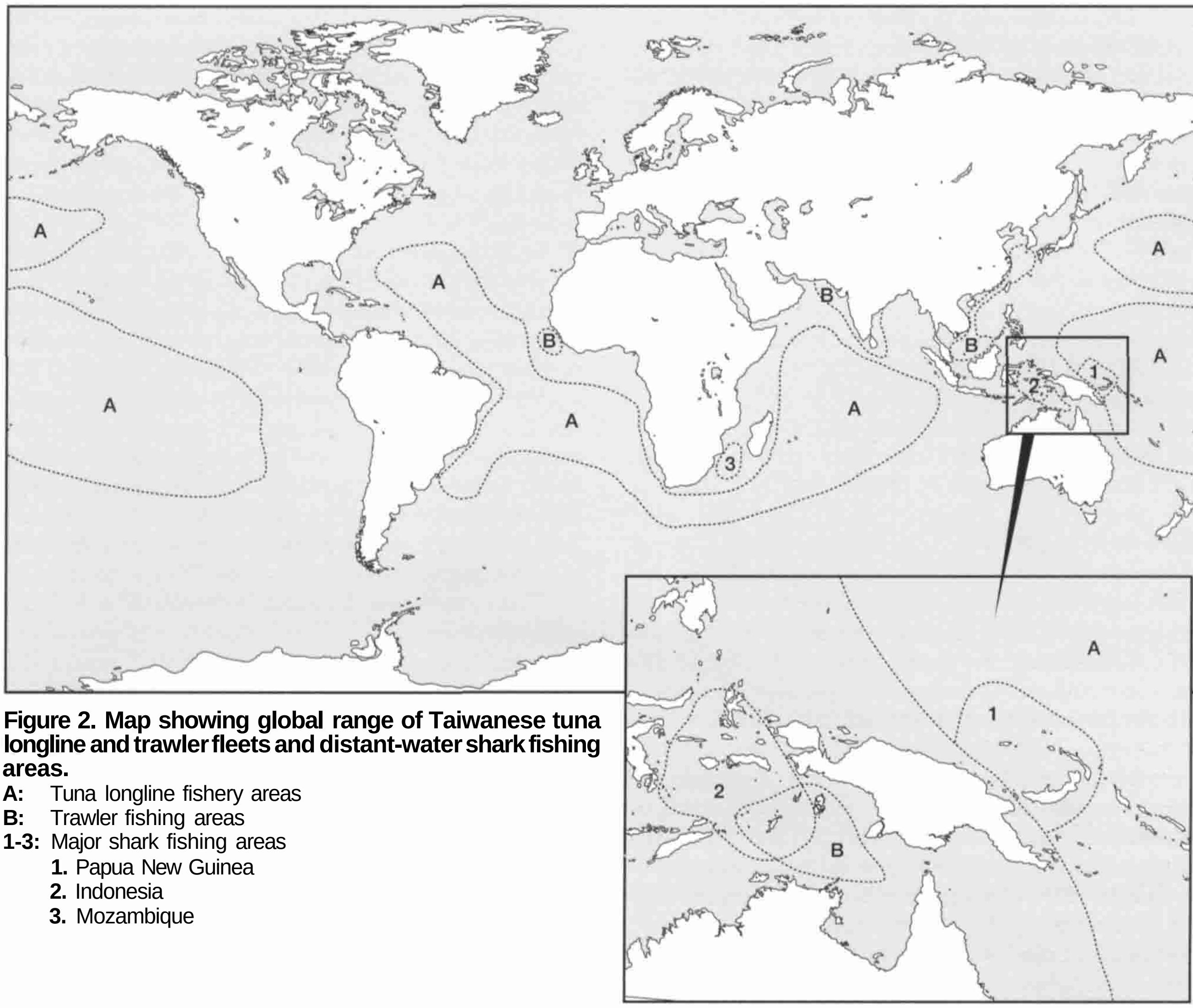


Figure 2. Map showing global range of Taiwanese tuna longline and trawler fleets and distant-water shark fishing areas.

A: Tuna longline fishery areas
B: Trawler fishing areas
1-3: Major shark fishing areas
 1. Papua New Guinea
 2. Indonesia
 3. Mozambique

and hammerhead sharks made up the remaining 10%. The average annual catch of 200t (n=40) per vessel in this area indicated a shark yield of 8,000t in 1995.

2. Indonesia (FAO fishing ground 71)

There were eight directed shark fishing vessels operating in this area in 1995. The fishing ground was located at 122°E, 8°S. These vessels were all from Kaohsiung. Sharks comprised 90% of their catch. The average annual catch of 300t per vessel (n=8) indicated a shark yield of 2,400t. Silky sharks were the dominant species.

3. Mozambique (FAO fishing ground 51)

There were four 300t shark fishing vessels from Kaohsiung making two voyages per year to this area, each averaging catches of 400t. Major species caught in these waters were silvertip sharks, hammerhead sharks, blue sharks, oceanic whitetip sharks and thresher sharks.

The processing and pricing of sharks from distant-water fisheries

Due to the lower value of sharks compared with tuna or billfish, primary processing was conducted immediately after each specimen was caught to maximise the economic value of the fishery, by reducing the volume of fish and increasing the unit price. The fins were cut off and all but the stomach, intestines and carcass discarded. These were transported back to Taiwan with two exceptions: small sharks (under 20kg) and blue sharks. Only the belly flaps of the latter are transported back to Taiwan.

With the exception of the blue shark, landing prices for sharks from distant-water fisheries are similar among species. Buyers can identify certain species of frozen dressed carcass even without the head and fins. Almost all sharks caught in distant water fisheries were transported back to Taiwan with the exception of the shortfin mako which is commonly sold overseas. In 1994, sales records for Chengchen fish market (Kaohsiung) indicated the following auction prices: "large shark" US$0.18-$2.01/ kg; blue shark US$0.22-$0.77/kg; and shark fin (wet) US$0.55-$32.94/kg, depending on size and species.

The fluctuation of shark catch from distant-water fisheries

According to the Fisheries Yearbook - Taiwan Area (Taiwan Fisheries Bureau 1985-1995), the shark landings from distant-water fisheries averaged 6,000t in the 1960s, was 10,000t in 1970, increased to 25,000t in 1975, ranged from 25,000t to 40,000t during 1975-1989, reached a historic high of 67,000t in 1990 and then significantly declined. Landings in 1991 were about 60,000t, 57,000t in 1992, 50,000t in 1993 and 34,000t in 1994.

Skates and rays

Skates and rays are of little importance to Taiwan. In 1980, the total production of skate and rays was just over 3,400t (6.5% of chondrichthyan catch). This has declined steadily.

A note on Taiwan's high-seas driftnet policy

In 1991, the United Nations passed a resolution requesting that all countries adopt a moratorium on the use of large-scale drift nets in high-seas fishing after 31 December 1992. In compliance with the UN resolution, the Council of Agriculture (COA) announced that, from 1 January 1993, driftnet fishing by Taiwanese vessels would be totally prohibited outside Taiwan's 200-mile Exclusive Economic Zone. In addition, the COA took a number of actions to assist fishermen in adjusting to the new regulations. Measures included a buy-back programme for vessels over 15 years old, subsidised loans to finance conversion to new gear types, allowing licenses to be combined to build new purse seiners of over 1,000 gross registered tonnes, and market promotion schemes for alternative species caught after vessels changed shifted from driftnet fishery (Anon. 1993).

Prior to 1993, the statistical category of "other" in the Fisheries Yearbook Taiwan area included sharks caught in driftnet fishing operations, while bottom longline shark catch was reported under tuna longline. Driftnet fishing was prohibited in Taiwan from 1 January 1993 resulting in a "0" entry for "other" in 1993. From 1994, bottom longline catch has been reported under the category of "other".

Discussion

The coastal and offshore shark yield did not decrease significantly in recent years according to the annual fisheries statistics reports and Nanfang Ao and Chengkung's daily catch records. However, certain demersal species once common in coastal and offshore fisheries have shown a decline in catch over the past 10-20 years. Although species-level catch data are unavailable, interviews with fishers and fish market surveys have shown that, during the last decade, some species have become difficult to find.

Existing data are insufficient to draw reliable conclusions on trends in Taiwan's offshore and coastal shark fisheries. In future, more data on species catch levels and fishing effort must be collected. Only then will it be possible to create a workable management regime.

With increasing recognition of the importance of resource conservation in recent years, management regimes and restricted catch quotas have been applied to many important marine resources in the high seas. However, interviews with various commercial fishery owners in 1995 and 1996 indicated that more vessels have engaged in shark fishing since 1990: a signal that distant-water shark fisheries need to be monitored more closely. Research into ways of preventing the collapse of shark populations is an important area for future work.

Recommendations

The conservation and management of shark resources is attracting increasing international attention. In 1991, IUCN/SSC established the Shark Specialist Group (SSG) to promote international research into the status and conservation of shark species. In 1994, the conference of the parties to CITES expressed their concern over increasing volumes of trade in shark products and the lack of available information to determine the impact of that trade.

- Taiwan is home to an important distant-water fishing fleet and is a major fisher of sharks, in excess, perhaps, of 7% of the world's annual total. As such, the international community may, in future, call upon Taiwan to participate in global efforts to manage shark catches. Taiwan needs to be prepared to do so.
- In 1995, Taiwan's top fishery authority, the Council of Agriculture, began preliminary investigations into shark bycatch by Taiwan's fishing fleet. However, the sheer number of vessels involved in distant-water fisheries (over 1,000 tuna longliners and 700 trawlers) makes it difficult to obtain reliable data. In order to improve future data collection, more resources - personnel and financial - need to be made available.
- A comprehensive data-collecting system needs to be established to collect fisheries information including species-level catch data (species, length, weight, sex, age, maturity), landings versus discards, geographical locations and catch per unit effort data. This

information can best be obtained through the combined use of logbooks and observers.

Also critical from a policy perspective is the collection and analysis of socio-economic information on fishers and other user groups. This information, in tandem with biological information, is central to the construction of an effective management system to reach the goals of optimum utilisation and conservation of shark resources.

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Elasmobranch Diversity and Status in Thailand

Chavalit Vidthayanon
Department of Fisheries, Kaset-Klang Chatuchak, BKK 10900, Thailand

The first work to be published on sharks and rays in Thailand was by Fowler (1934). Several studies have been published since. At least 145 species in 34 families of 13 orders have been reported in Thai and adjacent waters. The Thai elasmobranch fauna consists of one species of chimaera, 74 sharks and 70 batoids. Predominant are the ground sharks (Carcharhiniformes) with 49 species in five families, and stingrays (Myliobatiformes) with 45 species in six families. Eighteen elasmobranch species are known from the deep sea, 15 species are oceanic, 108 are coastal and 10 inhabit or penetrate into freshwater.

Four pristid sawfishes are considered to be locally endangered, and 43 species are threatened, especially the two freshwater stingrays, *Himantura chaophraya* and the Mekong River endemic *Dasyatis laosensis.* The main threats to Thai elasmobranchs are habitat loss and overexploitation. Sharks (2,200-4,600t annually) and rays are mainly caught as bycatch of otter-board trawls and gillnets. Major uses are as food, shark fin products and hides. Minor uses are the production of ornamental items and curios, and game fishing. Populations of whale sharks, mantas and other sharks off the southern coasts of the country can be used sustainabiy through dive tourism.

Introduction

Thailand is situated in the centre of the Indo-Pacific region. The country and nearby areas have been defined as a 'biogeographic cross roads', with extremely diverse aquatic and terrestrial faunas. Of c.560 freshwater and c.2,000 marine fish species, only 15 (0.006%) are endemic. The 145 species of 34 families of sharks and rays represent about 13% of the world's species and 61.8% of existing families.

Indo-Burmese, Indo-Chinese and Sundaic elements predominate in inland habitats. Thailand also has two coastlines: the Indian Ocean (Andaman Sea and Malaca Strait) and the Gulf of Thailand on the Pacific Ocean (South China Sea). The country's territorial seas are bounded by the Exclusive Economic Zone (EEZ) of surrounding countries. Because of the demand for protein by an increasing population, overfishing is the main threat to both stocks of Thailand's aquatic resources, as well as to their diversity.

This paper provides a preliminary study and overview of shark and ray diversity, their importance and status, a brief review of known reference materials, fisheries and recent bibliographies. Systematic studies, uses and threatened status are discussed.

Systematics overview

Previous studies on Thai elasmobranch diversity

Records of the elasmobranch fauna in Thailand since Fowler (1934), include the mainly freshwater species obtained from the expeditions of de Schuaensee in Siam (Thailand). Smith (1945) reported six cartilaginous fish species which occur in freshwater, including two species of pristid sawfish. Some sharks and rays were reported in Thai literature as important food fishes (Rofen 1963, Anon. 1969, Thiemmeth 1968). Anon. (1968) reported some endangered species of Thai elasmobranchs. More recent fisheries surveys have reported on the elasmobranch species found in Thai waters and adjacent areas (Pokapunt *et al.* 1993, Wongratana 1968, 1982, 1985, 1989).

Mongkolprasit (1984) wrote a taxonomic and species account of Thai elasmobranchs, recognising four orders, 12 families and 65 species. Three species of stingray from Thai inland waters, new to science, were described by Compagno and Roberts (1982), Roberts and Karnasuta (1987) and Mongkolprasit and Roberts (1990). For the Indo-West Pacific area, there are several references to elasmobranch records which include Thai waters (Compagno 1984a,b, Allen 1988, Allen and Swainston 1988, 1993, Michael 1993, Debelius 1993, De Bruin *et al.* 1994, Kuiter and Debelius 1994, Last and Stevens 1994, Randall 1995).

Systematic account

This paper provides a brief systematic account of the elasmobranch fauna found or expected to occur in Thai waters, together with their taxonomic status and habitats. The elasmobranchs of Thailand previously known include at least 13 orders, 34 families and 145 species, listed in Table 1, and are comprised of 74 sharks, 70 batoids (rays) and one chimaera.

Living sharks

Compagno (1984a,b) revised the systematic account of the world's shark taxa, recognising eight orders and 31 families. Seven orders, 20 families and 74 species known

Table 1. Preliminary Checklist of elasmobranch fauna found and possibly occur in Thai and adjacent waters. Based on Mongkolprasit (1984), Compagno (1984a,b), Last and Stevens (1994), Wongratana (pers. comm., 1985) and Compagno (in litt., 1997).

? = possibly occur, or doubtfu species
EC = economic species; **EN** = endangered, **V** = vulnerable; **end** = endemic

Scientific name	Common name	Status[1]	Deep sea	Oceanic	Coastal. contineiital shelf	FreshWiter euryhlaline
SHARKS						
HEXANCHIDAE						
Heptranchiasperlo	Sharpnose sevengill shark		+			
Hexanchusgriseus	Bluntnose sixgill shark		+			
SQUALIDAE						
Squalusblainvillei	Longnose spurdog		+			
Squalusmegalops	Shortnose spurdog		+			
Sqaulusmitsukurii	Shortspine spurdog		+			
ETMOPTERIDAE						
Etmopterusspinax	Velvet belly		+			
SOMNIOSIDAE						
Zameussquamulosus	Velvet dogfish		+			
SQUATINIDAE						
Squatinanebulosa	Clouded angelshark		+			
HETERODONTIDAE						
Heterodontuszebra	Zebra bullhead shark		+		+	
PARASCYLLIIDAE						
?Cirrhoscylliumexpolitum	Barbelthroat carpetshark		+			
ORECTOLOBIDAE						
Orectolobusmaculatus	Spotted wobbegong		+			
HEMISCYLLIIDAE						
Chiloscylliumgriseum	Gray bambooshark	EC			+	
Chiloscylliumindicum	Slender bambooshark	EC			+	
Chiloscylliumplagiosum	Whitespotted bambooshark	V			+	
Chiloscylliumpunctatum	Brownbanded bambooshark	EC			+	
GINGLYMOSTOMATIDAE						
Nebriusferrugineus	Tawny nurse shark				+	
STEGOSTOMATIDAE						
Stegostomafasciatum	Zebra Shark	V			+	
RHINCODONTIDAE						
Rhincodontypus	Whale shark	V		+	+	
ODONTASPIDIDAE						
Carchariastaurus	Sand tiger shark				+	
ALOPIIDAE						
Alopiuspelagicus	Pelagic thresher			+		
Alopiassuperciliosus	Bigeye thresher			+		
Alopiasvulpinus	Thresher shark			+		
LAMNIDAE						
Isurusoxyrinchus	Shortfin mako			+		
Isuruspaucus	Longfin mako		+			
SCYLIORHINIDAE						
?Apristurusinvestigatoris			+			
Atelomycterusmarmoratus	Coral catshark				+	
Bythaelurushispidus	Bristly catshark				+	
Cephaloscylliumfasciatum	Reticulated swellshark				+	
Cephaloscyllium sp.	Dwarf clouded swellshark		+			
Halaelurusbuergeri	Blackspotted catshark		+		+	
TRIAKIDAE						
lagoomanensis	Bigeye houndshark				+	
Hemitriakisleucoperiptera	Whitefin topeshark				+	
Hemitriakis sp.	Philippine spotted houndshark				+	
?Hypogaleushyugaensis	Blacktip topeshark				+	
Mustelusgriseus	Spotless smoothhound				+	
Mustelusmanazo	Starpotted smoothhound				+	
Mustelusmosis	Moses smoothhound				+	

Table 1 ... continued.

Scientific name	Common name	Status[1]	Deep sea	Oceanic	Coastal, continental shelf	Freshwater euryhaline
HEMIGALEIDAE						
Chaenogaleusmacrostoma	Hooktooth shark				+	
Hemigaleusmicrostoma	Sicklefin weasel shark				+	
Hemipristiselongatus	Snaggletooth shark	V			+	
Paragaleustengi	Straighttooth weasel shark				+	
CARCHARHINIDAE						
Carcharhinusalbimarginatus	Silvertip shark	V			+	
Carcharhinusamblyrhynchoides	Graceful shark	V			+	
Carcharhinusamblyrhynchos	Gray reef shark	V			+	
Carcharhinusamboinensis	Pigeye shark	V			+	
Carcharhinusborneensis	Borneo shark	EC			+	
Carcharhinusbrachyurus	Bronze whaler	V			+	
?Carcharhinusbrevipinna	Spinner shark				+	
Carcharhinusdussumieri	Whitecheek shark	EC			+	
?Carcharhinus falciformis	Silky shark				+	
?Carcharhinusgalapagensis	Galapagos shark			+		
Carcharhinushemiodon	Pondicherry shark				+	
Carcharhinusleucas	Bull shark	V			+	?
Carcharhinuslimbatus	Blacktip shark	EC V			+	
Carcharhinuslongimanus	Oceanic whitetip shark			+		
Carcharhinusmacloti	Hardnose shark				+	
Carcharhinusmelanopterus	Blacktip reef shark	EC V			+	
Carcharhinusobscurus	Dusky shark	V			+	
Carcharhinusplumbeus	Sandbar shark	V			+	
Carcharhinussealei	Blackspot shark	EC V			+	
Carcharhinussorrah	Spottail shark	EC V			+	
Galeocerdocuvier	Tiger shark	V			+	
?Glyphisgangesticus	Ganges shark					?
Lamiopsistemmincki	Broadfin shark				+	
Loxodon macrorhinus	Sliteye shark				+	
Negaprionacutidens	Sharptooth lemon shark	V			+	
Prionaceglauca	Blue shark			+		
Rhizoprionodonacutus	Milk shark	EC V			+	+
Rhizoprionodonoligolynx	Gray sharpnose shark				+	
Scoliodon laticaudus	Spadenose shark	EC V			+	
Triaenodonobesus	Whitetip reef shark	V			+	
SPHYRNIDAE						
Eusphyrablochii	Winghead shark	V			+	
Sphyrnalewini	Scalloped hammerhead	EC V			+	
Sphyrnamokarran	Great hammerhead	EC V		+	+	
?Sphyrnazygaena	Smooth hammerhead			+	+	
BATOIDS (RAYS)						
PRISTIDAE						
Anoxypristis cuspidata	Knifetooth sawfish	EN			+	+
Pristis microdon	Greattooth sawfish	EN			+	+
Pristis pectinata	Smalltooth sawfish	EN			+	
Pristiszijsron	Green sawfish	EN			+	
RHINIDAE						
Rhinaancylostoma	Sharkray	V			+	
RHYNCHOBATIDAE						
Rhynchobatusaustraliae	Whitespotted shovelnose ray	EC V			+	
?Rhynchobatus sp. A	Broadnose wedgefish				+	
?Rhynchobatus sp. B	Roughnose wedgefish				+	
RHINOBATIDAE						
Rhinobatosgranulatus	Sharpnose guitarfish	V			+	
Rhinobatoshalavi	Halavi guitarfish	V			+	
Rhinobatosschlegelii	Brown guitarfish	EC V			+	
Rhinobatos thouini	Clubnose guitarfish	V			+	
Rhinobatostypus	Giant shovelnose ray	V			+	

Table 1 ... continued.

Scientific name	Common name	Status[1]	Deep sea	Oceanic	Coastal, continental shelf	Freshwater, euryhaline
PLATYRHINIDAE						
Platyrhina cf. *limboonkengi*	Amoy fanray		+			
NARCINIDAE						
Narcine brunnea	Brown electric ray	V			+	
Narcine maculata	Darkspotted electric ray				+	
Narcine prodorsalis	Tonkin electric ray				+	
Narcine timlei	Blackspotted electric ray	V			+	
Narcine sp.	Indian electric ray	V			+	
NARKIDAE						
Narke dipterygia	Spottail electric ray	V			+	
Temera hardwickii	Finless electric ray	V			+	
RAJIDAE						
Dipturus sp. 1			+			
Okamejei boesemani	Black sand skate		+			
Raja ocellifer	Ocellated skate		+			
ANACANTHOBATIDAE						
?Anacanthobatis nanhaiensis	South China legskate		+			
UROLOPHIDAE						
?Urolophus aurantiacus	Sepia stingray				+	
POTAMOTRYGONIDAE						
Taeniura lymma	Bluespotted fantail ray	EC			+	
Taeniura meyeni	Fantail stingray				+	
DASYATIDAE						
Dasyatis brevicaudata	Shorttail stingray				+	
Dasyatis cf. *fluviorum*	Estuary stingray				+	
Dasyatis kuhlii	Bluespotted stingray	EC			+	
Dasyatis laosensis	Mekong freshwater stingray	EC V				end
Dasyatis microps	Thickspine giant stingray	V			+	
?Dasyatis ushiei	Cow stingray				+	
Dasyatis zugei	Pale-edged stingray	EC			+	
Dasyatis sp. 1		EC			+	
Himantura bleekeri	Whiptail stingray				+	+
Himantura chaophraya	Giant freshwater stingray	EC V				+
Himantura fai	Pink whipray	EC			+	
Himantura gerrardi	Sharpnose whipray (Species complex, 2 spp.?)	EC			+	
Himantura granulata	Mangrove whipray		+			
Himantura imbricata	Scaly whipray	EC			+	+
Himantura jenkinsii	Golden whipray	EC			+	
Himantura krempfi	Marbled freshwater whipray	EC				+
Himantura marginata	Blackedge whipray				+	
Himantura microphthalma	Smalleye whipray				+	
Himantura oxyrhyncha	Longnose marbled whipray	EC V				+
Himantura signifer	White-edge freshwater whipray	EC V				+
Himantura uarnak	Reticulate whipray	EC			+	
Himantura undulata	Leopard whipray [?= *H. fava]*	EC			+	
Himantura walga	Dwarf whipray	EC			+	
?Himantura sp. A	Brown whipray (2 spp?)				+	
Pastinachus sephen	Cowtail stingray (Species complex, 2 spp.?)	V			+	+
Urogymnus asperrimus	Porcupine ray	V			+	
Urogymnus laevior	Smoothfin porcupine ray				+	
GYMNURIDAE						
Aetoplatea zonura	Zonetail butterfly ray				+	
Gymnura bimaculata	Twinspot butterfly ray				+	
Gymnura sp. cf. *micrura*		EC			+	
Gymnura poecilura	Longtail butterfly ray	EC			+	
MYLIOBATIDAE						
?Aetobatus flagellum	Longheaded eagle ray				+	
?Aetobatus guttatus	Indian eagle ray				+	
Aetobatus narinari	Spotted eagle ray	EC			+	
Aetomylaeus maculatus	Mottled eagle ray				+	

Table 1 ... continued.

Scientific name	Common name	Status[1]	Deep sea	Oceanic	Coastal, continental shelf	Freshwater, euryhaline
Aetomylaeus milvus	Ocellate eagle ray	V			+	
Aetomylaeus nichofii	Banded eagle ray	EC			+	
Aetomylaeus vespertilio	Ornate eagle ray	EC			+	
RHINOPTERIDAE						
?Rhinoptera adspersa	Rough cownose ray				+	
Rhinoptera javanica	Javanese cownose ray	EC			+	
MOBULIDAE						
Manta birostris	Manta			+	+	
Mobula eregoodootenkee	Pygmy devilray				+	
Mobula japanica	Spinetail devilray				+	
Mobula kuhlii	Shortfin devilray				+	
Mobula tarapacana	Sicklefin devilray			+	+	
Mobula thurstoni	Bentfin devilray			+	+	
CHIMAERAS						
CHIMAERIDAE						
Chimaera phantasma	Silver chimaera		+			

1. These are the author's assessments at the time of writing and are not IUCN Red List assessments. The latter are available on www.redlist.org This list is according to local criteria in Thailand: By current occurrence in Thai waters, compared with previous abundance.

to occur or possibly occurring in Thai waters are listed here. Stevens (1987) and Taylor and Taylor (1995) comment on the biology, conservation and danger of sharks, especially in tropical areas.

Order Hexanchiformes, cow and frilled sharks. Two species of the family Hexanchidae, *Heptranchias perlo* and *Hexanchus griseus,* were reported from the deep sea of Phuket (Wongratana 1982, Pokapant *et al.* 1993).

Order Squaliformes, dogfish sharks. Three families of this order occur and possibly inhabit deep water in the South China and Andaman Seas. Three species of the family Squalidae were obtained from deep sea surveys of both offshore areas.

The two families of deep sea sharks which occur in the South China Sea and Indian Ocean may also occur in Thai waters: Etmopteridae, one species of lantern shark *Etmopterus spinax,* and Somniosidae, sleeper sharks (Pokapant *et al.* 1983, Compagno 1984a,b, *in lilt* 1997).

Order Squatiniformes, angel sharks. One species, possibly ***Squatina*** *nebulosa,* has been found at 200m depth in the Andaman Sea (Wongratana 1982).

Order Heterodontiformes, bullhead sharks. The zebra bullhead shark *Heterodontus zebra,* family Heterodontidae, is commonly found off the Malay Peninsula and in Vietnamese waters, but is seldom caught from southern Thailand.

Order Orectolobiformes, carpet sharks. These moderate (bambooshark) to colossal sized (whale shark) species mainly inhabit coastal areas. Six families occur in Thailand and adjacent waters.

— Family Parascylliidae, collared carpetsharks. One species of *Cirrhoscyllium expolitum***,** distributed in the central Indo-West Pacific, may also occur in the deeper zone of Thai waters.

— Family Orectolobidae, wobbegongs. *Orectolobus maculatus* is found in Vietnamese waters and possibly also occurs in moderately deep areas of the Andaman Sea.

- Family Hemiscylliidae, longtailed carpetsharks. The common species of this family inhabit inshore water; four species are found in Thai waters.

— Family Ginglymostomatidae, nurse sharks. Only one species of the large nurse shark *Nebrius ferrugineus* is found in Thai waters. It inhabits inshore areas especially around coral reefs and islands, and is well known to diver tourists as the 'sleepy shark'.

— Family Stegostomatidae, zebra sharks. A monotypic species, with similar habits to the above species, *Stegostoma faseiatum* (= *S. varium* in Randall 1995) is also an attractive fish to shark-watching divers. Widely distributed throughout the Indo-West Pacific, but found in decreasing numbers in Thai waters.

— Family Rhincodontidae, whale sharks. A monotypic circumtropical species, *Rhincodon typus* was reported as the world's largest fish from Thailand (Ko Chic, Chantaburi, Smith 1945). The species is often stranded or killed by fishermen in Thai waters, but is not consumed here. The occurrence of this shark is one of the greatest attractions for diving activities off the southern Thai coasts.

Order Lamniformes, mackerel sharks. Mostly oceanic inhabitants, seven species in three families occur in Thai and adjacent waters.

— Family Odontaspididae, sand tiger sharks. One species, *Carcharias taurus,* inhabits fairly deep inshore areas, but is uncommon in Thai waters.
— Family Alopiidae, thresher sharks. Three species of these oceanic sharks are occasionally reported from pelagic fishing activities or surveys, i.e. drift gillnet, tuna longlines, purse seine nets, mostly from the Indian Ocean.
— Family Lamnidae, mackerel sharks. Two oceanic species are obtained in the same way as the above from the Indian Ocean. The shortfin mako *Isurus oxyrinchus* is more common than the longfin mako *I. paucus.*

Order Carcharhiniformes, ground sharks. The largest taxon of Thai sharks, consisting of five families, and 49 species. Mostly coastal and inshore living forms, these species play important roles in elasmobranch fisheries in this region. Some species are regarded as dangerous to man, but there are no official records of attacks in Thailand.
— Family Scyliorhinidae, cat sharks. Small to moderate size sharks, inhabiting deep sea and inshore waters, these are mostly taken as bycatch of otter-board trawl nets. Six species are found or possibly occur in Thai waters.
— Family Triakidae, houndsharks. These are moderate sized sharks, coastal inhabitants and some are deep sea species. Uncommonly recorded from trawl nets, six species occur in Thai and adjacent areas (Table 1).
— Family Hemigaleidae, weasel sharks. Moderate to large size sharks with similar body shapes to houndsharks. Four species are found, mainly inhabiting coastal areas.
— Family Carcharhinidae, requiem sharks. This is the largest family and it includes the largest-sized groundsharks. These sharks are well-known for their economic importance as well as their potential danger to man. At least 29 species are found in Thai waters (Table 1), mostly inshore but some are oceanic. Two are known to be euryhaline species in the Indo-West Pacific area: *Rhizoprionodon acutus,* which has been found to penetrate the lower reach of rivers (Compagno 1996) and *Carcharhinus leucus,* which is expected to occur in the Mekong River mouth (Rainboth 1996) but has never been seen in Thai rivers. Either *Glyphis* cf. *gangeticus* or maybe *C. leucus* was anecdotally reported from the Karen people along the Salween River of Tak-Mae Hongson Province, northern Thailand. They say that a sacred, voracious fish with a high dorsal fin occurs in the River very rarely. They sometimes provide a sacrifice of a living goat to the fish. No scientific evidence for this has been seen. The carcharhinids are commonly found in fish markets and landing places; they are an important source of shark fin products and some species are regarded as good quality food-fish. Anglers consider requiem sharks to be big game fish. At least 17 species are disappearing or decreasing, and considered to be vulnerable species in Thai waters.
— Family Sphyrnidae, hammerhead sharks. Four species of these distinctive sharks occur in Thai waters, mostly inhabiting deeper areas of coastal waters and some are found in oceanic waters. The winghead shark *Eusphyra blochii* used to be common in Thailand but has now disappeared.

Living batoids (rays)

The Thai batoid fauna includes 70 species of 16 families and five orders. Four are freshwater dwellers, a few are found in deep sea and oceanic habitats, the rest are coastal. They are morphologically diverse, ranging from species with a shark-like appearance to manta rays; some families possess an electro-organ. The largest batoid is the manta ray *Manta birostris,* which attains a disc width of 4m. *Himantura chaophraya* is the largest ray, attaining a width of 2m and weight of 600kg.

Systematic studies of batoids in Thailand are incomplete; see Mongkolprasit (1984) for some species accounts. Nishida (1990) reviewed the phylogenetic relationships of the stingray groups.

Order Pristiformes, sawfishes. One family, the Pristidae, occurs in the Indo-West Pacific. These are large, shark-like batoids possessing a saw-like rostrum, up to 4m in length and weighing up to 500kg. Four species have been recorded in Thai waters, and two of them *(Anoxypristis cuspidata* and *Pristis microdon)* are reported to penetrate to the mid-reach of the Chao Phraya River and tributary (Smith 1945). Recently, specimens have been reported at Nontaburi and Ayuthya 50-100km from the Gulf of Thailand. These coastal species are highly regarded, both for their meat and fins. Their rostrum is usually used as a curio and in Chinese traditional medicines. All species of sawfish are disappearing from Thai waters, and they are considered to be threatened with extinction. The United States Government proposed to the June 1997 Conference of Parties to the Convention in International Trade in Endangered Species (CITES) that all sawfish should be listed in CITES Appendix I (Species Survival Network 1997), but the proposal was unsuccessful.

Order Rhinobatiformes, guitarfishes. These are shark-like batoids without a rostrum, moderate to large in size, which inhabit coastal waters. Three families are found in Thailand.
— Family Rhinidae, sharkrays. One species, the sharkray *Rhina ancylostoma* inhabits deep areas around the offshore islands, and is becoming rare in Thai waters.
— Family Rhynchobatidae, sharkfin guitarfishes or wedgefishes. Large guitarfishes, most with a shovelnose

rostrum. Three species have been recorded and may still occur in Thai coastal waters. The whitespotted wedgefish, known as *Rhynchobatus djiddensis*, may be a mis-identification of *R. australiae* or a different species (Compagno 1997 *in litt.)*.

— Family Rhinobatidae, guitarfishes. These are similar to the Rhinidae, but differ in their fin positions (see Last and Stevens 1994). They are small to moderate in size, and mainly coastal. Five species occur in Thai and adjacent waters. They are heavily exploited as food fish and a source of shark fins, and are considered to be vulnerable.

Order Torpediniformes, electric rays. These small to moderate sized, distinctive rays possess an electric organ in their thick, soft pectoral fins and inhabit coastal waters and sometimes the deep sea. Two families are found in Thai waters; the family Narcinidae, numbfishes (five species), and Narkidae, sleeper rays (two species). Although regarded as useless for consumption, the electric rays are heavily exploited as non-targeted bycatch of the otter-board trawl nets, and are disappearing from Thai waters.

Order Rajiformes, skates. These rays are known mostly from temperate waters, but also occur in the Indo-West Pacific in deeper zones, below 60m. Three species of the family Rajidae have been found off the Malay Peninsula in recent surveys and in the Andaman Sea (Wonngratana 1982).

— Family Anacanthobatidae, legskates. These little known skates occur in the South China Sea. One species may be found in deeper areas of Thai waters.

Order Myliobatiformes, stingrays. The largest taxon of the rays comprises seven families and at least 45 species inhabiting mainly coastal and some oceanic Thai waters. They have become some of the most economically important elasmobranchs, both as food fish and for their hides.

— Family Urolophidae, stingarees. One species, *Urolophus aurantiacus*, of this little known family of stingrays is found in the South China Sea, and possibly occurs in Thai waters.

— Family Potamotrygonidae, fantail stingrays. Two species in the genus *Taeniura* are known from Thailand.

— Family Dasyatidae, whiptail stingrays. The commonest and largest family of rays, with 23 species of four genera known from Thai waters. They inhabit coastal waters and three species are obligate freshwater inhabitants: *Dasyatis laosensis*, the endemic Mekong freshwater stingray, *Himantura signifer* and *H. oxyrhynchus* (known as *H. krempfi*, junior synonym). The cowtail stingray *Pastinachus sephen* is a coastal species, known to penetrate to the inner area of the Chao Phraya River. The large inland river and marine stingrays are heavily fished, both as bycatch and targeted for food and to supply hide products. They are decreasing in number and six species are considered to be vulnerable.

— Family Gymnuridae, butterfly rays. Moderate sized rays, which inhabit coastal and littoral seas. Four species are known from Thailand, taken by trawl nets and gillnets, and regarded as good quality rays for food.

— Family Myliobatidae, eagle rays. These large pelagic rays mainly inhabit areas around offshore islands and coral reefs. Seven species are known from Thai waters, three of which are economically important as food fish, usually taken by gillnet and bottom longlines. The ocellate eagle ray *Aetomylaeus milvus* is a locally rare species.

— Family Rhinopteridae, cownose rays. Similar to the Myliobatidae, but with a round-notched snout. Three species are known from the country; *Rhinopterajavanica* is regarded as a high quality ray for dried product.

— Family Mobulidae, devil rays. Some of the largest rays, widely distributed in the Indo-Pacific region and inhabiting offshore and nearby islands, coral reefs and oceanic areas. Occasionally caught as non-targeted species, but rarely for consumption. Six species are known from Thai and adjacent waters (Wongratana 1974, 1988) and Randall (1995). The manta *Manta birosiris* is often seen at the popular dive site of Similan Island in the Andaman Sea, southern Thailand.

Order Chimaeriformes, chimaeras

Two families of chimaera are known from the South China Sea, but only one species of Chimaeridae, *Chimaera phantasma*, has been recorded from Thailand, possibly in deep water from the Andaman Sea (Wongratana pers. comm.).

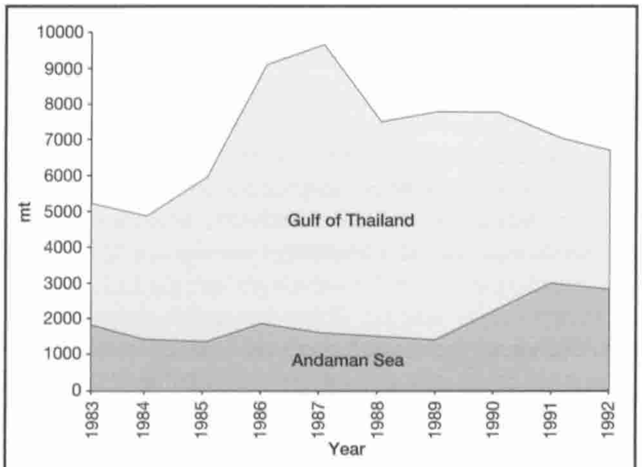
Fisheries and exploitation

Fisheries

Sharks and rays have become increasingly important in several fisheries industries in Thailand. There is no direct fishing for elasmobranchs; all are obtained as bycatch by otter-board trawling and gill net fisheries. Fins form the basis of the lucrative shark fin industry. This trade is seriously threatening shark populations.

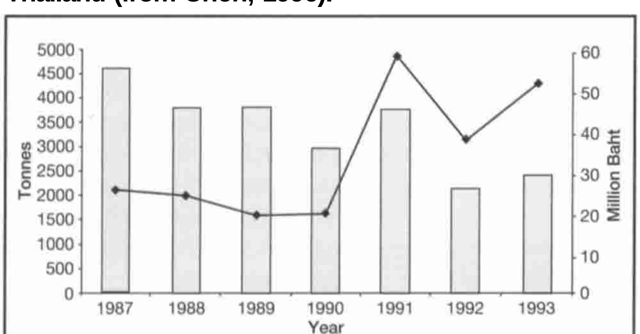
Elasmobranch fisheries have been documented since the 1960s, but have been in existence for much longer. The main fishing grounds for sharks and rays are in the Gulf of Thailand, from where an average of 2,955 t/year of sharks and 4,885 t/year of rays were landed between 1976-1989. The Andaman Sea is also an important area; landings over the same period averaged 1,042 t/year of sharks and 1,079 t/year of rays (Bonfil 1994, see Figures 1 and 2). Recently, all fish stocks in Thai waters have declined, causing Thai fishing fleets to move to foreign waters.

Figure 1. Nominal catches of sharks and rays (Rajiformes) in Thailand by areas, 1983-1992 (from Chen, 1996).



Source: FAO Fishery Statistics. 1992. Vol. 74: Catches and Landings

Figure 2. Production of sharks (in tonnes) landed in Thailand (from Chen, 1996).



Source: Fishery Statistics in Thailand

Up to 63% of sharks and 82% of rays are obtained from the otter-board trawlnet in the Gulf of Thailand, and 92% and 64% respectively from the Andaman Sea (Chen 1996). The other types of fishing gears involved in elasmobranch catches are gillnets, purse seines and bottom longlines. The main landing places are: Samutprakarn. Songkla and Samutsakorn Provinces in the inner Gulf of Thailand, and Ranong Province in the west coast. At Songkla, an estimated 100 vessels were reported to be involved in the shark fishery (Chen 1996).

Exploitation

Uses of elasmobranch in Thailand can be categorised at two levels, major and minor.

Major uses

Shark fin products. Shark fins are the main target for shark fisheries. Fins are taken from all sizes and species of sharks and shark-like batoids. Prices vary according to species, size, and the quality of the processing. Pectoral fins are the highest priced. In addition, part of the gill arches are used for yielding lower grade dried shark fin material.

The processing of shark fins is complicated, time consuming and dependent on specific "know-how". Fins are dried by sunlight or smoking, and may be salted. Well-dried fins may either be exported or further processed by boiling and removing skin and any excess material until only the fin rays and filaments remain. These are re-dried and packed. The grading of fins is based on size, colour, species, cut and rendering, and the moisture content of the products. In Thailand, there are very few large scale shark fin industries; most only process up to the stage of drying the raw fins and then export them. The largest export destination for Thai shark fin products is Singapore, followed by Hong Kong and Japan. Upto about 12.5,14.8 and 6.6 t/year respectively were exported to these countries during 1990-1994 (see Figures 3 and 4). The largest importer to Thailand is Japan, followed by Canada and Hong Kong, importing 38.2, 26.8 and 26.7 t/year respectively to Thailand (Chen 1996).

Food fishes. More than 20 species of elasmobranch are sold in the fish markets around Thailand. The flesh of shark and rays is usually processed into sweetened, salted, dried and fishball products. Small specimens of some sharks and most rays are cooked fresh. Four species of

Figure 3. Trade of shark fins dried or salted (in metric tonnes) in Thailand 1983-1992 (from Chen, 1996).

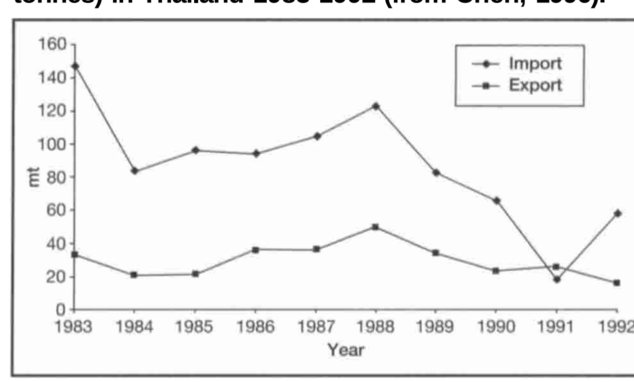
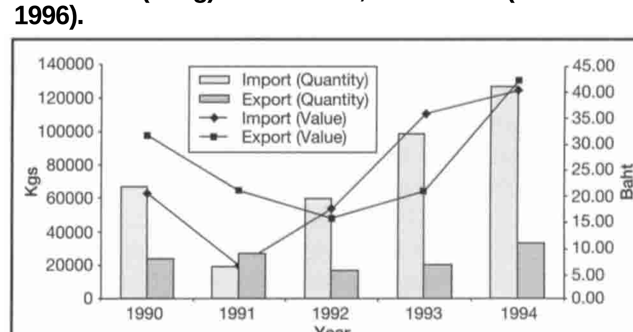


Figure 4. Import-Export of shark fins, dried, whether or not salted (in kg) in Thailand, 1990-1994 (from Chen, 1996).



Source: Foreign Trade Statistics, Thailand sharks are highly regarded: *Carcharhinus melanopterus, C. sorrah, C. dussumieri* and *Sphyrna* spp., as are the shark-like batoids. The cownose ray *Rhinoptera javanica* is highly esteemed when sweetened and dried. Some large individuals containing high levels of ammonia in their flesh go to fishmeal processors, after being skinned to supply hide industries.

Hides. The use of cartilaginous fish skins has become popular in the last decade. Samutprakarn Province of the inner Gulf of Thailand is the largest centre of shark and ray hide industries. Sharks and rays of over 1.5m are preferred. Shark leathers are used to produce luxury footwear. Only the trunk area of ray skins is used, and this is valued for the manufacture of wallets, handbags and belts.

Minor uses

Some elasmobranch species are used for ornamental or other purposes, either whole or in parts. Small sharks are sold, stuffed and mounted, in some tourist areas, e.g. Phuket and Pattaya. Sharks landed as game fish are sometimes stuffed, or replicas moulded in resin, as angling trophies.

Shark jaws are usually processed by cleaning and drying, then sold as curios or collectibles. Large carcharhinid jaws fetch US$80-200 each, smaller ones USS5-25. Jaws of eagle rays and nurse sharks are also valuable. The cephalic denticle of the sharkfin ray *Rhina ancylostoma* is used to make bracelets. The rostrums of sawfishes *Pristis* spp. are sold for decoration or as curios.

Smaller sharks, including *Carcharhinus melanopterus, ChiloscyIlium* spp. and rays *Taeniura lymna, Himantura signifer,* and *H. krempfi,* are found in the aquarium markets.

Threats to elasmobranch diversity in Thailand

South East Asian countries are now faced with the depletion of their fisheries resources, due in part to overpopulation and to inappropriate uses. Thailand's human population reached 60 million in 1996. The main threats to the fishery resource and also to elasmobranch diversity can be defined as:

- **Overfishing** - This occurs in both coastal and inland habitats, through targeted or bycatch fisheries, and affects populations of elasmobranchs more seriously than it does bony fishes, because most sharks and rays bear fewer offspring and take longer to reach maturity.
- **Habitat loss, including pollution** - This is more serious in the restricted freshwater habitats than in marine habitats. The alteration of marine habitats by mining and mangrove deforestation poses a threat to many coastal species. In adjacent areas of Cambodia and Vietnam, deforestation, residues of warfare chemicals and silting are main threats to freshwater and coastal elasmobranch species (Compagno and Cook 1996).

The most threatened elasmobranchs of Thailand are the four species of sawfish: *Anoxypristis cuspidata, Pristis microdon, P.pectinata and P. zijsron.* They have disappeared from the rivers and coasts of the country during the last 10 years. The two species of freshwater stingrays, *Himantura chaophraya* and *Dasyatis laoensis,* are heavily exploited for foodfish, especially the larger sizes.

Sustainable uses

There is no direct protective legislation for elasmobranchs in Thailand. However, fishing effort is regulated by quotas, and seasonally by the Fisheries Act 1992. The export of marine aquarium fishes was banned in 1995. At least 10 Marine National Parks and fishing preserve areas were recently established.

Sharks and rays can be used sustainably by tourism activities, especially shark-watching dive tours. Three areas are famous for their sharks and rays. Whale sharks and manta rays are often seen in the Similan and Surin Island Marine National Parks, and on the Andaman Sea coast of southern Thailand. Other sharks, zebra shark, whitetip reef shark and nurse shark, also inhabit the coral reef areas of the national parks and these could become attractive areas for shark watching dives.

Conclusion

Elasmobranchs are very important to marine and freshwater ecosystems as 'keystone species'. They are at the top trophic level of the aquatic food web, and act as bio-indicators for the health of aquatic environments. Management for the sustainable use of this group of fish needs to be implemented globally. In Thailand, this implementation is needed urgently, based on:

- Inventory surveys on systematics, biology and fisheries within Thai and adjacent waters. Collaborative research is welcomed.
- Conservation measures relevant to elasmobranchs, including protection of their habitats.
- Appropriate proposals for regulating the international trade in shark products should be considered.

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Elasmobranch Fisheries in the Maldives

R. Charles Anderson and Ahmed Hafiz
Marine Research Centre, H. Whitewaves, Male, Republic of Maldives

The elasmobranch fisheries in the Maldives are reviewed. There is little local demand for elasmobranch products other than crude liver oil, used for treating wooden boats. Export demand has driven the three major shark fisheries: 1. An offshore longline fishery for pelagic oceanic sharks. This fishery produces mainly salt-dried shark meat (for export to Sri Lanka) and dried shark fins (for export to East Asian markets). The fishery has expanded in recent years. There is a problem of conflict with local tuna fishermen (who maintain that oceanic shark fishing diminishes pole and line tuna catches) and there are concerns about the long-term sustainability of the resource. 2. A multigear fishery for reef sharks. This fishery also produces salt-dried meat and dried fins for export. The resource has been heavily exploited in recent years. This has led to conflicts with the important tourism industry, since reef sharks are a major attraction for visiting divers. It is estimated that about US$3 million is spent on reef shark and ray watching annually. 3. A vertical longline fishery for deep demersal sharks. This fishery produces high-value squalene~rich liver oil for export to Japan. The resource has been overexploited and the fishery has collapsed.

Introduction

The Maldives is a country of 26 atolls (land area 298km^2) in the central Indian Ocean, lying to the south-west of southern India and Sri Lanka. Although Maldivian fishermen have traditionally targeted tunas (Scombridae), there have been limited elasmobranch catches for centuries. Historically the main product obtained was crude shark liver oil, used as a preservative on local wooden fishing boats. During the last couple of decades the demand for crude liver oil for treating boats has declined as substitutes, such as fish oil (from the local tuna cannery) and coconut oil, have become more readily available. However, shark fishing has increased as a result of export demand for shark products, notably dried shark fins (from shallow-water oceanic and reef sharks) and high-value squalene-rich liver oil (from deep demersal sharks). The shark fins are exported to Singapore and Hong Kong, while the oil (which is not the same as the oil used to treat boats) is exported to Japan. In addition, salt-dried shark meat is exported to Sri Lanka.

Fifty-one species of elasmobranch (37 sharks and 14 rays) have been recorded from the Maldives to date (Table 1). Nearly all shark species are taken in the various shark fisheries. Rays are rarely caught. The shark fisheries of the Maldives were reviewed by Anderson and Ahmed (1993). The present review updates that work.

Materials and methods

Following the review of Anderson and Ahmed (1993) the senior author has taken part in numerous trips with tuna fishermen (some of whom take sharks as bycatch); taken part in deep slope shark fishing trips; interviewed oceanic shark fishermen; and visited many shark and ray watching sites in the Maldives. Catch and effort data for sharks have been collected by the Maldives Ministry of Agriculture and Fisheries since 1994, but are not thought to be comprehensive and are not published. Export data relating to two shark products (shark fins and high-value squalene-rich liver oil) are collected by the Maldivian Customs Department. Average yields of shark products were estimated by Anderson and Ahmed (1993) as follows:

Gulper shark liver oil	26.7 litres per 100kg gulper shark
Dried shark fins	1.44kg per 100kg shark
Salt-dried shark meat	27kg per 100kg shark

Salt-dried shark meat is exported, but exports are combined with those of salt-dried reef fish. Allowing for wastage, Anderson and Ahmed (1993) further estimated that for 1991 exports:

Export weight of salt-dried shark meat = 17.22 x export weight of dried shark fins
Fresh weight of shark catch = 70.83 x export weight of dried shark fins

These average yields and conversion factors are used to obtain rough estimates of catch from the export data. Prices are given in Maldivian Rufiyaa (MRf). Exchange rates have varied from about MRf7.0 = US$1 in 1983 to MRf11.7 = US$1 in 1996.

Results and discussion

Oceanic shark fishery

Oceanic (pelagic) sharks are mostly taken by longline. The pelagic longline fishery appears to have started in the

1960s (Anderson and Ahmed 1992, 1993). Traditional open wooden fishing boats of about 10-15m *(masdhonis)* are used in this fishery. The numbers of hooks set varies between about 40-200 per night.

The main species taken in the pelagic longline fishery (accounting for perhaps 70%-80% of the catch by numbers) is the silky shark *Carcharhinus falciformis.* Several other species are taken in smaller numbers, including oceanic whitetip *C. longimanus,* tiger *Galeocerdo cuvier,* blue *Prionace glauca,* silvertip *C. albimarginatus,* bignose *C. altimus,* shortfin mako *Isurus oxyrinchus,* threshers and hammerheads. Sizes of oceanic sharks caught by longline

Table 1. Elasmobranch species currently known from the Maldives. (Modified from Anderson and Ahmed 1993, Randall and Anderson 1993, Adam, Merrett and Anderson 1998, unpublished data.)

English name	Scientific name	Maldivian name
Frilled shark*	*Chlamydoselachus anguineus*	Ven miyaru?
Sharpnose sevengill shark	*Heptranchias perlo*	Madu miyaru?
Bluntnose sixgill shark	*Hexanchus griseus*	Madu miyaru
Bramble shark*	*Echinorhinus brucus*	Berebedhi miyaru?
Taiwan gulper shark	*Centrophorus niaukang*	Kashi miyaru
Leafscale gulper shark	*Centrophorus squamosus*	Kashi miyaru
Mosaic gulper shark	*Centrophorus tessellatus*	Kashi miyaru
Kitefin shark	*Dalatias licha*	Kashineh miyaru
Cookiecutter shark*	*Isistius brasiliensis*	? miyaru
Tawny nurse shark	*Nebrius ferrugineus*	Nidhan miyaru
Zebra shark	*Stegostoma fasciatum*	Hitha miyaru
Whale shark	*Rhincodon typus*	Fehurihi
Smalltooth sand tiger	*Odontaspis ferox*	Daiy dhigu miyaru
Crocodile shark	*Pseudocarcharias kamoharai*	? miyaru
Pelagic thresher	*Alopias pelagicus*	Kandi miyaru
Bigeye thresher	*Alopias superciliosus*	Kandi miyaru
Thresher shark	*Alopias vulpinus*	Kandi miyaru
Shortfin mako	*Isurus oxyrinchus*	Woshimas miyaru
False catshark	*Pseudotriakis microdon*	Hikandhi thun miyaru
New species	Pseudotriakid	Boathuni miyaru
Starspotted smoothhound	*Mustelus manazo*	? miyaru
Snaggletooth shark	*Hemipristis elongatus*	? miyaru
Silvertip shark	*Carcharhinus albimarginatus*	Kattafulhi miyaru
Bignose shark	*Carcharhinus altimus*	Mendhan miyaru
Gray reef shark	*Carcharhinus amblyrhynchos*	Thila miyaru
Silky shark	*Carcharhinus falciformis*	Ainu miyaru
Blacktip shark	*Carcharhinus limbatus*	? miyaru
Oceanic whitetip shark	*Carcharhinus longimanus*	Feekanfaiy miyaru
Blacktip reef shark	*Carcharhinus melanopterus*	Falhu mathi dhon miyaru
Spottail shark	*Carcharhinus sorrah*	Dhon miyaru
Tiger shark	*Galeocerdo cuvier*	Femunu
Sliteye shark	*Loxodon macrorhinus*	Oashi miyaru
Sharptooth lemon shark	*Negaprion acutidens*	Olhufathi miyaru
Blue shark	*Prionace glauca*	Andhun miyaru
Whitetip reef shark	*Triaenodon obesus*	Faana miyaru
Scalloped hammerhead	*Sphyrna lewini*	Kaaligandu miyaru
Great hammerhead*	*Sphyrna mokarran*	Kaaligandu miyaru
Bowmouth guitarfish	*Rhina ancylostoma*	Madi miyaru
Whitespotted guitarfish	*Rhynchobatus djiddensis*	Madi miyaru
Electric ray	*Torpedo* sp.	Assi madi
Bluespotted faintail ray*	*Taeniura lymma*	Narunagu madi
Fantail stingray	*Taeniura meyeni*	Narunagu madi
Thickspine giant stingray	*Dasyatis microps*	Narunagu madi
Pink whipray	*Himantura fai*	Narunagu madi
Mangrove stingray	*Himantura granulata*	Narunagu madi
Feathertail stingray	*Pastinachus sephen*	Narunagu madi
Porcupine ray	*Urogymnus asperrimus*	Narunagu madi
Spotted eagle ray	*Aetobatus narinari*	Madi
Ornate eagle ray	*Aetomylaeus vespertilio*	Madi
Manta	*Manta birostris*	Em madi
Sicklefin devilray	*Mobula tarapacana*	Em madi

*Not confirmed

are mostly within the range 1.7-2.5m (see Figure 1 for silky shark lengths). Longlining is normally carried out during trips of one or two nights duration. Sharks are usually processed when the boat returns to its island.

In addition to the longline fishery, some oceanic sharks are taken as bycatch by tuna fishermen. These fishermen occasionally catch sharks by pole and line, but they more commonly take them by handline or by hand. Sharks are taken by hand when schools of juvenile silky sharks are encountered with surface tuna schools; a tuna carcass held overboard brings the sharks alongside where they are grabbed by the dorsal or pectoral fin and swung inboard. Most are within the length range 0.9-1.5m (Figure 1). Tuna fishing is carried out on day trips only. Any sharks caught are processed on the island. Whole juvenile silky shark carcasses were bought from tuna fishermen by specialised processors on one island (B. Thulaadhoo) for MRf100 (US$8.45) in August 1995, and about MRf75 (US$6.35) in June 1997.

The main products from all oceanic sharks are dried fins and salt-dried meat. Some crude liver oil may be collected for treating boats, and some jaws are kept for sale as tourist curios (especially from large specimens or prized species such as tiger and mako sharks). Exports of shark fins and salt-dried shark meat are listed in Table 2. These export data do not distinguish

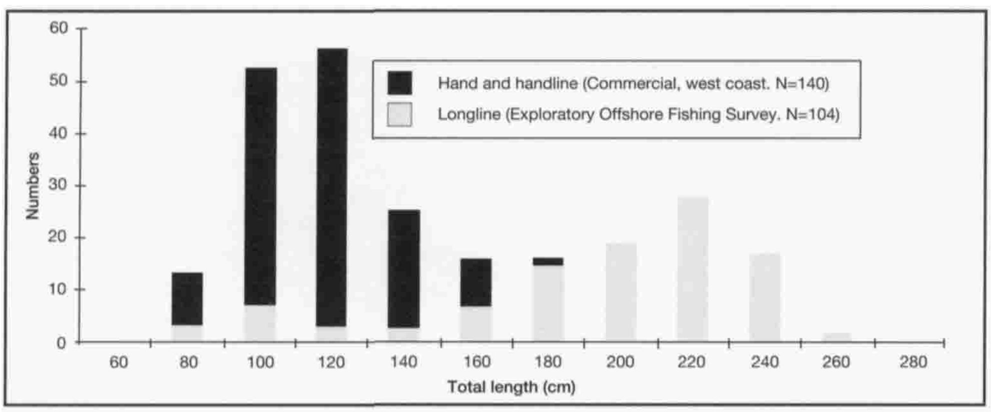

Figure 1. Length frequency distribution of silky shark *Carcharhinus falciformis* catches in the Maldives.

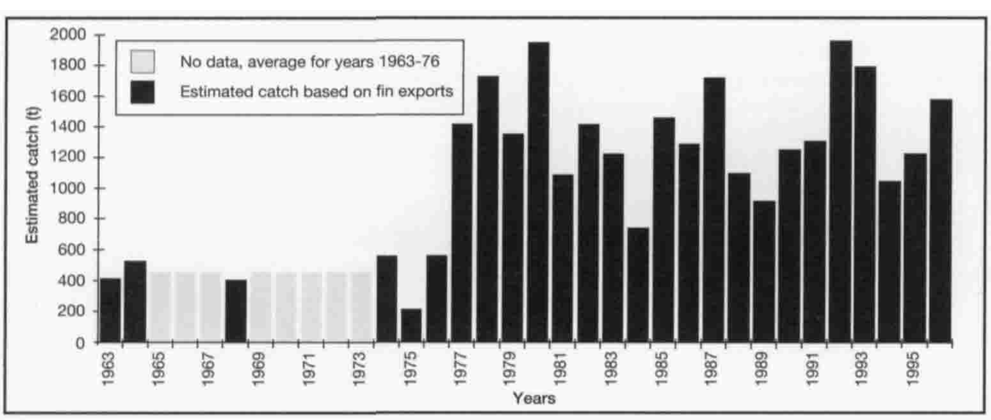

Figure 2. Annual catches of shallow water (i.e. oceanic and reef) sharks in the Maldives, 1963-1996. (Estimated from dried fin export data.)

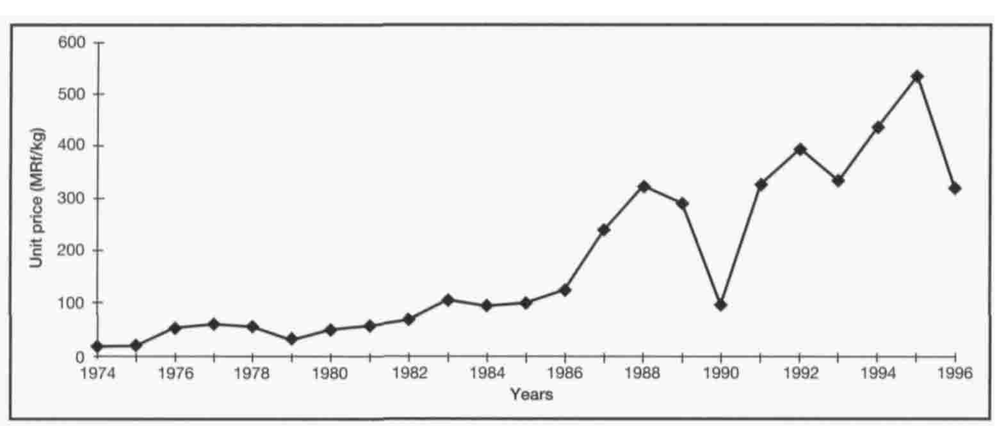

Figure 3. Annual average price of dried shark fins (FOB Male'), 1974-1996. (Customs data, compiled by Ministry of Fisheries and Agriculture.)

between products from the oceanic shark and reef shark fisheries. Estimated catches for the two fisheries combined are illustrated in Figure 2. Average fin prices are shown in Figure 3. Fin prices in the Maldives closely follow international trends (Cook 1990, Anderson and Ahmed 1993).

The Maldives is a tuna fishing nation. Nearly 90% of the total recorded fish catch is of tunas, and over 90% of the tuna catch is made by livebait pole and line (Anderson *et al.* 1996). The main oceanic shark species caught is the silky shark, and it is well known that silky sharks associate with tunas (Au 1991, Anderson and Ahmed 1993). In the Maldives, adult silky sharks are known as *ainu miyaru* (school shark) because of their close association with tuna schools. Thejuveniles are known as *oivaalimiyaru* (drifting object or flotsam shark). Drifting objects, and their associated fishes, are carried to the Maldives by the monsoon currents, so tend to appear off the west coast during the south-east monsoon (May to October) and off the east coast during the north-east monsoon (December to March). Maldivian fishermen search for flotsam, in order to catch the tunas associated with them. The most commonly caught varieties are juvenile yellowfin tuna *Thunnus albacares* and skipjack tuna *Katsuwonus pelamis*, but other target and bycatch species can also be found, including juvenile silky sharks.

Despite the fact that some tuna fishermen take silky sharks, they nearly all believe that doing so reduces tuna catches. They continue to take them because "everybody else does" and because of the economic incentives. Fishermen say that tunas follow silky sharks, and that if the sharks are removed the tuna schools will disperse or dive. For this reason most tuna fishermen are strongly opposed to pelagic longlining. For the same reason any type of fishing other than pole and line tuna fishing is banned in the vicinity of fish aggregating devices. This conflict between shark fishing and tuna fishing interests is a serious issue in the Maldives where tuna fishing is such an important industry.

A second potential problem with the oceanic shark fishery is that the species involved are believed to be highly migratory and, as such, to be subject to fishing mortality over a wide area. The oceanic sharks caught in Maldivian waters are likely to be also taken by:

- Longliners and gillnetters operated by fishermen from other coastal countries.
- Distant water tuna longline fleets, notably those from Japan, Taiwan and Korea. Japanese longliners first entered the Indian Ocean in 1952, with other fleets building up in the following decades.
- Tuna purse-seine fleets, notably those from France and Spain, which have a major operations base in the Seychelles. Although there had been some purse-seining in the Indian Ocean before, large-scale operations started in 1984.

Reliable shark catch data from these fleets are not available. Bonfil (1994) estimated that distant water longline fleets may have caught about 2,000,000 oceanic sharks (i.e. about 75,000t) per year in 1987-1989. From preliminary bycatch data provided by Lablache and Karpinski (1988), we estimate that the purse-seine fishery may be catching about 5,000t of oceanic sharks per year at present. These estimates are very crude, and the extent to which such catch levels may have caused stock depletion is unknown. However, this should be a cause for concern since Indian Ocean stocks of bigeye tuna *Thunnus obesus* and yellowfin tuna (which are often caught at the same time as oceanic sharks) may both now be being exploited at levels in excess of their estimated maximum sustainable yields (IPTP 1995). Some rough indication of the likely recent increase and current magnitude of oceanic shark fishing mortality by Indian Ocean tuna fleets may be given by the catch of those shallow water tropical tunas with which these sharks often associate (Figure 4).

Reef shark fishery

Small numbers of reef sharks have probably been taken for centuries, but the present day reef shark fishery appears to have started in about 1976-1977 (Anderson and Ahmed 1992, 1993). At that time the average annual catch of reef

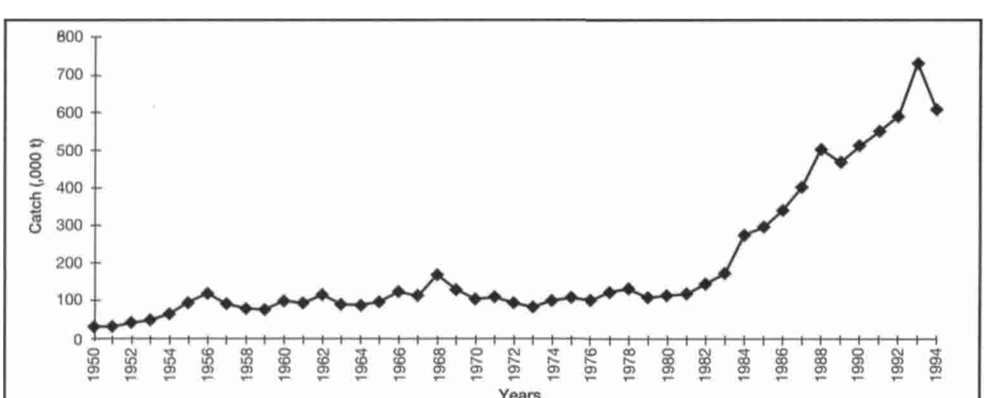

Figure 4. Total recorded catch of yellowfin, bigeye and skipjack tunas in the Indian Ocean, 1950-1994. (Data source: Indo-Pacific Tuna Programme.)

and oceanic sharks combined jumped from about 450t to a new average level of nearly l,400t (Figure 2). This is believed to be largely the result of increased reef shark fishing.

Reef sharks are caught mainly by bottom-set gillnet and handline, although bottom-set longline is also used. Shark gillnetting is carried out by fishermen from only a very few islands (Anderson and Ahmed 1993). These fishermen travel throughout the archipelago in search of sharks, normally completing fishing trips of about two weeks duration over the new moon period. The boats used for shark gillnetting are wooden vessels, usually 9-10m long, of typical *masdhoni* design, but with temporary shelter erected midships, and temporary plastic lined brine tanks rigged in one or more hull compartments. The sharks are processed on board.

Handlining is carried out for all types of reef fish by fishermen throughout the country; a range of vessel sizes are used. Gillnetting and handlining catch a similar array of shark species, with over a dozen varieties being taken altogether. The products obtained from reef sharks are exactly the same as those obtained from oceanic sharks. Dried fins and salt-dried meat from reef sharks and oceanic sharks are not distinguished in the export data (Table 2, Figure 2).

Without catch and effort data, it is difficult to make any assessment of the status of reef shark stocks. However, some information is available. From shark fin export data, total reef and oceanic shark catches can be estimated (Table 2, Figure 2). Thejump in catches in 1977 is attributed to the rapid expansion of reef shark fishing at that time (Anderson and Ahmed 1993). Since then catches have varied widely, but without obvious trend, around an estimated mean of nearly l,400t per year. Fishermen report that the last few years have seen an increase in oceanic shark fishing, and a drop in reef shark catch rates. This is consistent with both the recent trend in shark fin exports, and the growing number of complaints from divers about reduced numbers of shark sightings.

Table 2. Maldivian shark fin exports and estimates of shallow water shark catches . Note: oceanic and reef shark: catches combined.

Year	Dried fin exports (kg)	Fin export value (MRf)	Unit value (MRf/kg)	Estimated catch (t)
1980	27,702	1,363,414	491,962	
1981	15,374	888,831	581,089	
1982	19,988	1,373,104	691,416	
1983	17,403	1,886,743	108	1,233
1984	10,600	1,015,394	96,751	
1985	20,785	2,103,284	101	1,472
1986	18,434	2,345,861	127	1,306
1987	24,383	5,925,145	243	1,727
1988	15,576	5,104,805	328	1,103
1989	13,094	3,856,220	295,927	
1990	17,826	1,798,870	101	1,263
1991	18,726	6,182,866	330	1,326
1992	27,820	11,090,736	399	1,970
1993	25,528	8,654,037	339	1,808
1994	15,042	6,646,600	442	1,065
1995	17,605	9,739,107	539	1,247
1996	22,385	7,278,954	325	1,586

Note: In 1995, 1,010kg of frozen fins were exported; these are equivalent to 465kg of dried fins and have been added to the total exports for the year as such. Unit price refers to actual dried fins only.
Source: Customs data compiled by the Ministry of Fisheries and Agriculture

Reef elasmobranchs (reef sharks and stingrays) as well as other species that sometimes associate with reefs (whale sharks and manta rays) are recognised as having enormous economic value as tourist attractions in the Maldives (Anderson, this volume). Anderson and Ahmed (1993) estimated that reef shark watching by tourist divers was worth US$2.3 million in direct diving revenues alone during 1992. For comparison, export earning from all three shark fisheries amounted to about US$1.2 million in the same year, of which export earnings from reef shark products were estimated to be about US$0.5 million.

Anderson and Ahmed (1993) also estimated that a single gray reef shark at a shark diving site had an average value of about US$3,300 in terms of direct diving revenue generated per year. Taking into account indirect revenue, plus the fact that individually recognisable gray reef sharks are seen at the same dive sites for periods of several years, the total value of such a shark must be very much greater. In contrast, in 1992 the value of a dead gray reef shark to a fisherman was estimated to be about US$32.

Although diving revenue does not directly benefit local fishermen, tourism is the Maldives' greatest source of income, and thus contributes enormously to social development. In any case, with such an enormous vested interest in reef sharks, tourist diving operators have become strong advocates of reef shark conservation in the Maldives. As a result, 15 popular dive sites (of which nine are or were renowned for their sharks) were declared marine protected areas in 1995. Further protective measures are currently under consideration.

There is also some support for restrictions on reef shark fishing from tuna fishermen. The tuna pole and line fishery relies on regular and copious supplies of small live baitfish, which are caught on the reefs. The tuna fishermen complain that removal of reef sharks (and also groupers) reduces livebait catches. They believe that the presence of such top predators causes livebait to aggregate into tight, stationary schools which are easy to catch.

Deep slope shark fishery

A fishery for deep demersal sharks started in 1980 following a show of interest from Japanese buyers in the squalene-rich livers (Anderson and Ahmed 1992, 1993). The fishery started in the north of Maldives, but gradually spread throughout most of the country. The main target was gulper sharks *Centrophorus* spp., of which at least three species are found in the Maldives (Table 1). Too few catches have been sampled to make definitive statements about catch composition, but information from fourteen landings is summarised in Table 3. *Centrophorus* spp. made up 87% of the catch by numbers. Length frequency distributions of *Centrophorus* catches are illustrated in Figure 5. *Centrophorus niaukang* shows a bimodal length frequency distribution; all the small sharks (0.95-1.05m) were males while all the large ones (1.10-1.44m) were females. A substantial collection of *Centrophorus* material was made in 1996 (as part of a wider study of Maldivian deep demersal fishes funded by the British Darwin Initiative) and has been deposited at the Natural History Museum, London.

Table 3. Summary of information on catches of deep demersal sharks from 14 landings.

Species	Numbers	Size range (cm TL)	No. of females
Centrophorus niaukang	41	95-144	24
Centrophorus squamosus	21	78-131	11
Centrophorus tessellatus	11	72-93	8
Centrophorus (not identified)	3	77-132	2
Hexanchus griseus	7	180-320	2
Odontaspis ferox	1	310	0
Pseudotriakis microdon	2	234-302	2
Pseudotriakid (new species)	1	56	0
Total	87		

Source: Marine Research Section, Ministry of Fisheries and Agriculture, Male'

Fishing takes place at night on the outer atoll slopes, in depths of 250–800m. The most frequently fished depth range is 300–500m. Vertical longlines with 6-12 hooks are used, with 2 4 lines being deployed at one time.

The large livers are broken up by hand to release the squalene-rich liver oil. Domestic demand (for local medicine) is minimal, and most of the liver oil produced is exported. Note that export-quality liver oil is extracted from nearly all the sharks caught in the deep slope fishery, but from none of the sharks caught in the oceanic and reef shark fisheries. In contrast, most of the sharks caught in the deep slope fishery do not yield commercially valuable fins or meat.

Records of shark liver oil exports are maintained by the Maldivian Customs Department (Table 4). These export data provide a rough index of the size of the deep demersal shark catch. Anderson and Ahmed (1993) estimated the average yield of liver oil from Maldivian *Centrophorus.* Knowing this, and assuming that the *Centrophorus* yield estimate is a rough approximation for yield from the other shark species involved, the size of the fishery has been estimated (Table 4, Figure 6).

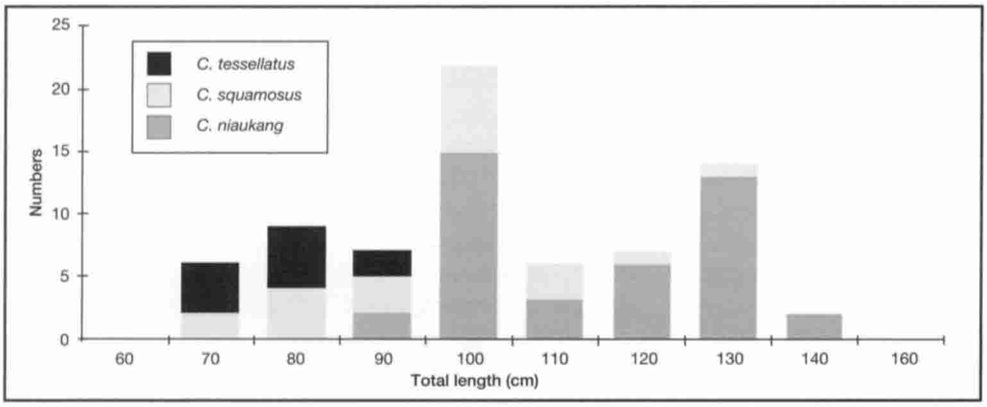

Figure 5. Length frequency distributions for three species of *Centrophorus* caught in the Maldivian deep demersal shark fishery.

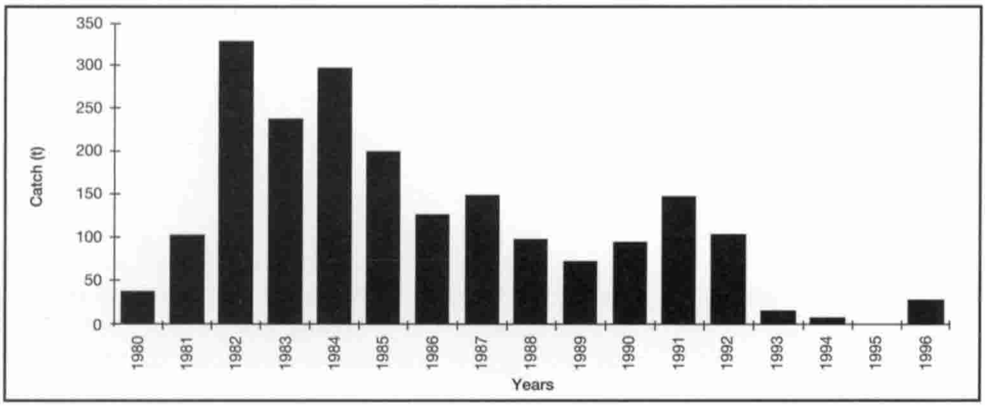

Figure 6. Annual catches of deep demersal sharks in the Maldives. (Estimated from shark liver oil export data.)

Table 4. Shark liver oil exports and estimates of deepwater shark catches.

Year	Quantity of oil (l)	exported (kg)	Value of oil exported (MRf)	Unit value (MRf/l)	Estimated catch (t)
1980	9,600	8,160	60,129	6.26	36
1981	27,200	23,120	349,725	12.86	102
1982	87,400	74,290	1,106,353	12.66	327
1983	63,400	53,890	1,796,010	28.33	237
1984	79,400	67,490	2,411,610	30.37	297
1985	53,400	45,390	1,890,751	35.41	200
1986	33,400	28,390	1,242,230	37.19	125
1987	40,000	34,000	1,040,168	25.25	150
1988	26,000	22,100	640,747	24.64	97
1989	19,002	16,152	724,297	38.12	71
1990	25,600	21,760	1,203,382	47.01	96
1991	39,765	33,800	1,814,530	45.63	149
1992	27,918	23,730	865,801	31.01	105
1993	4,094	3,480	196,054	47.89	15
1994	1,706	1,450	140,300	82.24	6
1995	0	0	0	_	0
1996	7,715	6,558	208,978	27.09	29

Note: Shark liver oil exports were reported in kg in 1991-1994, and in litres in other years; a conversion actor of 0.85kg/l is assumed.
Source: Customs data complied by the Ministry of Fisheries and Agriculture

The deep demersal shark fishery (Figure 6) started in 1980 and peaked very rapidly, with a maximum average annual catch of about 300t in 1982-1984. Total catch then declined rapidly to only 71t in 1989. There was a brief rally during 1991-1993, caused in part by the relatively high prices paid in 1991-1992 and in part by the development of the fishery in the south of Maldives, where the resource has not been as badly overexploited as in the north. Since 1993 estimated catches have been minimal, averaging less than 13t per year.

Other elasmobranchs

Until recently small numbers of whale sharks *Rhincodon typus* were caught by Maldivian fishermen for their liver oil (used in treating boats). The catching of whale sharks was banned by the Ministry of Fisheries and Agriculture in 1993. Because of some ambiguity in the wording of the original law, a second notice confirming the banning of fishing for whale sharks was issued in 1995 (Anderson and Maniku 1996).

Relatively small numbers of stingrays (Dasyatidae), manta rays *Manta birostris* and guitar sharks (Rhynchobatidae) have been traditionally caught in the Maldives to supply oil for treating boats, bait for shark fishing, and skins for musical drums. Total catches are unknown, but are very small, perhaps as little as l0t per year. In recent years, rays have become an increasingly important attraction for visiting tourists. Manta rays are particularly popular with divers. The main species involved is *Manta birostris*, but some devil rays *Mobula* spp. are also seen. A small-scale tagging programme has been started by local divers to investigate the seasonal movements of manta rays within the Maldives (Schmidt 1996, Anderson 1996). Stingrays are fed every evening at several island resorts and form a major attraction for visitors, who can watch them from the beaches or jetties. There is also one popular dive site where stingrays are fed. The two main species involved are *Taeniura meyeni* and *Himantuni fai.*

The economic value of ray-watching in the Maldives is unknown but must run into many hundreds of thousands of dollars annually. The total value of shark and ray watching in the Maldives may therefore be something of the order of US$3 million per year, in direct revenue alone. In order to protect Maldivian stocks of stingrays and manta rays, and to forestall the development of export markets for ray products, the export of rays was banned from June 1995. The export of ray skins (which might find a market with leather manufacturers) was specifically banned from 1 January 1996.

Conclusions

The deep demersal fishery for gulper sharks peaked in its third year and collapsed within 12 years of starting. In order to allow stocks to recover, a ban on exports of shark liver oil of at least 15 years has been recommended (MRS 1997).

The reef shark fishery is suffering from declining catch rates, and is responsible for reducing the numbers of sharks seen at popular (and extremely valuable) shark diving sites. Various recommendations for the control of reef shark fishing, particularly within the tourism zone, have been made (MRS 1997) and are currently under consideration by the government.

The oceanic shark fishery is still giving high yields, but there are concerns about the long-term sustainability of this fishery too. Management of this fishery would require fisheries data and international will to act, both of which are lacking at present. However, it is encouraging that the Indo-Pacific Tuna Programme (IPTP), which was replaced in 1997 by the Indian Ocean Tuna Commission (IOTC), has requested all its members to compile and submit data on shark bycatch (IPTP 1994).

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A Review of Australian Elasmobranch Fisheries

John Stevens
CSIRO, Division of Marine Research, G.P.O. Box 1538, Hobart, Tasmania 7001, Australia

There are three main directed shark fisheries in Australia: a south eastern fishery for *Galeorhinus* and *Mustelus,* a Western Australian fishery for *Furgaleus, Mustelus* and *Carcharhinus obscurus* and a northern fishery for *C. tilstoni* and *C. sorrah.* The combined annual landings from these three fisheries is about 7,000t, which is worth some AUS$25 million. Each of these fisheries is subject to a range of management measures. There is also a small eastern fishery for *Orectolobus.* Sharks and rays comprise a substantial bycatch in several fisheries, notably the northern prawn, tuna longline and south east trawl. Targeted sportfishing for sharks is highest on the east coast, but catches are relatively small. About 1,200 sharks are caught annually in shark control programmes on the east coast of Australia.

Introduction

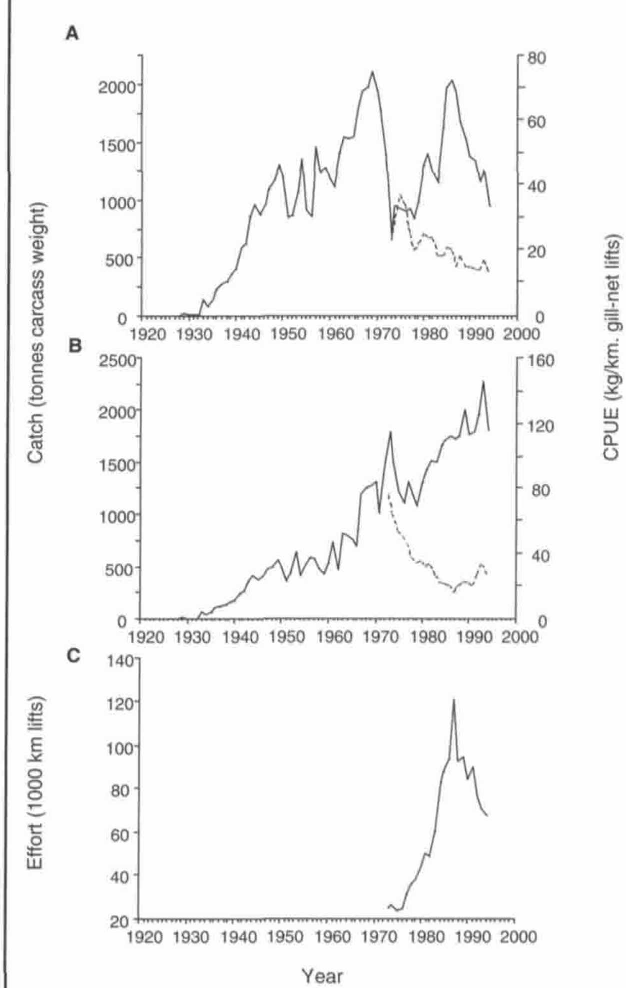
Australia is unusual in having directed shark fisheries which are viewed as relatively important. In the southern half of the country, where these fisheries are of moderate value, being worth some AUS$22 million/year, shark meat is an important product on the domestic market. The fishery has a long history and is socially complex. As a result, Australia has invested in an integrated research and management plan for its southern shark fisheries which are divided into south east and south west components. The south-east fishery, known locally as the Southern Shark Fishery (SSF), targets school *Galeorhinus galeus* and gummy *Mustelus ontarcticus* sharks, while the south west fishery targets dusky *Carcharhinus obscurus,* whiskery *Furgaleus macki* and gummy sharks. A northern fishery for blacktips *Carcharhinus tilstoni* and *C. sorrah* operates from northern Western Australia through Northern Territory waters to northern Queensland. There is also a small fishery for wobbegongs *Orectolobus* spp. in New South Wales.

Southern Shark Fishery (SSF)

The SSF currently lands about 4,000 tonnes (t) live weight annually of mainly school and gummy shark by demersal gillnet and longline, with a value of some AUS$15 million to fishermen in Victoria, Tasmania and South Australia (Figure 1). Most of the shark is sold through the fresh food trade for local consumption, particularly through 'fish and chip' shops; very little is exported. The fishery has a long history of exploitation with school shark landings dating back to the early 1900s supplying fresh fillets to the Melbourne market. During the Second World War, Australia depended on the fishery for supplies of vitamin A from the livers, with the price of shark reaching a maximum in 1949. During the mid 1940s fishermen complained of declining catches, and effort switched from inshore to offshore areas. Following a collapse of the liver

Figure 1. Southern Shark Fishery (from Stevens *et al.* 1997).

Catch (tonnes carcass weight), total equivalent gillnet effort (1,000km. gillnet lifts) and cpue (kg/km, gillnet lifts) by year:
A. School shark (solid line catch, dashed line cpue)
B. Gummy shark (solid line catch, dashed line cpue)
C. Fishing effort



oil market, there was no expansion in the fishery for a number of years. Until this time the fishery had targeted school sharks with 10km longlines with several hundred hooks. In the mid 1960s, monofilament gillnets were introduced, and within a few years most of the catch was taken by this method. This change, together with the discovery of high mercury levels in large school sharks, led to gummy sharks becoming increasingly important in the catch (Figure 1). A significant bycatch of two sawsharks *Pristiophorus cirratus* and *P. nudipinnis*, elephant fish *Calloihyncluis milii*and, in South Australia, whiskery and dusky whaler are also taken. Smaller numbers of school and gummy sharks are also caught by the trawl, dropline, offshore longline and recreational fisheries.

Rising catches and declining catch per unit effort (cpue) in the mid 1980s (Figure 1) led to introduction of a management plan in 1988. Management consists of limited entry, gear controls on the net and hook sector, nursery area closures and minimum sizes. A possible government buyback is being considered in order to further reduce effort in the fishery. Output controls in the form of Individual Transferable Quotas are being considered for future management of the SSF.

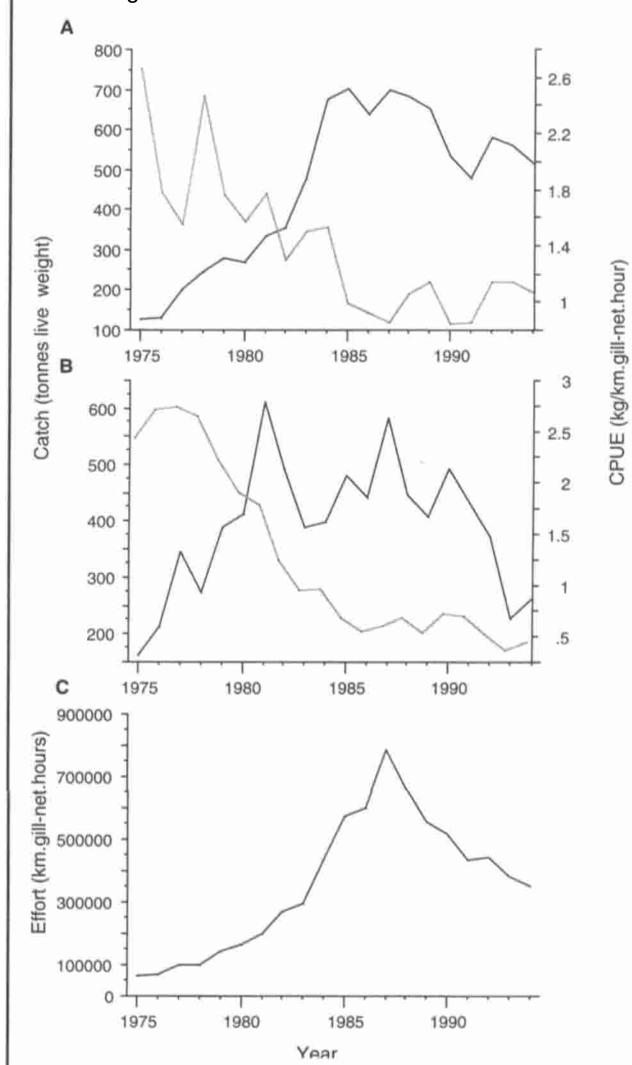
The biology of the two target species have been relatively well researched since the 1940s (Olsen 1954, 1984; Walker 1992) and research priorities are now set by a five year strategic plan developed by government and industry. Periodic stock assessments are required by the Australian Fisheries Management Authority (AFMA). School shark assessments based on catch rates and stochastic age-structured models suggest the 1995 biomass is between 15-46% of mature virgin biomass (Punt and Walker 1996). Current catches are not considered sustainable, and a 35% catch reduction is required to give an 80% probability that mature biomass in 15 years time is above the 1996 level. Stock assessments on gummy shark, using catch rates and deterministic age-structured models, suggest that the population has been reduced to between 40-55% of virgin biomass and that current catches are sustainable (Walker *et al.* 1995).

South Western Australian shark fishery

The South Western Australian shark fishery currently lands about 1.100t live weight of dusky, whiskery and gummy sharks. The fishery started in the 1940s using longlines, but expanded rapidly during the late 1970s and early 1980s with the introduction of gillnets (Heald 1987). Dusky sharks are targeted as newborn individuals in the inshore nursery areas; catches increased from about l00t live weight in 1975 to about 700t in the mid 1980s (Figure 2). The catch of whiskery sharks increased from 150t in 1975 to over 600t in 1981 (Figure 2). Other carcharhinids, sphyrnids, orectolobids and triakids are taken as bycatch. Concerns over rapidly increasing effort and declining catch rates in the mid 1980s (Figure 2) led to the implementation of a management plan limiting entry and imposing gear restrictions (Lenanton *et al.* 1990). The fishery is managed under a joint authority with the Commonwealth of Australia. Fishing mortality on dusky sharks is restricted to the 0+ and 1 + age classes and is estimated at 30%. The adult stock is not subject to any significant fishing pressure. The sustainability of Western Australian dusky shark catches will not be apparent for a few more years, when the first fished age classes recruit into the breeding population (Simpfendorfer *et al.* 1995). Whiskery shark assessments, based on analysis of catch rates and deterministic age-

Figure 2. South-west shark fishery (from Stevens *et al.* 1997).

Catch (tonnes live weight), total equivalent gillnet effort (km. gillnet. hours) and cpue (kg/km, gillnet. hour) by year:
A. Dusky shark (solid line catch, dashed line cpue)
B. Whiskery shark (solid line catch, dashed line cpue)
C. Fishing effort



structured models indicate that stocks are presently over-exploited and currently at about 25% of virgin levels (Simpfendorfer *et al.* 1995). The models suggest the sustainable catch is about 250-300t per year.

Western Australia's shark fishery extends up the west coast where it is managed under a number of different zones by the State with one area effectively closed to shark fishing through gear controls. In this area, droplines with steel traces are banned, as are gillnets and longlines, to protect breeding stocks of carcharhinids. All zones are limited entry and, with the exception of the northern zones, are managed using effort controls in the form of time/gear units. One of the two northern zones is managed under a joint authority with the Northern Territory and is limited entry with gillnets, longlines and droplines permitted. The other northern zone is under State control with droplines and longlines permitted. The catch is mostly tiger shark *Galeocerdo cuvier* and hammerhead shark *Sphyrna* spp. which are marketed for fins, but the catch is now minimal as the one operator who was taking most of the catch has sold his license (Colin Simpfendorfer pers. comm.)

Northern shark fishery

In the 1980s, a Taiwanese gillnet fleet took up to 6,500t live weight of shark (mainly blacktips) annually from the Arafura Sea and northern Gulf of Carpentaria, but these vessels were excluded from the Australian Fishing Zone (AFZ) in 1986 (Stevens and Davenport 1991). Currently there is a small domestic fishery for the same species, which lands about 1,400t live weight annually from Northern Territory and Queensland waters. These catches are probably sustainable. However, it has been estimated that traditional Indonesian vessels fishing within the northern AFZ are currently taking between 3,700-6,000t of shark (presumably mainly blacktips). Following the exclusion of Taiwanese gillnetters from the AFZ, much of their effort transferred across the AFZ border to Indonesian waters. No data are currently available on their catches. This fishing effort may impinge on the same stocks (Stevens 1993). With recent jurisdictional changes between the Commonwealth of Australia and States/Territory resulting from the Offshore Constitutional Settlement, the fishery is now managed as three separate Commonwealth-State/Territory Joint Authorities across the top end of Australia between 123°45'E and 141°20'E. However, fishing for northern shark species also extends down both the Western Australian and Queensland east coast. Queensland has no specific shark management plan but the fishery is covered by the inshore east coast and Gulf net license which is still open access. However, there are a number of gear restrictions and a closed season. Although there are concerns about high prices for shark fin causing increased effort, there are currently no controls to prevent this or to control finning. The Northern Territory fishery is limited entry and there are also gear controls.

Elasmobranch bycatch in commercial fisheries

Various fin-fish and prawn trawl fisheries take elasmobranchs as bycatch in Australia. The South East Trawl Fishery (SET), Australia's largest fin-fish trawl fishery with a Total Allowable Catch of about 32,000t currently has a reported elasmobranch bycatch of about 450t. The SET is a multi-species fishery catching more than 80 commercial species both on the continental shelf and slope (down to about 800m). About 130 vessels are now licensed for this fishery which extends from Sydney south around Tasmania to Kangaroo Island in South Australia. No detailed analyses have been carried out on the elasmobranch bycatch, which is estimated at about 2.5% of total landings from the fishery (Patrick Coutin, MAFRI, Victoria, pers. comm). The main species of elasmobranchs taken as bycatch in the SET are school and gummy shark, saw sharks, elephant fish, angel shark *Squatina* spp., dogfish (mainly *Squalus* spp., *Centrophorus* spp. and *Deania* spp.), skates and rays (Stevens 1993). Under reporting of bycatch is likely to occur.

In 1988, shark and ray bycatch in the Northern Prawn Fishery in waters adjacent to the Northern Territory was estimated at 2,612t (Pender *et al.* 1992). Eleven families of sharks and rays were recorded including 1,864t of shovelnose rays and sharkrays (Rhynchobatidae), 305t of carcharhinid sharks and 294t of stingrays (Dasyatidae). Most of the bycatch was discarded at sea, with only carcharhinid and hemigaleid sharks retained for the domestic market (trunked and sold as blacktip sharks) and fins (particularly from shovelnose rays) retained for the Asian market. The retention of shark bycatch, particularly for the lucrative fin market, has increased in recent years. Prawn trawlers now often target sharks with hook and line which have been attracted to the boat during hauling of the trawl. Much of this shark catch for fins is unrecorded. No quantitative data on elasmobranch bycatch are available from other prawn trawl fisheries in Australia although dogfish are listed as a major bycatch of one of these fisheries in New South Wales (NSW).

Other fin-fish trawl fisheries operate in the Great Australian Bight (GAB), and in western and northern waters. Elasmobranch bycatch includes angel shark (which is a minor target species in the GAB), dogfish, saw, school and gummy shark, carcharhinids and wobbegongs *Orectolobus* spp. (Stevens 1993).

Both domestic and foreign (Japanese) longline vessels target tuna in Australian waters. The average seasonal fishing effort by the Japanese off Tasmania is about 3.3 million hooks. This results in a landed bycatch of some

34,000 blue sharks *Prionace glauca* at a catch rate of about 10 fish per 1,000 hooks. Since the average weight of blue sharks caught is about 8kg this represents some 275t live weight (Stevens 1992). The average number of shortfm mako sharks (*Isurus oxyrinchus*) caught in Tasmanian waters is 0.5 per 1,000 hooks suggesting a total catch by the Japanese each season of 1,594 fish, or about 25t (average weight in Tasmanian waters is about 15kg) (Stevens 1992). Blue shark catch rates for Japanese vessels working north of Tasmania average about 2.5 fish per 1000 hooks between 10-40°S (Peter Ward, BRS, Canberra, pers. comm). Smaller numbers of other shark species are also caught by Japanese longliners in the AFZ. These include threshers *Alopias* spp., porbeagle *Lamna nasus*, school shark, crocodile shark *Pseudocarcharias kamoharai*, several species of squalids and, in northern waters, carcharhinids. The domestic longline fishery for tunas sets about 2 million hooks annually; bycatch species are similar to those taken by Japanese vessels. Whilst current regulations effectively prevent the Japanese from retaining fins, no such restrictions apply to domestic vessels. Most sharks come up alive on the longlines and while many are released a large proportion are killed. Outside the AFZ, most sharks caught by Japanese longliners are finned and the carcasses discarded.

Shark control programmes

Beach meshing as a protective measure against shark attack is practised in two States in Australia: New South Wales (NSW) and Queensland, and is carried out by government contract. Meshing was introduced in NSW in 1937, with Queensland following suit in 1962. The programmes use large-mesh gillnets which are anchored off popular swimming beaches. Queensland also uses baited single-hook drumlines anchored to the bottom. In Australia, shark meshing costs over $800,000 annually. No scientific use is made of the sharks, the carcasses being dumped at sea. Some basic data are collected, but these are of limited use because the species identification is poor. Bycatch is a major concern: between 1972-78 the Queensland nets killed at least 10,889 rays, 2,654 turtles, 468 dugongs and 317 dolphins. The current annual catch is about 200 sharks in NSW and 1,000 sharks in Queensland. Catches were much higher at the start of the programs. The main species caught are carcharhinids, sphyrnids, tiger sharks and angel sharks (Stevens 1993).

Recreational fishing

Angling is a major leisure activity in Australia. Most fishers target teleosts, but some target sharks and rays and others take them incidentally. Few data are available on angling catches of sharks and rays. Game fishing is popular all around Australia, with the greatest fishing pressure currently on the east coast. Billfish and tunas are the most sought after species, but sharks are also taken, and some analyses of these data have been carried out (Stevens 1984; Pepperell 1992). The data suggest that some 300 sharks are caught annually around Australia with a total weight of 25t. The most frequently taken species are blue, mako, hammerhead, tiger and other carcharhinid sharks. There is an increasing trend towards tag and release.

Recreational net fishing is still permitted in a number of Australian States. While teleosts are the normal target species, sharks and rays are also caught incidentally. Few data are available on recreational net fishing catches. In 1990, a study was carried out in the largest proclaimed nursery area in Tasmania to estimate recreational net fishing effort and incidental capture of sharks. Preliminary estimates demonstrated that recreational net fishing in this area can contribute significantly to mortality of juvenile school and gummy shark (Williams and Schaap 1992). Other elasmobranch species taken in relatively large numbers in this study were white-spotted dogfish *Squalus acanthias*, piked dogfish *Squalus megalops*, sawshark and elephant fish.

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Shark Fisheries in the Philippines

Noel C. Barut and John S. Zartiga
Bureau of Fisheries and Aquatic Resources, 860 Arcadia Building, Quezon Avenue, Quezon City, 1100 Philippines

This report contains details of the production, fishing grounds, fishing gear and marketing of sharks in the Philippines. Except for piked dogfish *Squalus acanthus,* sharks were generally a bycatch of some major fisheries in the late 1960s to early 1980s. Since the early 1980s shark meat has been used for fish balls while the fins are dried and sold to local hotels and restaurants. Piked dogfish is a target species due to the demand for squalene oil. The whale shark *Rhincodon typus* is also fast becoming a target species, for both local and export markets. The average annual production from sharks for the past 20 years was 5,882t. The West Sulu Sea, Lamon Bay and Visayan Sea are the three most important shark fishing grounds in the Philippines. Although there has been no thorough study, several reports have shown that at least 20 species of sharks are reported to occur in Philippine waters. Trawl and handline are the major gears catching sharks. Japan is the primary importer of shark liver oil, while the fins and meat are exported to Hong Kong. The prevailing price of shark meat in the local market ranges from PhP20.00 to PhP60.00 per kg, depending upon the size of the shark. Dried shark fins fetch a price of PhP1,800.00 to PhP2,000.00 per kg, while the buying price for dried hide is around PhPIO.OO to PhP15.00 per kg. Shark fisheries in the Philippines are still continuing to expand.

Introduction

Sharks are caught in most waters surrounding the Philippine archipelago. Commercial exploitation of sharks started in the late 1960s, particularly for the piked dogfish because of the demand for squalene oil. However, shark catches were only included in the Philippine Fisheries Statistics in 1976. Sharks were being caught before the 1960s, but only as a bycatch of some major fisheries such as those for tuna and trawl fisheries. Piked dogfish are particularly popular in the central Visayas where traders set up trading posts for squalene oil. The Central Visayas and northern Mindanao are also known for their whale shark fisheries.

Shark fins were initially the only part of sharks collected as bycatch by purse-seine, longline and trawl, and the meat was discarded at sea. However, in recent years fins, meat and hides have been sold in the local market. Whale shark meat and fins are exported to Hong Kong and Taiwan. Whale shark meat is also dried and sold at a higher price in the local market. Shark meat is also used to make fish balls and sold in the local supermarkets.

The Philippine fishery statistics categorise landed catch according to the gross tonnage of fishing vessels. Catches landed by vessels of less than 3t gross are classified as municipal fishery production, while catches of vessels of more than 3t are considered commercial fishery production. Under the new Local Government Code, commercial fishing vessels are not allowed to operate within 15km of the shore (formerly 7km). The Philippine statistics do not categorise the landings of sharks by species, but rather by the volume of the whole catch, regardless of species.

The increasing harvest of sharks, particularly whale sharks, prompted the Bureau of Fisheries and Aquatic Resources to initiate a project in 1997 entitled "Inventory of sharks and rays in Philippine waters". The study aimed to collect information on the distribution, occurrence and abundance of the different shark and ray species found in Philippine waters. This study will be used to provide the baseline information on, for example, shark stock assessments, population genetics (particularly for whale sharks) and other biological studies on sharks. The results will also be used for the management of whale sharks.

Table 1. Annual shark production (t) in the Philippines, 1976-1995.

Year	Commercial	Municipal	Total
1976	19	4,883	4,902
1977	16	4,604	4,620
1978	426	3,876	4,302
1979	720	3,608	4,328
1980	604	3,702	4,306
1981	444	7,545	7,989
1982	417	5,593	6,010
1983	226	4,661	4,887
1984	166	5,817	5,983
1985	311	5,490	5,801
1986	467	9,386	9,853
1987	1,258	5,709	6,967
1988	755	6,379	7,134
1989	663	7,440	8,103
1990	253	7,706	7,959
1991	260	7,800	8,060
1992	268	3,229	3,497
1993	309	4,376	4,685
1994	329	3,846	4,175
1995	144	3,935	4,079
Mean	402.75	5,479.25	5,882.00

Source: Fisheries Statistics of the Philippines 1976-1986, BFAR; Fisheries Statistics 1987-1995, BAS.

Shark production

Statistics show that the mean annual catch from 1976 to 1995 was 5,882t (Table 1). The average municipal fishery sector annual catch was 5,479.25t, and the average commercial fishery sector annual catch was 402.75t. The highest registered landing of sharks was 9,853t recorded in 1986, the same year as the highest municipal catch of 9,386t. The highest commercial sector catch was 1,258t in 1987. Landings of sharks declined from 1993 to 1995. It is unclear whether this was a result of increased under-reporting of the shark catch, or declines of shark populations.

Fishing grounds and gear

The fishing grounds of the Philippines, have been divided into 24 cells to record fishery catch statistics (Figure 1). The most productive commercial fishing grounds are the West Sulu Sea, followed by Lamon Bay and the Visayas Sea, for all local shark species (Table 2). In the Central Visayas, the Bohol Sea is the major whale shark fishing ground (see Alava *et al.*, this volume). The hunting season in the Bohol Sea is from November-May, with March and April peak months. This season coincides with the appearance of manta rays *Manta birostris* and whales. As a result of the ban on catching dolphins and whales in late

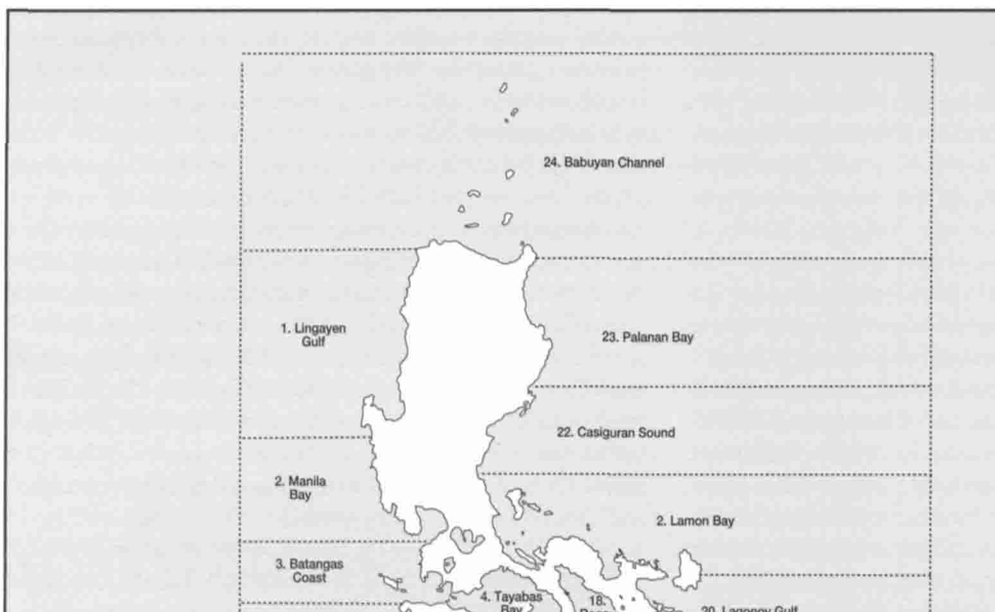

Figure 1. Map of the Philippines showing the 24 statistical fishing areas.

Table 2. Annual commercial production (t)of shark by statistical fishing area, for municipal fishing vessels during 1976-95.

Fishing area	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Babuyan Channel			1												11					
Batangas Coast																			1	
Bohol Sea				11													2	59	163	1
Camotes Sea																				
Davao Gulf																	1			
Guimaras Strait			3	1	3		4					136					1	2	14	7
Lagonoy Gulf		4			2				4											
Lamon Bay		1	50	85	211	132	116	84	94	81	105	114			6	4	8			
Leyte Gulf						1											10	11		1
Lingayen Gulf									2						3					
Manila Bay			7	26	9	4	8	1	1	30		11			4	4	1	1	2	1
Moro Gulf				1				2		99					10		1	4	2	4
Ragay Gulf			6		4															
Samar Sea		3	6	7	7	7	11	1									2	1	1	1
Sibuyan Sea			3			1	3			1		79			6		1		1	1
East Sulu Sea			9	19	14	18	18	22	11	11	12	66			4	3		28		
South Sulu Sea			76	502								110			15	9	24	9	5	56
West Sulu Sea			34		341	270	225	86	49	80	230	514			33	7	20	15	11	1
Tayabas Bay			100																	
Visayan Sea		8	126	68	13	11	31	30	5	9	116	228			62	117	112	94	38	16
West Palawan Waters			5												97	115	83	85	91	43
Casiguran Sound																				
Cuyo Pass							1				4				2	1	2			12
PalananBay																				
Total	19	16	426	720	604	444	417	226	166	311	467	1,258	755	663	253	260	268	309	329	144

Source: Fisheries Statistics of the Philippines 1976-86, BFAR; Fisheries Statistics of the Philippines 1987-95, BAS.

1992, local fishermen from this area started or shifted their effort to whale shark and manta rays, fisheries not yet regulated or banned in the Philippines. *[Editor's note:* The Philippines government introduced legal protection for whale sharks and manta rays throughout Philippine waters in 1998.]

Reports gathered from the local fisheries office in the province of Misamis Oriental (Mindanao) noted that the number of fishermen hunting for whale sharks is increasing while the catch is steadily decreasing. The total catch from that area in 1994 was estimated to be around 100 sharks, which declined to 80 sharks in 1995 and was down to around 40 sharks in 1996 (Alava *et al.*, this volume). Sharks are taken as bycatch by trawls in the commercial fishery sector, and by hook and line or handlines in the municipal fishery sector (Table 3). Most of the gears used to catch large and small pelagic fish also take sharks as bycatch. In areas with targeted shark fisheries, particularly for whale sharks, the fishermen use either the traditional method of metal spears or a large steel hook.

Species of sharks

Herre (1953) reported 52 species of sharks found in Philippine waters. Recently, only 20 species have been confirmed as present in Philippine waters (Table 4). This

Table 3. Annual production (t) of shark by fishing gear and fishery sector, 1979-87.

	1979	1980	1981	1982	1983	1984	1985	1986	1987
Purse-seine	111	4			4				3
Trawl	592	580	442	392	213	166	185	459	1,117
Bag net	12								
Hook and line	4	20	2	25	1		99	8	11
Muro-ami	1								
Ringnet					2				
Longline					6		27		123
Gillnet									4
Commercial total	720	604	444	417	226	166	311	467	1,258
Gillnet	1,046	579	1,311	1,315	921	954	1,093	1,986	1,103
Hook and line	1,958	2,714	3,486	3,030	2,148	3,364	2,548	4,463	3,371
Beach seine				5	3	8	56	58	6
Longline	491	251	2,091	533	485	863	993	657	209
Baby trawl	8		2	3	123	44	1	4	16
Bag net					1				
Fsh corral	45	12	106	42	107	42	1	10	1
Purse-seine/ringnet		60		5	1	3	5	5	28
Fish pot	4				2	95	122	661	
Round-haul seine	1							18	
Jigger		1							
Spear		29	393	402	364	368	548	1,085	548
Troll line			58	48	46		2	70	19
Pole and line			7	1	17				
Lift net				1	6				
Others	55	56	91	205	165	38	73	7	101
Filter net				3		10	17		
Drive-in-net					272	8	31	246	307
Cast net						22			
Push net								116	
Municipal total	3,608	3,702	7,545	5,593	4,661	5,817	5,490	9,386	5,709
Grand total	**4,328**	**4,306**	**7,989**	**6,010**	**4,886**	**5,983**	**5,801**	**9,853**	**6,967**

Source: Fisheries Statistics of the Philippines 1976-1986, E3FAR; Fisheries Statistics of the Philippines 1987-1995, BAS.

Table 4. Shark species reported to occur in Philippine waters.

Scientific name	Common name
Alopias superciliosus	Bigeye thresher
Alopias vulpinus	Thresher shark
Atelomycterus marmoratus	Coral catshark
Carcharhinus amblyrhynchos	Gray reef shark
Carcharhinus limbatus	Blacktip shark
Carcharhinus melanopterus	Blacktip reef shark
Carcharhinus sealei	Blackspot shark
Carcharhinus sorrah	Spottail shark
Carcharodon carcharias	Great white shark
Chiloscyllium indicum	Slender bambooshark
Centrophorus spp.	Gulper sharks
Galeocerdo cuvier	Tiger shark
Isurus oxyrinchus	Shortfin mako
Nebrius ferrugineus	Tawny nurse shark
Rhincodon typus	Whale shark
Sphyrna lewini	Scalloped hammerhead
Sphyrna mokarran	Great hammerhead
Sphyrnazygaena	Smooth hammerhead
Squalus acanthias	Piked dogfish
Triaenodon obesus	Whitetip reef shark

Sources: Compagno 1995, Conlu 1986, Pawikan Conservation Project 1995, and the on-going Shark Project of the Bureau of Fisheries and Aquatic Resources.

does not mean that the 52 species are not to be found in Philippine waters, but rather that very few studies have taken place since the survey conducted by the United States Fish and Wildlife Service in the early 1950s.

Marketing

Methods of processing, selling shark meat and prices vary throughout the Philippines. In Luzon, the meat is sold fresh in the market, whilst in the Visayas and Mindanao, the meat is sold fresh or dried. Shark fins are dried before being sold. In Luzon, fresh shark meat is sold at PhP20.00 to PhP60.00 per kg, while in the Visayas and Mindanao, fresh shark meat is sold at around PhP 10.00- PhP25.00 per kg. The buying rate at the landing site is lower. Dried meat commands a higher price of PhP35.00-PhP75.00 per kg. Dried shark fins are sold at PhPl ,800.00-PhP2,000.00 per kg. In addition, they are sold by sets, consisting of dorsal, pectoral, anal and caudal fins from a single shark. A whole whale shark can fetch a price of PhP20,000.00 to PhP30,000.00, depending upon the size of the whale shark.

Squalene oil is exported primarily to Japan. Hong Kong and Taiwan are the major importers of shark fins and meat.

Management

The Bureau of Fisheries and Aquatic Resources (BFAR) is responsible for gathering information and statistics, and for the development of future management and conservation strategies for sharks. At the time of writing, shark stocks remain unregulated.

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Fishery and Trade of Whale Sharks and Manta Rays in the Bohol Sea, Philippines

Moonyeen Nida R. Alava and Erwin Rommel Z. Dolumbaló,
WWF-Philippines, 69 Masikap Street, Teachers Village Central, Diliman, Quezon City 1101, Philippines
Arnel Andrew Yaptinchay and Romeo B. Trono
WWF-Philippines, 40 Matulungin Street, Barangay Central, Diliman, Quezon City 1101, Philippines

Reports suggest that fishery and trade of whale shark *Rhincodon typus* and manta ray *Manta birostris* in Philippine waters have been operational for several generations, especially around the Bohol Sea. Concern is growing about the sustainability of such a fishery, and the possibility that both species may become extirpated in the wild. This led to a KKP (Kabang Kalikasan ng Pilipinas or World Wide Fund for Nature-Philippines)-funded research on the catch volume and trade of the fishery during the 1997 season, leading to the development of a conservation strategy for these animals. Methods of data collection included site visits to coastal villages involved in whale shark and manta fisheries, market surveys, fishers' interviews and daily landing site enumerations. Initial study sites were Pamilacan Island in Bohol, Balite and Looc in Catarman, Manuyog in Sagay and Talisayan in Misamis Oriental. Fishery profiles and activity patterns related to whale shark and/or manta fisheries in these sites are presented. During the study, 31 fishery sites were operational or had recently been operational. Traditional fishing grounds were not limited to areas within the Bohol Sea, but extended as far as the seas of Sulu and Mindanao. The fishery is flourishing, with fishing effort (number of persons and number of boats) increasing. Products traditionally marketed dried were fins, skin and meat, while the rest were given or thrown away. These are now also sold fresh. The demand has also expanded from local and/or inter-island to national and international markets. Data collected suggest that the whale shark and manta ray populations in the Bohol Sea are threatened. Conservation measures through a fishery ban, however, were unwelcome to most hunters. Some of the reasons given by hunters opposed to the ban were economic dependency on the fisheries, seasonal opportunity, inexhaustible supply of the resources, and religious concepts. Management strategies employing Integrated Conservation and Development projects, ensuring conservation of the species as well as protection of fishers dependent on the fishery, are recommended.

Introduction

The Bohol Sea, encompassing the waters fronting northern Mindanao, southern Bohol, eastern Siquijor and western Surigao Norte, has been the favoured fishing ground for many hunters of whale shark *Rhincodon typus* and manta ray *Manta birostris* in Pamilacan Island (Bohol), Camiguin Island and Misamis Oriental (Mindanao). Reports on fisheries indicate that they have been in operation for generations. In 1993, Silliman University's on-site monitoring programme on cetacean and fishery interaction in Pamilacan Island recorded 30 whale sharks landed within 44 observation days (Alava *et al.* 1997). Visits to some cetacean fishery sites in Mindanao also revealed a flourishing elasmobranch fishery, particularly for whale sharks and mantas. There were difficulties encountered in segregating catch data for species of *Manta* and *Mobula* and these were collectively referred to as mantas.

Concern over the sustainability of the fisheries and their target species is growing. Little is known about the biology and natural history of either whale sharks or mantas. Extinction of these species from the traditional fishing grounds will lead to the collapse of a number of fishing communities now dependent on these particular resources. The need to assess the status of these whale shark and manta ray fisheries cannot, therefore, be overemphasised.

In the 1997 hunting season, Kabang Kalikasan ng Pilipinas (KKP or World Wide Fund for Nature-Philippines), together with researchers from Silliman University Marine Laboratory, studied the whale shark and manta ray in the Bohol Sea, assessing the status of the fishery in at least five fishing villages in central Visayas and northern Mindanao. The main objective of the project was to provide sufficient baseline information to produce a management strategy for these animals.

Methods

The study was divided into three components:

1. fishery profiling of areas with known whale shark and/or manta ray fisheries;
2. on-site monitoring of catch and effort data in selected landing sites and markets;
3. biological data collection from landed catch.

Fishery profiling of selected fishing communities was gathered from both secondary and primary sources.

Secondary sources included municipal reports or any published information on the fishery of the study sites. Primary sources were interviews (based on a structured survey questionnaire) of fishers and key personalities in the same sites, as well as vendors in fish markets. During the interviews, additional elasmobranch fishery sites were noted and, when possible, visited. Fishery data included: fishing population, vessel and gear characteristics, catch composition, fishing effort (in terms of number of boats, men and hours required per trip), fishing operations, seasonality, fishing grounds, catch per unit effort (CPUE) and income per unit effort (IPUE).

Note was taken of the use of whale shark and/or manta ray body parts for economic, cultural, religious and medical purposes. Additional information was collected on the fishers' level of ecological awareness and resource management perception.

Information on daily fishing operations gathered from interviews was checked against monitoring of fishing activities in selected sites in Pamilacan Island and local sources such as local government officials, line agency representatives and concerned private individuals.

Biological data collected included sex and linear body measurements of catch landings, mainly for whale sharks. Tissue samples were also collected for future DNA analysis.

Results and discussion

Fishery sites

The primary study sites selected were the communities previously identified as having active fisheries for whale shark *Rhincodon typus* and mantas and/or devilfishes *Manta* and *Mobula* spp. (WWF-Philippine Programme 1996, Alava *et al.* 1997). One major fishery was initially identified in Visayas (Bohol: Pamilacan Island) and four in Mindanao (Talisayan: Guiwanon, Sagay: Balite and Manuyog, and Catarman: Looc) (see Table 1).

During the study, 31 additional sites were reported to be involved in whale shark and/or manta fishing (Table 1). Twenty-one were found to be active and four inactive. (The classification 'inactive', however, applies only with regard to whale sharks; mantas or other elasmobranchs may still be caught.) Eight of the 21 active sites landed whale sharks in the 1997 season, with or without reported landings of mantas (i.e. Kinoguitan, Libertad, Lopez-Jaena, Mantigue Island, Mati, Plaridel, Samal Island, Tigbauan). Except for Mantigue Island and Samal Island, targeted whale shark hunting is more recent than manta ray fishing. At Mantigue Island, there were no locally based island fishers; instead, transient Bohol fishers used the site as a landing, processing and resting area. In Samal, the hunting was reportedly done by an ethnic minority tribe (Dy, pers. comm.). It was not known whether the fishery was traditional or recent.

Whale sharks have been sighted in Sogod Bay, southern Leyte (Alava and Kirit 1994), and Dapitan Bay, northern Mindanao (Fernandez 1997). No whale shark fishery was identified in these areas.

The development of whale shark fisheries in most of the Mindanao sites was primarily promoted by wholesale fish brokers with contacts in the export market. Some Pamilacan hunters also acted as small-time brokers, buying meat or fins from other hunters in northern Mindanao.

The remaining seven active sites (i.e. Dauin, Enrique Villanueva, Garcia-Hernandez, Jagna, Siaton and Siquijor) were mostly landing mantas, and taking other elasmobranchs opportunistically. One whale shark stranding was reported in Siaton in 1994. The animal was released by the townsfolk the following day.

The four inactive whale shark fishery sites were Balingoan, Panglao Island, Salay and Selinog Island. Inactivity at the first three sites was attributed to the sinking of the fishing boats, sunk by deep-diving whale sharks still attached by reel to the boats during failed hunting operations. This had also occurred to two boats in Talisayan. Five boats were reported sunk and not recovered between 1993 and 1995 in these inactive sites. The fishers never recovered their boats and stopped fishing on their own. Some joined other boats as crew or 'pangabay'. In Selinog, the fishery ceased after the death of the single harpoon hunter, who also harvested cetaceans (Dolar *et al.* 1994). Fisheries for other elasmobranchs (e.g. hammerheads, dogfish and rays) as well as for cetaceans were continued by other fishers using other gears.

Whale sharks were reportedly landed in six other sites (Argao, Caseres, Oslob, Santander, Samal Island and Surigao). The status of these fisheries was not confirmed. An incidental catch of a whale shark was reported in Amlan during April-May 1997. Mantas were also landed and sold in Siquijor markets during the season. Other sources of manta meat were reported to be Apo Island and Siaton in Negros Oriental. Catches in transit to Siquijor were seen at the Dumaguete pier between February and May. Direct fishery sites in the island are still to be identified. One manta, accidentally caught with fish traps, was reported in July 1996.

Fishing population and methods

A total of 85 fishers were interviewed in the five main study sites. All were municipal fishers operating motorised or non-motorised boats of less than 3t gross weight. The majority were fishing full-time using traditional gears, such as single or multiple hook and lines, troll lines, long lines, jigger, gillnets (set, drift or pamo), fish traps, fish

Table 1. Whale shark and manta ray fishery sites in Visayas and Mindanao, Philippines.		
	Targeted Elasmobrancr species	
Fishery sites	Primary	Secondary
Visayas		
Bohol		
Baclayon (Brgy.Pamilacan I.) OR	whale sharks T-SC	mantas T-SC, others T-SC
Garcia-Hernandez AD	mantas T-SC	others T-SC
Jagna AD	mantas T-SC	others T-SC
Panglao AD	whale sharks INA	
Cebu		
Argao AD	whale sharks UC	mantas, others UC
Caseres AD	whale sharks UC	mantas, others UC
Oslob AD	whale sharks UC	mantas, others UC
Santander AD	whale sharks UC	mantas, others UC
Negros Oriental		
Amlan AD	whale sharks I	
Dauin (Brgy. Apo I.) AD	mantas T-SC	
Siaton AD	mantas T-SC	others T-SC
Siquijor		
Siquijor AD	mantas MUC	others MUC
Villanueava AD	mantas I	
Mindanao		
Camiguin I.		
Catarman (Brgy. Looc) OR	mantas T-SC	whale sharks T-SC, others T-SC
Mahinog (Brgy. Mantigue 1) AD	mantas LS, T-SC	whale sharks LS,, others T-SC
Sagay (Brgy. Balite) OR	mantas T-SC	whale sharks T-SC, others T-SC
Sagay (Brgy. Manuyog) OR	mantas T-SC	whale sharks T-SC, others T-SC
Davao Oriental		
Mati (Sitio Tagdodo) AD	whale sharks RC	
Davao (Samal I.) AD	whale sharks UC	
Misamis Occidental		
Dapitan (Brgy. Aliguay I.) AD	mantas T-SC	others T-SC
Dapitan (Brgy. Selinog I.) AD	mantas T-SC	whale sharks INA; others T-SC
Dipolog AD	mantas T-SC	others T-SC
Lopez-Jaena AD (Brgy Katipa) AD	mantas T-SC	whale sharks RC, others T-SC
Lopez-Jaena AD (Brgy. Puntod) AD	mantas T-SC	others T-SC
Plaridel (Brgy. Dukaling) AD	mantas T-SC	others T-SC
Plaridel (Brgy. Kauswagan) AD	mantas T-SC	others T-SC
Plaridel (Brgy. Looc) AD	mantas T-SC	others T-SC
Plaridel (Brgy. Poblacion) AD	mantas T-SC	others T-SC
Plaridel (Brgy. Usocan) AD	mantas T-SC	whale sharks RC, others T-SC
Misamis Oriental		
Balingoan AD	whale sharks INA	
Kinoguitan AD	whale sharks RC	
Libertad AD	whale sharks RC	
Salay AD	whale sharks INA	
Sugbong-cogon AD	whale sharks RC	
Talisayan (Sitio Guiwanon) OR	whale sharks T-SC	
Surigao del Norte		
Surigao (Dinagat I.) AD	whale sharks UC	

Legend: AD = newly identified site; I = incidental catch only INA = inactive whale shark fishery; LS = landing site; MR = major study site; MUC = market only, unconfirmed fishery; RC = recent; T-SC = traditional, still continuing; UC = unconfirmed fishery; OR = original sites identified.

corral or spear gun (Table 2). The majority of these fishers had been catching pelagic or demersal fishes during most of the year, using one or more type of gears per trip. Some shift to manta rays and/or whale sharks seasonally, using specific gears. Gears used for catching whale sharks and mantas tend to reflect geographic differences in fishing operations, practices and preferences.

Visayas

The most important elasmobranch fishery in the country is in Brgy. Pamilacan Island, Baclayon (Bohol), where about 240 fishers primarily target whale sharks (locally known as balilan) and also manta and/or devilfishes (locally known as sanga, salanga or pagi). Fishers interviewed (n = 39 respondents) used relatively more efficient and larger outrigger boats, 8-16m in length, fitted with 80-120 horsepower Japanese diesel truck engines, and with a gross tonnage of 0.2-2.7t.

The primary gear type used by Bohol whale shark hunters was the gaff hook or steel hook, locally known as pilak, gansu, or kawil pangbalilan. The gaff hook and its use were described in detail by (Dolar *et al.* 1994, Perez 1995, WWF-Philippines Programme 1996 and Alava *et al.* 1997). For the 1997 season, about 26 functional units were used. In 1993, only 18 units were reported (Alava *et al.* 1997).

The gaff hook has also been used to catch elasmobranchs (rays *Manta* and *Mobula.* and *Dasyatis* spp. and sharks in general) and teleosts (big jacks or *Caranx* spp., dugso or lethrinids). This gear was also traditionally used to catch whales and dolphins (Dolar *et al.* 1993). Hand spears or harpoons are also used to catch whale sharks and were more prevalent in Mindanao; only two units were reported in Pamilacan. Sixty-eight whale sharks were landed in Pamilacan in 1997. Incidental takes of whale sharks in Pamilacan were also reported for pamo drift gillnets (3 units) in previous years.

Single incidental catches of whale sharks were reported in some parts of the Visayas by other gears: purse seine in Amlan, Negros Oriental (Uypitching, pers. comm.), and fish corral in Buyuan.Tigbauan (Fernandez 1997). Amlan has had numerous sightings of whale sharks off their shores in previous years.

Other efficient gears for sharks and rays in Pamilacan, as confirmed from on-site monitoring, were: long lines (for *Squalus* sp.), hook and line *(Alopias* spp, *Manta* and *Mobula* spp.), and gillnets *(Mobula* spp., *Alopias* spp., other sharks). Set gillnets were the primary gears used in direct manta takes in most sites in Visayas (Apo Island, Pamilacan Island, Jagna, Garcia-Hernandez and Siaton).

Visits to Bohol fish markets (Jagna, Garcia-Hernandez, Baclayon, Tagbilaran) indicated common selling of dried manta meat, suggesting heavy fishing pressure on mantas. The size of the manta fishery was unknown. The manta fishery seems to be traditional, with some people claiming that the operation started way back in the 1800s.

A manta of over 9m was reportedly entangled in the retrieving lines of five large fish traps (or bobô) at Tulapos, Enrique Villanueva (Siquijor), in June 1996.

Table 2. Type and number of gears in the five primary whale shark and/or manta fishery sites in central Visayas and northern Mindanao based on interviews conducted in February-March 1997. (N = 85 respondents).

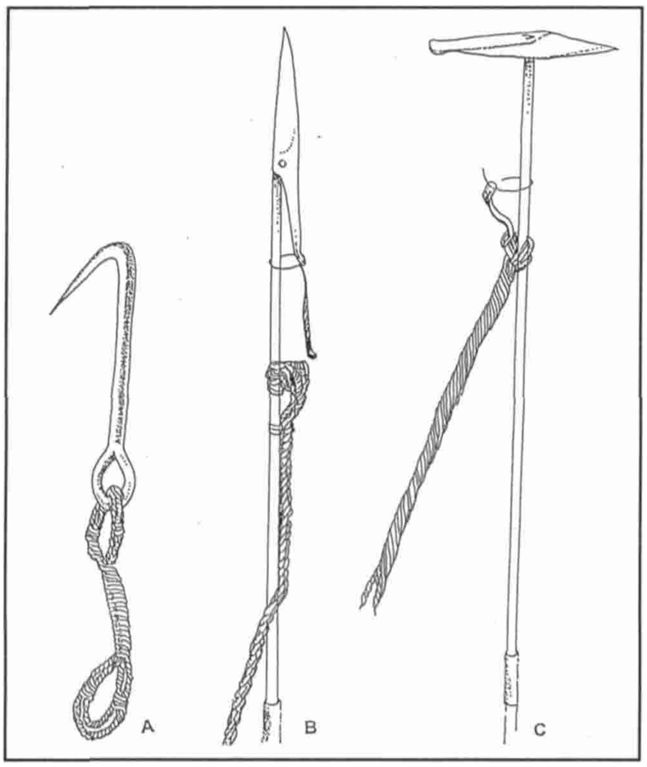
Gear type	Code	Local Name	Sites total					
			Pamilacan	Guiwanon	Balite	Manuyog	Looc	Total
Number of respondents			(39)	(16)	(10)	(8)	(12)	
Hand equipment								
Gaff hook	GH	pamilac	26	5				31
Harpoon/metal spear	H-EZ	bangkaw, ise, pamilac, pangtawiki	2	12	6		6	26
Spear gun	SG	pamana	5				5	10
Hook/lines								
Hook and line	HL	bira-bira, pamahawin, pamingwit, panonton, pasol, sapang	53 [200]	11 [200]	3 [250]	4 [5]	2	73
Jigger	J	aranyas, pangnokos			3 [210]	2 [30]		5
Multiple hook and line	MHL	palangre, panubid, panulingan, pasol, panglahoy	4 [9]	3 [50]	3 [30]	3		13
Sagiwsiw	SGSW	sagiwsiw	1 [2]					1 [2]
Nets								
Bottom set gill net	BSGN	panamaw, pukot	[2]		1 [11]	[4]	1 [1]	2
Drift gill net	DGN	pamo, palaran	3 [4]	1 [13]	2 [34]	2 [40]	7 [5]	15
Gill net	GN	palaran, pamo, pangsolid, panulingan, pukot	22 [65]	8	1	1	8	40
Ring net - pangpagi	GN-P	pangpagi					3	3
Scoop net - pangsanga	GN-S	panuga			[22]		[5]	
Set net	SN	pukot		1				1
Traps								
Fish corral	FC	bungsod		1				1
Fish trap	FT	bubo		1 [26]				

Key: [ ] estimated numbers of units per gear, as reported by key persons in the area: fishers may have more than one gear at any time.

Mindanao

The second most important whale shark fishery is in Sitio Guiwanon, Talisayan (Misamis Oriental), where about 40 fishers (n = 16 respondents) are directly involved. Generally, Mindanao fishers used smaller and less efficient boats. In Talisayan, boat sizes range from 6 to 10m in length, with 5-16 horsepower Kohler or Briggs and Stratton engines, and a gross tonnage of 0.2-1.5t (Table 3).

Figure 1. Primary fishing gears used in whale shark hunting in the Bohol Sea: (A) gaff hook; (B and C) handspear/harpoon. (From Trono, 1996.)



Whale sharks (locally known as tawiki, toki or toki-toki) were hunted by Mindanao fishers primarily with a hand spear or harpoon (locally called ise or bangkaw) (Dolar *et al.* 1994, WWF-Philippine Programme 1996, Alava *et al.* 1997). A total of 24 hand spear/harpoon units were reported: 12 units for Talisayan, and 12 units for Sagay.

In previous years, harpoon catches other than whale sharks were of small- to medium-sized reef or reef-associated finfishes. Common catches were balo or belonids, katambak or lethrinids, danggit or siganids, lapu-lapu or serranids, molmol or scarids, nokos or squids. There was no report of manta catches using harpoons in Talisayan.

Another whale shark gear type reported being used in Talisayan was the gaff hook (5 units), as used in Pamilacan. About 37 whale sharks were directly taken between February and May 1997 using harpoon and/or gaff hook. One was trapped in a fish corral in September 1997.

Other gears used for elasmobranchs were multiple hook and line (7 units) for mantas and long line (3 units) for lahoy or dogfish *(Squalus* spp.).

Other fisheries

The third most important traditional whale shark fishery is Sagay, Camiguin (Balite, n = 9 respondents; Manuyog, n = 12 respondents), where 55 of the 632 municipal fishers take both whale sharks and mantas. About 25 elasmobranch fishers were reported in Balite and 30 in Manuyog. Most boats were small (6-10m) and non-motorised, carrying gears that normally target smaller demersal species during the off-season. The engine capacity of motorised boats was about 5-16 horsepower (Table 3).

The primary whale shark hunting gear used in these sites was the hand spear (Balite = 6 units, Manuyog = 6 units) which caught other species also, such as sanga or pantihan *(Manta* and *Mobula* spp.), iho (unclassified

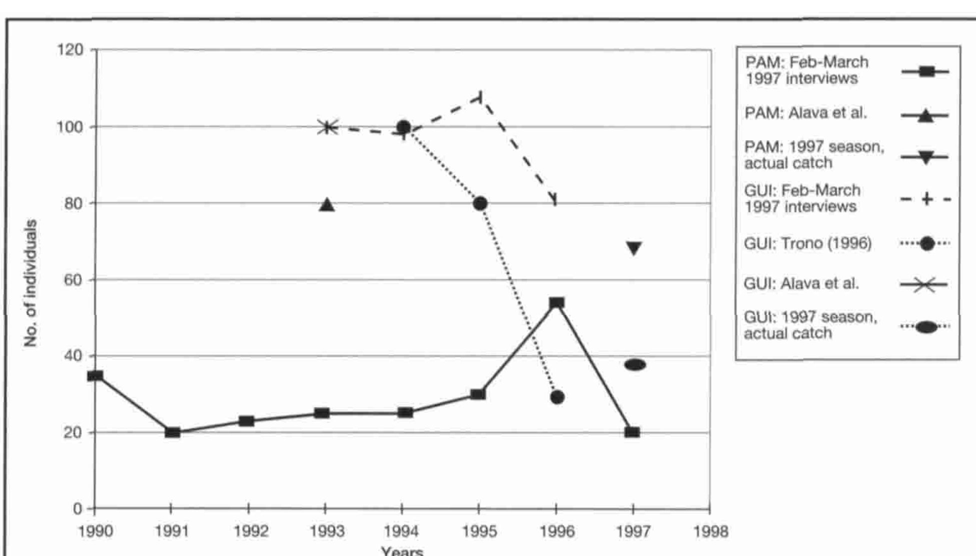


Figure 2. Comparative data on 1990-1997 catches of whale shark in Pamilacan (PAM) and Guiwanon (GUI).

Table 3. Fishers classification and fishing vessel characteristics in the five primary whale shark/manta fishery sites in central Visayas and northern Mindanao based on interviews conducted in February-March 1997.

	Classification of fishers						Fishing vessel characteristics		Gear used for WS/M	
Fishery site	Full time	Part time	Total	M	NM	Total	Hp	Length	prjmary gear	Secondary gear
Pamilacan I., Baclayon, Bohol (N=39)	36 [323] *240	3 [323] *240	39 [50] *40	43 [100]	18 [150] *40	61	80-120	8-16m	Gaff Hook	Harpoon
Guiwanon, Talisayan, Misamis Oriental (N=16)	15 *45	1 *45	16 [11]	15 [120]	13 [131]	28	7-16	6-10m	Harpoon	Gaff hook
Balite, Sagay, Camiguin (N=10)	8 [180] *25	2 [252]	10 [432] *25	3 [20]	6 [250]	9 [270]		5-16m	Harpoon	Gill Net
Manuyog, Sagay, Camiguin (N=8)	8 [200] *30	4	12 [200] *30	9	7	16		5-16m	Harpoon	Gill Net
Looc, Catarman, Camiguin (N=12)	10 *40	2 *40	12 [6]	10 [50]	2 [56]	12		10-16m	Gill Net	

Hp = Horsepower of motorised boats; m = metres; M = motorised; N = number of respondents; NM = non-motorised; WS/M = whale shark and/or manta; [ ] = values in brackets are estimated number of fishers reported by key persons in some areas; * = estimated number of fishers involved in WS/M fishing.

sharks) and baelena (whales). Also used for elasmobranchs in these sites were bottom-set gillnets (for sanga, scarids, siganids and squids) and drift gillnets (for whale sharks as well as scombrids).

In Catarman, Camiguin (Looc, n = 9 respondents), 40 fishers were primarily involved in the manta fishery. Most boats were small, as in Talisayan, with engine power of 10-16 horsepower; five boats were reported to have engines with a capacity of 80-85 horsepower (Table 3). These boats carried gillnets (locally known as pukot, pang-pagi, pananga, palaran or pamanaw) fabricated from nylon cord, with mesh sizes of up to 60cm. Gillnet catch was predominantly of sanga or pantihan (rays), followed in decreasingdominance by tulingan or pidlayan (scombrids), dugso (lethrinids), liplipan (marlins), iho (sharks) and dolphins.

In Mantigue Island (in Mahinog, Camiguin), transient Pamilacan hunters landed at least six whale sharks in February-March 1997. In one observation day, 22 mantas were landed at the island by fishers from Pamilacan and Camiguin using gillnets.

In most of the recently developed whale shark fishery sites in Mindanao, old fishing vessels and gears are still used. The usual small-scale demersal and pelagic fishery shifted toward the novel and large-scale whale shark fishery. The shift was often instigated by enterprising brokers.

According to one source, whale shark hunting was introduced to small-scale fishers in Tagdodo, Mati (Davao Oriental), by artisans from Guiwanon (Talisayan). Guiwanon hunters were hired and brought to the site by the manager of the brokering company. The Guiwanon hunters conducted the initial hunting operations in the area, accompanied by some Tagdodo fishers. Towards the end of the whale shark season, the Tagdodo fishers conducted local operations using four municipal boats, with 4-5 persons per boat. About eight additional people were involved in processing, making a total of 24–28 fishers involved in the fishery.

One ethnic minority tribe in Samal Island (Davao) was reported to have landed a whale shark in mid-October 1997 (Dy pers.comm.). The fishing population, history and status are unknown as yet.

In Kinoguitan, Misamis Oriental, Surigao brokers instigated the whale shark fishery. These brokers managed to convince local fishers (e.g. in Kinoguitan) to request a mayor's permit to operate whale shark fishing in their waters. A letter from the Office of the Department of Interior and local governments allowing such practice was reportedly shown to the mayor. In the absence of a national law protecting the animals, the request was granted. Prior to the request, the mayor was getting involved in a whale shark awareness group in Mindanao (Mindanao Marine Wildlife Watch). As of February 1997, two whale sharks were caught by the Kinoguitan hunters and were landed in Guiwanon. According to some fishers, the same brokers also promoted a new whale shark fishery in Surigao del Norte.

In Libertad, Misamis Oriental, one whale shark landing in February 1997 was monitored by the Department of Environmental and Natural Resources Region 10 (Canete pers. comm.). Additional details were not available.

In Misamis Occidental, preliminary interviews revealed a predominantly manta and/or devilfish fishery. Whale sharks, however, were landed last March in Katipa in March 1997, one individual in Lopez-Jaena in May, and four individuals in Usocan, Plaridel, using the gaff hook. The use of gaff hooks in catching whale sharks suggests a strong influence of the Bohol hunters on local fishers.

Some Pamilacan hunters who extend their fishing operations to Misamis Occidental waters may alternate as buyers or brokers of whale sharks and/or manta rays. Among 12 fishers interviewed in Lopez-Jaena (Puntod, n = 9; Katipa, n = 3), one revealed owning two gaff hooks. In Plaridel, five units were reported among 19 fishers interviewed. Assuming one gaff hook is assigned to only one boat, seven boats with 3-4 people per boat suggests at least 21 28 fishers involved, potentially, in direct whale shark fishery.

Gears used in catching mantas were pukot, panamaw, or pamantihan (gillnets) and palangre (long line). About 60-70 manta fishers were reported for Lopez-Jaena. In Plaridel, at least 29 panamaw (manta gillnets) were reported within barangays Usocan, Dukaling, Kauswagan, Looc and Poblacion, with at least 100 fishers involved. The oldest fisher interviewed could remember manta fishing operations from as early as 1947.

Fishing grounds

The primary fishing grounds for most of the fishers interviewed were the coastal waters of various islands in central Visayas and northern Mindanao. The extent of their fishing grounds was limited by the engine capacity of their boats. There were five fishing grounds frequented by Bohol hunters: Site A - north-western part of the Bohol Sea, waters off Jagna to Garcia-Hernandez (before Guindulman Bay); Site B - south-eastern part of the Mindanao Sea, waters off Salay and Binuangan municipalities in Misamis Oriental; Site C - southern part of Cebu Strait, fronting the municipalities of Oslob and Santander, in Cebu Province; Site D southern part of Tañon strait; Site E - south-eastern part of the Sulu Sea (see Figure 3).

Most of the Misamis Oriental hunters, particularly Talisayan fishers, limited their hunting activity to the area around fishing site B (i.e. Salay waters), rarely venturing into other areas. Camiguin hunters hunted within municipal waters or travelled towards fishing site B (Salay waters). Misamis Occidental hunters focused their hunting activities in the area of fishing site C. About 15 whale sharks were sighted west of this area (in Dapitan Bay) in June 1932 (Fernandez 1997).

Hunters in new whale shark fishery sites in Davao limited their hunting activity to their municipal waters:

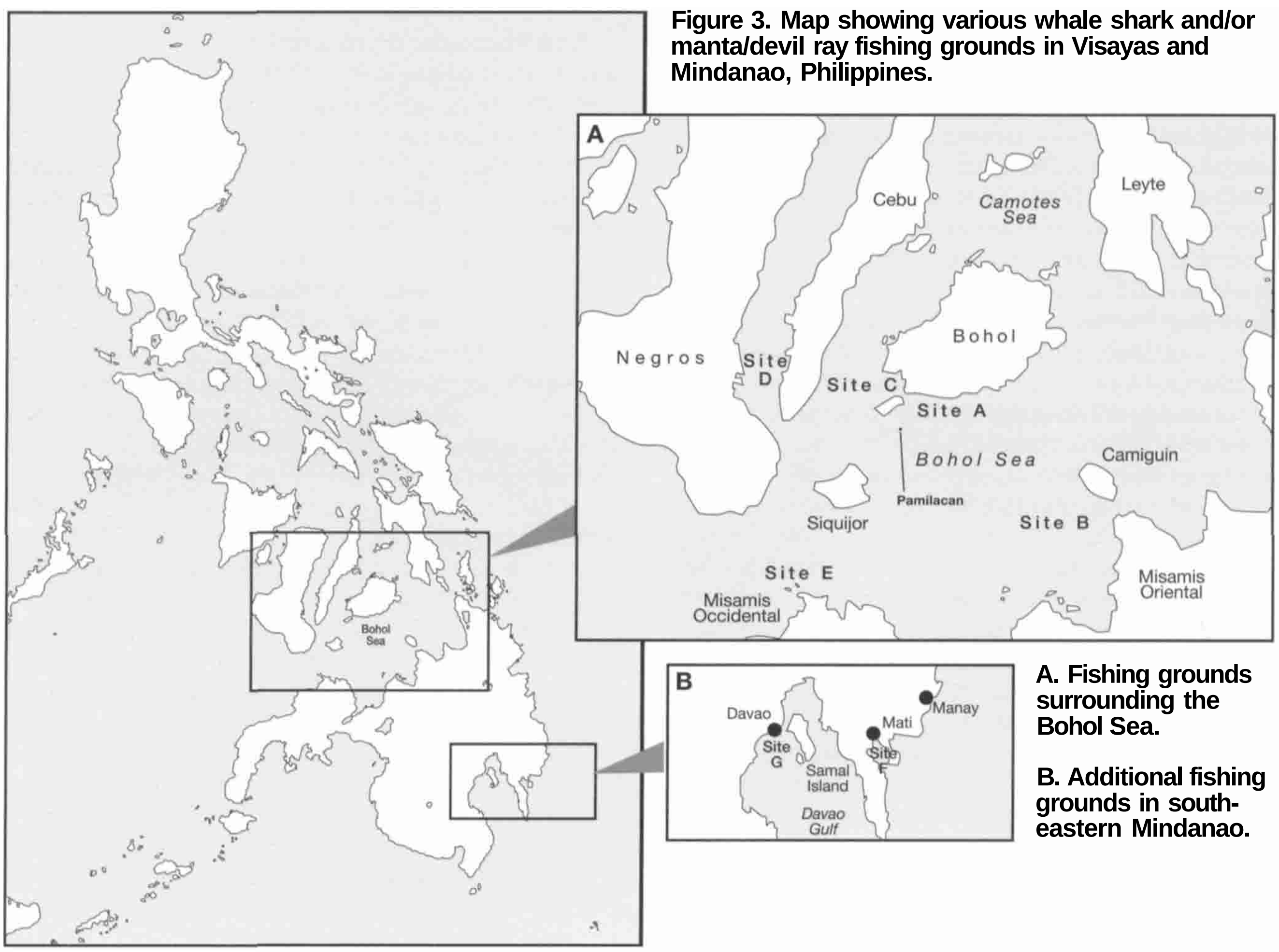


Figure 3. Map showing various whale shark and/or manta/devil ray fishing grounds in Visayas and Mindanao, Philippines.

A. Fishing grounds surrounding the Bohol Sea.

B. Additional fishing grounds in south-eastern Mindanao.

Pujada Bay (Site F) and Davao Gulf (Site G) in the southern Philippines.

Season

The whale shark season in the Bohol Sea was reported to run from December to May or June of each year. These months also coincided with the appearance of baleen whales (Dolar *et al.* 1993, WWF-Philippine Programme 1996, Alava *et al.* 1997). Peak months (highest number of individuals sighted or landed) for whale sharks were between April and May (WWF-Philippine Programme 1996, Alava *et al.* 1997) or from January to March, as reported in Mindanao-Camiguin (Cabio 1996). In 1997, however, the peak months were in February-March. In Mati, Davao Oriental, the whale shark season was between April and October, with peak months from June to September. The hunting season in Samal Island, Davao, is not known. The latest hunt, however, was reported during the third week of October 1997.

For mantas, the season started as early as September and ended in May or June. Peak months for these animals were in November and December at most sites.

Whale sharks are reported to frequent shallow waters where they feed on uyap (krill shrimps) and/or anchovies. A local diver/resort operator in Balingoan, Misamis Oriental, reported plankton bloom coinciding with the arrival of whale sharks. The water was described as thick, with visibility limited to a depth of only a few feet (Uy pers. comm.). Plankton samples were taken at two sites A (Bohol) and C (Tañon Strait) only. Results of the analysis will be presented in a separate report (Alava in prep).

Fishing operations

Gears used in whale shark fishing have been described (Dolar *et al.* 1994, Perez 1995, WWF-Philippine Programme 1996, Cabio 1996, Alava *et al.* 1997). The operation can be divided into four stages: (1) preparation; (2) search; (3) hunt; (4) return. Processing begins when sharks are landed.

1. **Preparation.** This took place between 5 and 7 a.m., and included loading fishing equipment and food supplies. The number of participants required depended primarily on the type of gear used and on boat capacity. Each boat had a head hunter or spotter, a driver and a crew of 2-7 people (see Table 6). The head hunter/spotter was in charge of boat direction, of gaffing or spearing the whale sharks and was the first person to jump on the shark's back. In Guiwanon, the head hunter controlled the selling price of the landed whale shark.
2. **Search.** The head hunter/spotter gave directions. Travel to the fishing grounds took 2-6 hours, depending on the origin of the fishers and boat speed. Pamilacan fishers heading for Site A (Jagna area) required 2-3 travel hours, for Sites B-D (Tañon Strait and Bohol Sea) 3-6 hours. Talisayan-Camiguin fishers going to Site B (Salay waters) required a travel time of only 1-2 hours.
3. **Hunt.** Once sighted, the boat approached the animal at high speed. When the whale shark was within striking distance, the head hunter lunged at it with the gaff hook and/or spear. The engine was turned off while the rest of the crew paddled to get the boat alongside the animal. Hook attachment took about 5-15 minutes. Pamilacan hunters preferred gaffing the animal at the base of the pectoral fin or kapay, while Talisayan hunters preferred spearing the animal in the head, about a metre away from the mouth or just behind the eye. Responses of the animals varied from direct deep diving after hook attachment, swimming away or in circles until they were weak, or panicked thrashing. The waiting time varied, from 30 minutes to 3 hours, and was proportionate to the size of the animal.

   Whilst the head hunter gaffed or speared the shark, one other crew member jumped onto the animal's back, applying a deep cut (about 15-30cm deep) behind the head. The cut, severing the spinal cord, paralysed or killed the animal slowly. The tagged animal was towed towards the landing site.
4. **Return.** The return trip could take 2-6 hours, depending on where the animal was caught.

   If whale sharks were absent, some hunters returned to base to refuel; others tried to save on operation costs by seeking refuge in shores closer to their fishing grounds (e.g. Camiguin, Talisayan, Plaridel). Some of them also bought shares of the catches of other hunters in the refuge sites, and brought these catches back to the home base. Mindanao hunters, on the other hand, always went back to their villages at the end of each hunting day. Others hunted for whales or dolphins as the opportunity arose (e.g. Kinoguitan hunters in February 1997).

The distance of the fishing ground from the home village influenced fishing activity. In one instance, a Pamilacan hunter reported finning a 5m whale shark and sinking the carcass in the middle of Tanon Strait in February 1997. The income derived from the animal was not worth the effort expended in towing it back to the village.

At high densities, some hunters float-tagged weakened or dying whale sharks, temporarily leaving them floating in the water, and moved on to other kills. The number of individuals taken also depended on the size of the fleet working in the area. Tagged animals were towed back to the landing sites singly or in twos at the end of the hunting trip, others were marked by floats or buoys, and left in the fishing ground for transport later in the night or early dawn of the next day.

After the first or third successful hunt, Guiwanon hunters performed a long-established ritual burning of incense and offerings of sardines, candies, cooked rice and other dishes at a site they refer to as 'bugtong-bato'. The hunters, and members of their families participated in the ceremony. It was regarded by most as a thanksgiving ceremony. The hunters believed that the animals belong to the gods. They performed the ceremony to appease the spirit of the sea and to ensure good catches for the rest of the season. Some fishers in Pamilacan and Camiguin also prayed, burned incense and offered gift offerings for the same reasons. Opposing beliefs also existed: some other fishers blamed the whale sharks for bad weather.

Processing

Processing of landed whale sharks took about 2-3 hours per shark. Processing time was proportionate to the size of the animal, the number of animals landed in a day, and the number of people involved. In Pamilacan, processing was a community activity in which each of the crew's relatives, and neighbours might work as a team. Fish vendors, who struck deals with some crew members, also helped to get their share of the catch.

In Talisayan, there were recognised 'slicers', or manglapa, from Brgy. Nabuod, a neighbouring village of 15 households was the major, if not the only, landing site for whale sharks in Misamis Oriental. This was partly because the foul smell of butchered animals so offended most other municipalities that landing was prohibited on their shores, but also because the waters between Guiwanon and Nabuod were deep enough to allow easier handling of the catch near-shore. A team of eight Nabuod slicers worked on a shark. The team leader made deals with the head spotters of different boats to get contracts for each shark landed. The contract was worth at least PhP600 per shark, shared equally among members of the team. Heads of whale sharks were usually given to the slicers as a bonus.

Three hunters from Guiwanon also undertook work as slicers. They either worked independently, or with some of the Nabuod slicers.

There were three basic steps involved in whale shark processing: finning, skinning, and slicing of meat. Finning took less than 30 minutes and involved cutting off all the fins and giving them to the boat owner as his rightful share. Skinning and slicing of the meat was done immediately after finning, with each slicer working on a different section. Skinning and meat slicing took about 1-3 hours, depending on the number of people involved. Traditionally, meat was sliced thinly for drying, which could take up to half a day.

The sliced meat, about half an inch thick, along with some other parts of the sharks (e.g. fins, skins, gills), was sun-dried by hanging or spreading on thin bamboo slats. Drying took about 2-10 days, depending on the weather. The best meat was obtained after drying for 4-5 days. Talisayan whale shark meat was preferred by consumers, as the drying process involved regular washing and/or wiping of the drying meat, at least for the first three days.

More recently, thin slicing and drying of whale shark meat has been unnecessary. Wholesale buyers (at least in Talisayan and Davao Oriental) gave contracts for freshly landed sharks. The meat was cut into bigger chunks to fit large wooden containers topped with crushed ice for immediate transport to the nearest airports. Thus the slicing process became less labour-intensive. An average processing time of 2 hours was required, although scrap meat was sliced and sun-dried in the traditional way.

Resource utilisation and trade

Pamilacan

In Pamilacan, the meat, fins, skin and gills of whale sharks were marketable as dried products. The meat was classified into white and dark. White meat was more expensive than dark meat (Table 4), but the supposedly better-tasting dark meat sold faster than the white. The wide range of cost per kilogram of dried meat depended on the season as well as the age and quality of the meat. Expensive meat was pale yellow, fleshy and oily. Cheaper meat was darker-yellow to brown, dry and stringy. Fresh chunks were also sold to neighbours who dried their meat for selling later. Dried gills, sold at between PhP20-40/kg, were considered to have medicinal value.

Fins were sold at PhP400-500/kg or PhPl ,700/set dry, while the skins were at PhPl0-15/kg fresh or PhP50/kg (or PhP2,000/animal) dry. The head was often sold whole at PhP750-800/head, fresh, or PhP50-80/kg, dry. The jaws, traditionally thrown away, are now retained as trophies, and sold to visitors and tourists at PhPl,000-8,000/set. The price of the jaws was proportionate to size and quality.

Some parts were kept for home consumption: scrap meat, hearts, parts of the liver and intestines (either dried or salted). The liver and the intestines were sometimes sold at PhP 100/container (about 40 litres) to buyers in Baclayon, Loon and Loay; most often they were given away to other neighbours or thrown away at sea. Liver was once reported being made into salted paste (locally known as bagoong). A near-fatal food poisoning incident caused by eating bagoong precluded further attempts to process liver as salted paste in the island (Alava *et al.* 1997). Cartilage and other left-overs were always discarded at sea. A penalty of PhP500 was levied on any hunter who left parts rotting on the beach.

Mantas, on the other hand, were either sold whole, at PhP700-8,000/individual, or in sun-dried pieces. Preferred parts were meat, gills and skin (Table 5). Manta meat, also classified into dark and white, was more highly priced than whale shark meat. Dried white meat was sold at

PhP130-200/kg; dark meat at PhP150/kg. Dried gills, considered as food or medicine, were sold at PhP60/kg (white) or PhP40/kg (dark). Internal organs were kept and cooked, thrown away or sold as salted paste for pig feed.

The major market was the town of Baclayon, during Pamilacan's market day or tabô every Wednesday. Dried meat and gills (for whale sharks and mantas/devil rays) were often sold to regular market-goers or wholesale buyers/brokers from the area or from neighbouring municipalities (e.g. Baclayon, Alburquerque, Loay, Loon, Tagbilaran, Cebu, Davao, Manila). Sometimes they were bartered for root crops and vegetables (Alava *et. al.* 1997). Fins and skin, on the other hand, were sold in bulk to one or two major brokers in Baclayon or Tagbilaran. Little is known about the trade of the fins and the skin beyond the Baclayon and Tagbilaran brokers. Apparently, the fins and skin were sold to buyers from Cebu or Manila. The Cebu/Manila brokers reportedly sold these to Chinese restaurants for use in shark fin soup. Others claim the skin was exported to Taiwan or that the meat was also sold to some other brokers who use it as an ingredient in fish balls. This information, however, needs confirmation.

Guiwanon, Talisayan

In Guiwanon, Talisayan, the meat was priced at kg, fresh, or PhP50-90/kg, dried (Table 4). Due to regular washing and wiping of whale shark meat during the sun-drying process, Talisayan meat was considered of better quality than that from Pamilacan or Camiguin. The difference in the selling price, however, was not remarkable. Whole whale sharks were priced at PhP2,000-7,000/ individual, depending on size. Traditionally, fins were thrown away. Recently, these were sold at PhP60/kg, dried, or PhP2,000 -3,000/set. Dried skin was sold at PhP10 -20/kg.

Liver was only processed for oil in Talisayan. An enterprising local, one of the pioneering whale shark hunters in the area, now retired, recently initiated an oil extraction process. The oil, said to have medicinal qualities like squalene, was sold at P3.50/litre. Heads and internal organs were given away to the slicers or thrown back to the sea. All the cartilage, even the jaws, were also thrown away in deeper waters.

The dried meat was usually sold in strips in waiting sheds or made-up shacks along the highway in Talisayan and Balingoan. Passing travellers and motorists were frequent buyers. Consumers from other municipalities

Table 4. Resource utilisation of whale shark in the five primary whale shark/manta fishery sites in the central Visayas and northern Mindanao based on interviews conducted in February-March 1997. (N=85 respondents).

Body parts	Pamilacan [para](n=39)	Guiwanon [para] (n=16)	Balite [para] (n= 10)	Manuyog [para](n=8)	Looc [para](n=12)
Cartilage	TW/GA	TW/GA			
Fins	SH/SD: PhP400-500/kg, dr; PhP 1,700/set	SD: PhP60/kg, dr; PhP2,000-3,000/set, dr	SD: PhP500-1,000/set; PhP300-500/kg, dr	SD: PhP1,500-5,000/set, dr; PhP500/kg, dr; PhP200/kg, fr	
Gills	SH/SD: PhP1,700/set, dr	TW/GA			
Head	SD: PhP750-800/head, fr; PhP50-80/kh, dr	TW/GA	SH/GA	TA/GA	
Heart	TA/GA	TA/GA	SH/GA		
Intestines/ internal organs	TA/GA/SD: PhP100/40li, slt	TA/GA	SH/GA/TA	TA/GA	
Jaws	SD: PhP1,000-8,000/set, dr (souvernir)	TA/GA			
Liver	TA/GA/SH/SD: PhP100/40li, slt	TA/GA/SD: P3.5/li (oil)	TA	TA	
Meat		SD: PhP3-4/kh, fr; PhP50-90/kg, dr	SD: PhP2-20/kg. fr; PhP18-30/kg, dr	SD: PhP25-30/kg, dr	
Meat (dark)	SH/SD: PhP8-10/kg, fr; PhP10-100/kg, dr				
Meat (white)	SH/SD: PhP10-15/kg. fr; PhP10-100/kg, dr				
Skin	SH/SD: PhP10-15/kg, dr; PhP2,000/ind, dr	SD: PhP20/kg, dr	SD: PhP2-5/kg, dr	SD: PhP6-10/kg, dr	
Whole	SD: PhP100-120/kg, fr; PhP8,000-P15,000/ind	SD: PhP2,000-7,500/ind	SD: PhP500-3,000/ind	SD: PhP3,000-10,000/kg, dr	SD: PhP7,000/ind, fr

GA = given away PhP = Philippine pesos; SH = shared; SD = sold; TA = thrown away; dr = dried; fr = fresh; slt = salted.

Table 5. Resource utilisation of *Manta/Mobula* spp. in the four of the primary whale shark/manta fishery sites in the central Visayas and northern Mindanao, based on interviews conducted in February-March 1997. (N = 85 respondents).

Body parts	Pamilacan (n=39)	Balite (n=10)	Manuyog (n=8)	Looc (n=12)
Gill (black)	SH/SD: PhP40/kg, dr(food/medicine)			
Gill (white)	SH/SD: PhP 60/kg, dr			
Intestines/ internal organs	SH			
Liver	TA/SD: PhP100/40li, slt (food; pig feed)			
Meat		SD: PhP35/kg,fr; PhP 50/kg, dr	SD: PhP100-120/kg, dr	SD: PhP100/kg, dr
Meat (white)	SH/SD: PhP13/kg,fr; PhP 130-200/kg, dr (food)			
Meat (black)	SH/SD: PhP150/kg, dr (food)			
Skin	SH/SD: PhP60-160/kg, dr (food)			
Whole	SD: PhP 3,000-10,000/ind (food)	SD: PhP700-3,000/ind	SD: P400-500/ind., fr	

GA = given away; PhP = Philippine pesos; SH = shared; SD = sold TA = thrown away; dr = dried; fr = fresh; sit = salted.

purposely travel to Talisayan to buy the meat and some of them have already formed buyer-vendor relationships through the years, called suki.

Recently, the market has expanded due to wholesale buying by one fish brokering company. It has been reported that the said company transported fresh meat to Cagayan de Oro City, from where it was taken to Cebu or Manila by air. From there, the product was reportedly exported to Hong Kong, Singapore and Taiwan. Meat from Davao was reportedly transported directly to Japan. Again, these reports have to be confirmed. Only Hong Kong relayed information that whale shark meat was imported from the Philippines.

Camiguin

In Camiguin, the fins, meat and skin were traditionally sold dried. The rest were given away or thrown away (Table4). Mantas were sold as whole individuals at between PhP400 -3,000/individual at landing sites, or sold as fresh slices at PhP35/kg. Dried meat was sold at PhP50-20/kg (Table 5). Dried and fresh mantas were marketed locally (e.g. Sagay or Catarman) or bought by buyers from other areas in Mindanao (e.g. Zamboanga, Talisayan, Cagayan, Bohol).

Catch and effort data

A high degree of effort, expressed in terms of total man-hours, was expended for all whale shark hunting operations, particularly those using gaff hooks (Table 6). The average fishing effort of fishers using gaff hooks was about 316 man-hours in Pamilacan and 115.2 man-hours in Guiwanon.

When using hand spears, the Pamilacan hunters again spent more fishing effort than the Guiwanon hunters. For one respondant in Pamilacan, fishing effort was calculated at 144 man-hours compared with an average fishing effort for hand spearing by Guiwanon hunters of 83 man-hours. Average fishing efforts for Balite and Manuyog hand spear users were calculated at 61.6 man-hours and 23.3 man-hours, respectively. Pamilacan hunters spent more time travelling to the fishing grounds than Mindanao hunters.

The volume of landed catch was highest in Pamilacan compared with either Guiwanon or Camiguin (Table 7). The average volume landed per trip by Pamilacan hunters was reported at 2.47t (gaff hook) and 6.5t (spear). Guiwanon reported only 2t for gaff hook and 3.9t for hand spear. Balite and Manuyog reported hand spear catches of 4.4 and l0t, respectively. Both gaff hooks and hand spears in most sites (except for hand spears in Pamilacan) were used not only for whale sharks but for other species as well, such as mantas, devilfishes, other sharks, and even dolphins and whales.

Income per unit effort (IPUE) of hunters follows trends observed in landed catch, particularly on a per trip basis (Table 7). Assuming the income was shared equally among crew members regardless of status, Pamilacan gaff hook users had a higher income than Guiwanon hunters. On a per man-hour basis, spear hunters at both Pamilacan and Guiwanon earned more than gaff hook users. Sharing strategies varied between fisheries. Typically, most of the catch and income went to the owner of the boat and the head hunter. Local capitalists and/or brokers who lent the hunters money for operations received the highest income since they have the right to the catch.

Table 6. Fishing effort (manpower x fishing hours) of selected geartypes used in the five primary whale shark and/or manta ray fishery sites, based on interviews conducted in February-March 1997.

				Manpower (MP)		Fishing hours (FH)			Fishing frequency		
Gear type	Local name	N	Number of species	Range	Avg.	Range	Avg.	Effort MP x FH)	Trip/ day	Days/ Month	Months/ Year
Pamilacan		**39**									
DGN	pamo	3	6(F)	3-20	12	5-15	7.8	93.6	1-2	9.2	6.3
GH	pamilac	5	6 (F,WS)	3-7	5.75	7-168	55	316	1	16	4.3
GN	pangsanga	9	3 (F,M,R)	5-7	5.67	3-168	52	295	1	19.3	5.3
	pangsolid	1	1 (F)	8	8	3-10	6.5	52			8
	pukot	13	23 (F,S,M, R)	2-5	2.8	2-18	9	52.2	1-2	17.4	5.7
H-EZ	pamilac	1	1 (WS)	6	6	24	24	144	1		5
Guiwanon		**16**									
DGN	palaran	1	1(WS)	1-2	1.5	3	3	4.5	1	20	6
GH	pamilac	5	1 (WS)	7-10	9.12	7-20	12.62	115.2	1	11-20	2-4
GN	pukot	4	12 (F,WS)	1-5	2.62	5-12	10.5	27.6	1	7-26	12
H-EZ	ise. sapang	8	14 (F,WS,M,)	2-8	6.62	6-16	12.5	82.8	1	15-26	2-4
Balite		**10**									
BSGN	pukot	1	4 (F, M)	6	6	4	4	24	1	26	3
DGN	pamo/palaran	2	2(F)	1-2	1.-5	5-7	6	9	1	15-18	12
H-EZ	pamilacan	6	5 (WS, N,R,C)	2-7	4.28	2-24	14.4	61.63	1-2	30	12
Manuyog		**8**									
DGN	pamo/palaran	3	2 (F, WS)	3	3	5	5	15	1-2	16-31	12
H-EZ	pamilacan	6	2 (WS,M)	3-6	4.67	5	5	23.35	1	30	1-5
Looc		**12**									
BSGN	pamanaw	1	1 (M)	5	5	10	10	50	1	15-28	12
DGN	pukot/palaran	7	2 (F,M)	4-6	4.75	4-12	7.4	35.15	1	7-30	1-12
GN	pukot	1	1 (F)	4-6	5	14	14	70	1	15-28	4
	pang-pagi	1	3 (F,MR,S)	4-7	5.43	14	14	76.02	1	25-30	1-12
	pananga	3	4 (F,M)	4-7	5.5	4-13	10.14	55.77	1	25-30	1-12

Avg. = average; C =Cetaceans; F = fishes in general; FH = number of fishing hours per trip; 1 = invertebrates; N= number of respondents; M = *Manta* and *Mobula:* MP = manpower or number of fishers; R = rays in general; S = sharks in general; WS = whale sharks. (Note: fishers may have more than one gear at a time).

Table 7. Catch per unit effort (CPUE) and income per unit effort (IPUE) of selected geartypes used in five primary whale shark/manta fishery, based on interviews conducted in F ebruary-March 1997.

				CPUE (kg)			Avg. IPUE (PhP)	
Gear type	Local name	N	Number of species	Range kg/trip	Avg/trip	per mnhr	per trip	per mnhr
Pamilacan		**39**						
DGN	pamo	3	6(F)	4-200	82.9	0.89	2,072.50	22.25
GH	pamilac	5	6 (F,WS)	10-9,000	2,470	7.82	125,970	398.82
GN	pangsanga	9	3 (F,M,R)	10-1,000	257	0.87	23,130	78.4
	pangsolid	1	1(F)	10-70	40	0.77	1600	30.8
	pukot	13	23 (F,S,M, R)	100-2,000	103.9	1.99	3,169	60.7
H-EZ	pamilac	1	1 (WS)	5,000-8,000	6,500	45.14	65,000	451.4
Guiwanon		**16**						
DGN	palaran	1	1(WS)	10-100	55	12.22	4,550	101.11
GH	pamilac	5	1 (WS)	0-7,000	2,000	17.36	5,657.35	49.11
GN	pukot	4	12 (F,WS)	2-1,500	310.55	11.25	13,263.4	480.56
H-EZ	ise, sapang	8	14 (F,WS,M,)	0-60,000	3,917.65	47.31	43,282.62	522.74
Balite		**10**						
BSGN	pukot	1	4 (F, M)		34.5	1.44	575	23.96
DGN	pamo/palaran	2	2(F)	50	100	11.11	3,250	361.11
H-EZ	pamilacan	6	5 (WS, N,R,C)	20-7.000	4,416.67	71.66	21,558.33	349.79
Manuyog		**8**						
DGN	pamo/palaran	3	2 (F, WS)	10-700	258.33	17.22	1,916.67	127.78
H-EZ	pamilacan	6	2 (WS,M)	100-7,000	10,366.67	443.97	13.191.67	564.95
Looc		**12**						
BSGN	pamanaw	1	1(M)	80-100	90	1.80	550	11.00
DGN	pukot/palaran	7	2 (F,M)	1-300	75.57	2.15	2,050	58.32
GN	pukot	1	KF)	0-150	30.83	0.44	650	9.29
	pang-pagi	1	3 (F,MR,S)	20-200	127.5	1.68	1,950	25.65
	pananga	3	4 (F,M)	30-400	224.17	4.02	3,691.67	66.19

Avg. = average; C = Cetaceans; F = fishes in general; I = invertebrates; N= number of respondents; M = *Manta* and *Mobula;* MP = manpower or number of fishers; R = rays in general; S = sharks in general; WS = whale sharks; mnhr = man hours. (Note: fishers may have more than one gear at a time).

Table 8. Comparative data on 1990-1997 whale shark catches in four of the primary fishery sites, based on interviews conducted (June 1996[a]; February-March 1997[b]) and actual on-site enumeration (April-May 1993[c]; 1997[d]).

	Pamilacan		Guiwanon		Balite		Manuyog		
Year	No. ind.	L (min-max, m)	No. ind.	L (min-max, m)	No. ind.	L (min-max, m)	No. ind.	L (min-max, m)	Total
1990	35[b]	3.7[b]			5-10[b]	4-7[b]			44-52[b]
1991	20[b]	5.5-9.2[b]					1[b]		21[b]
1992	23[b]	5.5-9.2[b]					2[b]	9.2-11[b]	23[b]
1993	25[b] (80[c])	5.5-9.2[b] (1.85-9.43[c])	100+[b] (100[c])	6.7[b] (3-6[c])			7[b]	9.2-12.8[b]	132[b] (180[c])
1994	25[b]	5.5-9.2[b]	98[b] (100[a])	2.5-5[b]					123[b] (100[a])
1995	30[b]	5.5-12.8[b]	108[b] (80[a])	2.5-5.5[b]			10[b]	5-11[b]	153-159[b] (80[a])
1996	54[b]	5.5-9.2[b]	80[b] (30[a])	2.5-5[b]	1[b]	4.5[b]			135[b] (30[b])
1997	20[b] (68[d])	3.0-12.8[b]	(38[d])	1.5-12[b]	(20-30/yr prior to 1997[b])	2.5-7[b]			20[b] (106[d])
TOTAL (exc. 1997)	**212[b]**		**386+[b]**		**6-10[b]**		**20[b]**		**624-627[b]**

ind = individual ; m = meter; min = minimum; max = maximum; L = length; No = number.

Table 9. Summary of whale sharks landed in various fishery sites in Visayas and Mindanao for the 1997 season, based on on-site enumeration and reports from cooperators in this study (Note: data from Camiguin are not available.)

Fishery sites	No. individuals landed
1. Pamilacan I, Baclayon (Bohol)	68
2. Guiwanon, Talisayan (Misamis Oriental)	38
3. Tagdodo, Mati (Davao Oriental)	19
4. Mantigue I., Mahinog (Camiguin)	6
5. Usocan, Plaridel (Misamis Occidental)	4
6. Katipa, Lopez-Jaena (Misamis Occidental)	
7. La libertad (Misamis Oriental)	1
8. Kinoguitan (Misamis Oriental)	2
9. Amlan, Negros Oriental	1
10. Buyuan, Tigbauan (Panay)	1
11. Samal I., Davao	1
Total	**142**

Table 10. Comparative estimates of 1993 and 1997 whale shark catch per unit (or CPUE, expressed in number of whale shark taken/boat) in two fishery sites - Pamilacan (PAM) and Guiwanon (GUI).

	1993 Season (Alava *et al*. 1997)		1997 Season (this study)	
	PAM	GUI	PAM	GUI
Catch (No. of whalesharks)	80	100	68	38
Unit effort: no. of boats	18	10	40	10
CPUE estimates	4.44	10	1.7	3.8

CPUE= catch/unit effort

The highest income per man-hour went to Manuyog hand spear users, who also had the shortest time per trip.

Comparative whale shark catch data 1990-1997 in four of the primary fishery sites, based on fishers' memory, published information and on-site recording, are given in Table 8. Surprisingly, the more efficient Pamilacan hunters reported a smaller number of whale shark landings compared with Guiwanon hunters. Between 1993 and 1996 Pamilacan hunters caught an average of 30 individuals per year, whilst Guiwanon hunters caught about 96 individuals per year. Together the two sites landed 598 whale sharks 1993-1996.

From on-site monitoring in Pamilacan and Guiwanon alone, a total of 106 whale sharks were landed in 1997 (Tables 8 and 9), about 29% lower than the yearly average for the two sites in previous years. In nine fishery sites, at least 140 whale sharks were landed for the 1997 season (Table 9). The average number of whale sharks landed per site, therefore, is about 16 individuals, some 27% lower than the average yearly catch in two sites alone for the past four years. This clearly suggests that there is a decline in the number of whale sharks taken, despite an increase in the number of fishery sites.

Comparing the 1993 and 1997 catch data there was a sharp decline in the CPUE values, expressed in terms of the number of whale sharks taken per boat (Table 10).

Fishers' memory of the historical catch of mantas and/ ordevilfishes was sketchy (Table 11.) Fishers had problems segregating catches into species, often confusing mantas and devilfishes. Most often, catches were underestimated. Fishers feared that the Bureau of Internal Revenues would investigate them if they reported higher catches. During

Table 11. Fishers' recall on historical catch of *Manta/Mobula* spp. in four fishery sites.

	Number of ind.	Estimated Length (m) (min-max)	No. boats	No. men per boat
PAMILACAN I., BACLAYON				
***Manta* spp.**				
1960s	100			
1967	15	3.7-5.5	1	4
1969	9	3.7-5.5	1	4
1975	2	3.7	1	3
1995	8	3.7	1	5
1996	50	4.6-14.6	1	5
***Mobula* sp.**				
1800		2-3	1	4
(devil ray)				
1960s	1-20	1.8-5.5		
1970	5-10	1.8-5.5	20	5-6
1996	50		2	
1997	40	2-3	3	5-6
BALITE, SAGAY				
***Mobula* sp.**				
1960s	50	1.83	6	5
1963	1,000	1.83-9.15	10m; 10nm	3/5
1985	1		4	3
1990s	2-3			
1996	1		4	3
MANUYOG, **SAGAY**				
***Mobula* sp.**				
1960s		1.5-3.5	8nm; 15m	5-7
1970s	2-35	1-3.5	6	2
1960	1	2-4	1	4
LOOC, CATARMAN				
***Mobula* sp.**				
1970	8			
1980	1-4	1-3	1	5
1960S-1996	500+	2-7.3	4	5-7
1997	19			

m = metre; min = minimum; max = maximum; mo = motorised; nm = non-motorised)

the 1995-1996 season in Bohol, the fishers reported landing about 1,000 individuals (WWF-Philippine Programme 1996). In 1997, the estimate was 50. Despite such limitations, the reported values show higher landings in the 1960s than in later years. Though actual catch data for mantas were not available for this paper, the total number of mantas landed is probably much higher than the number of whale sharks in a season.

Whale shark and manta ray fisheries, therefore, are viable, judging by the increasing number of fishing villages, people and boats, involved. Conversely, declining catch rates for both the whale shark and manta ray indicate that populations may soon be threatened.

Ecological perception of the fishing population

Most fishers interviewed in Misamis Occidental believed that the manta catches are dwindling due to greater efficiency of gears and boats. In the primary study sites, only a small percentage (15%) believed this (Table 12). Most (63%) claimed that the resources are inexhaustible. Some of the reasons cited were: the fishery is seasonal so the fishing pressure is limited to the season only and not throughout the year, the wild population is still high (there are still numerous whale sharks and mantas in the water); high productivity (i.e. the animals are still reproductive, reproduce twice a year, produce many young, reproduce fast, reproductive adults, especially the females, are not often taken), or that God will never allow the depletion of the resources to happen.

Table 12. Preliminary results on perceptions of fishers in the primary study sites on the whale shark/manta resources based on interviews conducted in February-March 1997. (n = 85 respondents).

A. Compared to previous years, are your catches this season increasing or decreasing?

Answers	PAM	GUI	CAM	Total	%
No change	23	10	9	42	49.41
No answer	8	2	9	19	22.35
Decrease	2	0	11	13	15.29
Increase	5	4	1	10	11.76
Not sure	1	0	0	1	1.18
Total	39	16	30	85	100.00

B. Will the whale shark and/or manta ray resources in the wild be depleted?

Answers	PAM	GUI	CAM	Total	%
No	27	13	14	54	63.53
Yes	2	0	16	18	21.18
No answer	8	2	0	10	11.76
No change	2	1	0	3	3.53
Total	39	16	30	85	100.00

C. What is your perception on the significance of these animals?

Answers	PAM	GUI	CAM	Total	%
No answer	11	8	13	32	37.65
None	19	1	7	27	31.76
Economically important only	6	4	8	18	21.18
Prey on krill and small fishes		2	0	4	4.71
Ecologically important	.	0	1	2	2.35
Harmful/dangerous	0	1	1	2	2.35
Total	39	16	30	85	100.00

D. Should these aanimals be conserved?

Answers	PAM	GUI	CAM	Total	%
No	31	7	12	50	58.82
No Answer	5	5	9	19	22.35
Yes	3	3	9	15	17.65
Maybe	0	1	0	1	1.18
Total	39	16	30	85	100.00

CAM=Camiguin; GUI =Guiwanon; PAM=Pamilacan. Balite Manuyog and Looc are pooled under Camiguin

Also, most of these fishers had no perceptions of any significance of these animals (no answer = 37%; no significance = 32%). A good percentage viewed the animals as valuable purely for economic reasons or as a food resource (21%), while a few viewed the animals as harmful to other marine organisms (such as krill and smaller fishes), as well as dangerous to fishers or disruptive to fishing activities (2%) and thought they should, therefore, be fished out.

Most fishers thought conservation or protection of the animals was unnecessary (59%). In fact, the suggestion of a fishery ban was unwelcome and was met with strong opposition from some sectors (e.g. at Pamilacan). The primary reason given for resisting a ban, or any conservation measures, was the economic dependency of the hunters on the animals. A small percentage (17%), however, was amenable to the idea if alternative sources of livelihood were to be provided and all hunters were to be asked to cooperate and support the ban.

Management strategies

Since opposition to conservation measures was largely based on economic arguments, it was recommended that alternative (and supplemental) sources of livelihood be identified, particularly in the traditional fishery sites. One of the most viable options identified was ecotourism, with a shift from consumptive to non-consumptive utilisation of resources. The hunters would be able to continually reap economic benefits from their resources without having to kill those resources. A management strategy employing Integrated Conservation and Development projects, ensuring conservation of the species, as well as protection of fishers dependent on the fishery, was proposed.

At Pamilacan Island, a community-based whale-watching project is being implemented by the Inter-Agency Task Force for Marine Mammal Conservation (IATFMMC) in collaboration with the local government unit of Baclayon and the community of Pamilacan Island. The IATFMMC, created in 1994, is composed of line agencies of the government (such as the Protected Areas and Wildlife Bureau of the Department of Environment and Natural Resources (PAWB-DENR), Bureau of Fisheries and Aquatic Resources of the Department of Agriculture (BFAR-DA), Office of Product Research and Development of the Department of Tourism (DOT) and private organisations/institutions (such as Kabang Kalikasan ng Pilipinas or KKP/WWF-Philippines, Silliman University Marine Laboratory or (SUML), Marine Turtle Foundation, and Bookmark Inc.). The primary objective of the project is the development of an integrated plan for the conservation of the marine natural resources of Pamilacan Island. Programmes to be employed will include developing novel tourism products, such as whale watching and whale shark and manta diving, and promoting already established activities such as swimming, snorkelling and diving. The following activities are also proposed: construction of a whale museum, establishment of a community organisation to take charge of future management of the tourism enterprise, non-formal education on resource management, training and capacity-building for local people in tourism services and identification of other sources of livelihood to supplement tourism activities. It is hoped that, as these schemes grow, locals will see the economic benefit of protecting resources worth much more to them alive than dead.

In Misamis Oriental and Camiguin provinces, a Mindanao Marine Wildlife Watch (MMWW) was created primarily to protect whale sharks and other marine wildlife such as whales, dolphins and turtles. MMWW, proposed in December 1996 and started in March 1997, was spearheaded by the Department of Tourism Region 10. It is composed of other line agencies of the government (such as DA-BFAR and DENR), local government units of the municipalities of both provinces, as well as private groups such as the Mantangale Alibuag Dive Resort Inc., CIC Project Management Office and members of the IATFMMC (KKP-WWF, SUML and Bookmark, Inc.). The group will undertake activities similar to those of the Pamilacan programme. Priority projects include: passing local ordinances to prohibit killing and catching of whale sharks, strict enforcement of the national bans on marine mammals and sea turtles, creation of Marine Wildlife Watch at the municipal and local levels (to provide a technical working group who will conduct education, information and communication (EIC) campaigns for whale shark protection, as well as conduct monitoring programs on whale shark sightings), identification of alternative livelihoods for fishers involved in whale shark fisheries, and raising political and financial support among the governors and congressmen of the affected areas.

MMWW is supporting the Whale Shark Hunters Association (WSHA), an affiliate organisation composed of all active whale shark hunters in Talisayan. DOT region 10 sponsored the WSHA's whale watching familiarisation and educational tour in Bais City in October 1997 (Bais City was the first established whale-watching tourism programme in the country). The tour's objective was to inform and encourage the whale shark hunters to participate in the whale-watching industry. Whale and whale shark watching is being promoted for next season.

Conclusion

Whale shark and manta fishing has increased as the number of fishing villages and people has grown. Demand has also grown. Previously, the traditional market catered just for local consumers, now the market has grown nationally (e.g. Cebu, Davao, Manila) and internationally (e.g. Hong Kong, Taiwan, Japan, Singapore). At the same time, processing methods have changed, decreasing processing time, and raising income for the fishers.

Like other elasmobranchs, whale sharks and rays are not legally protected in the Philippines. *[Editor's note:* The Philippines government introduced legal protection for whale sharks and manta rays throughout Philippine waters in 1998.] The current exploitation rate is increasing so rapidly that a recommendation for a national ban on the fishery may be needed. The economic benefits of the whale shark and manta fishery are considerable and are reflected by the increasing number of sites involved. Most fishers, however, do not understand that the practice is unsustainable and, unless altered, will lead to the collapse of the fishery and the decline of their fishery-dependent communities. It is recommended that hunting practices in traditional sites should be regulated. Together with regulation, however, an intensive EIC programme should be implemented. Alternative sources of income should also be identified especially in the traditional whale shark fishery sites. Suggested programmes include the non-consumptive use of resources promoted by ecotourism. It is hoped that once communities realise that the animals are worth more to them alive than dead, hunting will cease.

Some fishers have suggested an introduction of a quota on the number of whale sharks and mantas taken each season. Although this control may work, especially in the traditional sites where initial conservation efforts are being undertaken, it can easily be circumvented by promoting new hunting operations in any of the numerous coastal fishing villages in the country. Using controls necessitates the establishment of a good monitoring system (presently absent) in the fishery, and for trade of elasmobranchs in general. One result of regulating cetacean catches was that the fishing operation went undeclared, and some meat was passed off as fish or shark (Alava and Dolar 1995). There is a need for training in elasmobranch species identification to run an effective elasmobranch monitoring system in the country.

For new sites, regulation of the fishery and trade is probably easier. Most are promoted by brokers who buy wholesale products for export. It is proposed that export of whale shark parts is prohibited, limiting the market and demand for whale sharks. Most of the new hunters will be discouraged from direct takes in the absence of buyers, and if they have to spend additional effort in processing. A national EIC campaign on the biology and ecology of whale sharks and mantas (or elasmobranchs in general) should also be established in order to educate fishers and non-fishers alike on the ecological significance of the animals. This strategy might be especially valuable in areas where whale sharks have been accidentally caught.

National government, government agencies and local governments should act together, supporting each other's strategies in marine wildlife conservation and management. Cases have been seen where conservation measures at the local government level were overshadowed by some of those in the higher offices (e.g. in Kinoguitan). (The opposite can also be true, for example when a national ban on dolphin catches was not implemented in a number of municipal waters; Alava and Dolar 1995). Since municipal waters are within the jurisdiction of local government units, they should be educated in resource management measures, in order to support conservation initiatives in other sites.

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Development of Shark Fisheries and Shark Fin Export in Indonesia: Case Study of Karangsong Village, Indramayu, West Java

Takashi Suzuki
1-10-13 Hara-Cho, Suita-shi, Osaka, Japan

Indonesia has a long-established shark fin export trade. Rocketing market prices for shark fins in Hong Kong in 1987 were reflected in Indonesia. Many new fishermen and traders joined the shark fishing and shark fin trade. Competition intensified and the domestic market price of shark fins increased sharply. The paper describes the development of the shark fishery in Karangsong Village, from the 1960s when nylon nets were used and shark flesh was salted for sale, to the introduction in the 1980s of motorised fishing vessels, use of ice, fish market developments in larger cities and the growth of longlining. The pattern of involvement of traders in the industry over this period is outlined. Boat owners started longlining for sharks and increased their profits (40%-50% of which came from shark fins) in the 1980s. The fishery grew rapidly with increased demand for shark fins in 1987. More traders became boat owners and offered incentives to skilled shark-fishing captains. The economics of this developing fishery are described.

Introduction

This paper reviews the rapid development of longline shark fishing in Karangsong, Indramaya, West Java in the 1980s.

Longline coastal shark fishing in the village of Karangsong in Indramayu Province on the North coast of Java dates back to the 1930s. With the introduction of nylon nets in the 1970s and the development of drift gillnet fishing, catches of shark increased. The salted shark meat was shipped to domestic markets in the mountainous interior. In the 1980s, longline shark fishing for large sharks began, and grew rapidly with the sharp rise in the shark fin market price in 1987.

The volume of Indonesia's shark fin exports rose sharply from the latter half of the 1970s, and by 1991 had reached 376 tonnes (t), valued at US$10 million (Rose 1996) (Table 1). Until the 1980s most exports were to Singapore (Rose 1996). From the latter half of the 1980s prices on the shark fin market in Hong Kong escalated, and exports to Hong Kong increased. The export price for Indonesian shark fins rose 1.9 times from 1983 to 1984, and doubled again between 1986 and 1987. The high-grade 'tongari' fins from *Rhynclwbatus djiddensis* exported to Hong Kong are believed to be the main factor in this price increase. Correcting prices to reflect the devaluation of the rupiah in 1983 and 1986, the price rises amounted to as much as 3 and 3.5 times, respectively. This rise in the export price of shark fins spurred the development of shark fishing in the outer islands and fierce competition among buyers, greatly altering the system of shark fin distribution in Indonesia. The demand for shark fins also grew in Indonesia itself with the opening of luxury hotels and Chinese restaurants in Jakarta. Surabaya and other large cities. With this surge in demand and prices for shark fins both domestically and abroad, shark fishing for fins started even in small fishing villages.

The price for exports to Hong Kong was double that for exports to Singapore (Table 2). The volume of shark fins from Indonesia absorbed by the Hong Kong market doubled from 1986 (77t) to 1987 (162t), and the price nearly tripled (Table 3).

The shark fins exported to Hong Kong were mainly from giant guitarfish *Rhynclwbatus djiddensis* caught in the Maluku and Arafura seas in Eastern Indonesia. By

Table 1. Shark capture and shark fin export in Indonesia 1975-1991.

Year	Shark capture (t)	Shark fin export (dried) volume (t)	value (US$1,000)	JS$/kg	rupiah/kg
1975	17,246	10	6	0.4	158
1976	16,911	277	177	0.6	257
1977	17,531	87	63	0.7	299
1978	19,189	134	155	1.2	481
1979	20,254	186	202	1.1	670
1980	28,174	179	259	1.4	886
1981	29,007	225	363	1.5	929
1982	30,351	249	497	2.0	1,234
1983	33,620	334	600	1.8	1,107
1984	36,998	232	797	3.4	3,337
1985	35,562	327	677	2.1	2,008
1986	34,360	429	1,034	2.4	2,338
1987	36,884	547	2,697	4.9	8,135
1988	39,055	458	6,297	13.7	22,671
1989	47,997	475	10,473	22.0	39,380
1990	45,115	n.d.	n.d.	n.d.	n.d.
1991	46,125	376	10,680	28.4	55,573

n.d.: no data available
Source: Statistik Perikanan Indonesia and Statistik Expor dan Impor Hasil Prikanan Indonesia, 1975-1991

Table 2. Shark fins exported from Indonesia to Hong Kong.

Year	Volume (kg)	Value (HK$)	Average (HK$/kg)
1975	29,718	476,699	16.0
1980	75,161	217,007	2.9
1985	62,134	1,788,097	28.8
1986	76,738	4,721,331	61.5
1987	162,141	28,215,655	174.0
1988	155,379	38,955,339	250.7
1989	170,073	59,477,555	349.7
1990	116,652	45,339,304	388.7

Source: Statistics of Hong Kong Trade Council, 1975-1990.

Table 3. Shark fins exported from Indonesia, by country of destination.

Year	Unit	Destination: Hong Kong	Destination: Singapore	Destination: Japan
1980	kg	119,550	58,644	n.d.
	US$(FOB)	188,671	69,757	n.d.
	US$/kg	1.6	1.2	n.d.
1986	kg	201,227	121,835	n.d.
	US$(FOB)	435,505	555,599	n.d.
	US$/kg	2.2	4.6	n.d.
1987	kg	337,530	184.190	394
	US$(FOB)	1,100,591	1,526,883	2,740
	US$/kg	3.3	8.3	7
1988	kg	245,064	167,642	7,543
	US$(FOB)	3,187,916	2,781,500	138,576
	US$/kg	13	16.6	18.4
1989	kg	262,795	164,927	12,130
	US$(FOB)	4,468,753	5,423,456	271,965
	US$/kg	17	32.9	22.4
1991	kg	133,296	127,836	26,770
	US$(FOB)	3,383,223	6,494,576	473,986
	US$/kg	25.4	50.8	17.7

FOB: export price
n.d.: no data available.
Source: Statistik Expor and Impor Hasil Perikanan Indonesia.

1992 the resources had been so overfished that the Chinese investors were not getting a return on their investments and withdrew.

Materials and methods

An analysis is presented of the results of a long-term survey of Indonesian fishing villages between 1989 and 1991. The primary sources for the survey consisted of interviews with boat owners, traders, captains, crew members and other villagers, and field observations of various on-shore aspects of the industry.

Secondary sources included documents borrowed from the village office, fisheries bureau, port bureau, the statistics bureau, and from the fishery cooperative. Documents held by boat owners and shark fin traders for operating costs, catches, and sales account books were also used. These latter were particularly valuable in providing data on operating costs and operating results, purchases of catches and selling prices, and fishermen's share. The data obtained from the account books were analysed by boat owner and boat. Data were cross-checked in follow-up interviews with several key informants among the traders and fishermen.

Results and discussion

Development of longline shark fishing in Karangsong Village

Karangsong Village, Indramayu District, is 200km east of Jakarta at the mouth of the Cimanuk River. Villagers have engaged in small-scale longline shark fishing since the 1930s. Nylon nets were introduced in the village in the latter half of the 1960s, drift gillnet fishing (called *ngawa* in the region) developed, and fishing voyages lasting from one to three months brought in catches of over 2t, over half of which consisted of shark species.

The shark flesh was salted on the boats, brought back to the village and shipped to the interior mountainous area of West Java. The catch was mainly small-sized sharks. As sharks brought the highest prices of the fish caught, the fish traders were able to make a profit from sales of the salted shark meat. The shark fins were mostly small-sized, accounting for no more than 10% of the value of the catch.

By the 1970s, the catch from more than 300 boats was being purchased. Large-scale traders emerged, one of whom owned more than 40 boats. In the 1980s, with the motorisation of fishing boats and use of ice, villagers engaged in fresh fish production. With the emergence of long line fishing (called *es-esan)* and the change in the type of boat owner, *ngawa* fishing declined, and there was a drastic drop in the traders' fish business and the volume of fish traded.

In 1982, when this changeover was taking place, boat owners concluded sales contracts with traders, borrowing money from the traders to motorise their boats, and switched over to longline shark fishing. By 1985 each owner was operating five or six boats. Longline shark fishing was geared to catching only larger sharks. The price of shark fins from larger sharks was high, and the share of shark fins in the total value of the catch reached 30%-40%.

Around this time, a local trader, attracted by the high shark fin prices, got into the fin trade. In 1986 he went in with a trader who had been dealing in the local salted shark meat, and started collecting and selling shark fins. With the capital accumulated from sales of shark fins, a bank loan, and money borrowed from a Chinese shark fin exporter, he became an owner of a longline shark fishing boat. After that, other traders in salted shark meat also started contracting with boat owners to loan the latter fishing equipment and funds for motorisation. They also provided advances to cover operating costs, in exchange for sale of the catch, or they themselves became owners of motorised boats. Many new boats were built from 1988 to 1989. In the second half of 1989 there were 17 new boat owners and 176 new longline shark fishing boats in Karangsong.

Most of the owners were traders dealing in salted shark meat and shark fins and owned a number of boats. The biggest owner had 42 boats, and there were seven people who owned more than 10 boats. Although their productivity was low, by increasing the number of their boats, they were able to increase the volume offish handled from the catch.

Longline shark fishing boats and equipment

Initially in 1987, boats were 10m vessels previously used in ***ngawa*** fishing, fitted with second-hand 12-horsepower diesel engines. In 1989, the cost of building a new boat was 4 million rupiah (approximately US$2,200 at the time of writing), which was also the price of an engine. A set of equipment cost about 600,000 rupiah, so that at least 8.5 million rupiah (about US$4,700) was needed to start fishing with a new boat. Most boat owners started operating with their old boats, then had new boats built with the profits from sales of the salted shark meat and fins and using by bank loans.

Longlines are made from the unravelled strands of the rope used to moor large ships, and wire is wound around the branch line so that it is not cut by the sharp teeth of the sharks. Large 12cm-long fish hooks are used. The longlines are 3km in length and have about 200 hooks on them.

The boats have a cabin which is about 1 m in height and contains a cooking stove. Rice and salt are stored in the hold under the deck, which is also where the shark is kept after being cut up and salted.

Fishing grounds and operations

Four men, including the captain, operated a fishing boat, which was in use all year round. During the easterly monsoon season from April to November the boats crossed the Java Sea, going as far as the Natuna Sea and fishing in the Anambas Islands, the Tambelan Islands and the Natuna Islands area. On the way to the fishing grounds the boats called at Seliu, a small island south of Belitung Island, to take on fresh water and exchange information with other fishing boats. One fishing trip usually lasted from 40 to 60 days. There were about 30 to 50 days of actual fishing. Three or four fishing trips were made between April and November.

From November to April the following year, the fishing fleet moved to Kotabaru in the southern part of the island of Kalimantan, which was the base for fishing operations. On the way the fleet fished around the Masalembu Islands. Two Kotabaru-based fishing expeditions were made, or four including fishing to and from Kotabaru.

Shark fin traders took turns staying in Kotabaru to handle the catch and to supply necessities for the fishing boats. The fins were flown to the traders back in the village, while the salted shark meat was sent by ship to

Table 4. Buying price (rupiahs) of salted meat and shark fins by traders in village.

	1986	1987	1988	1989	1990	1991
Meat						
shark	400-450	450-500	450-500	375-500	550-600	700
ray	350	200-215	250	200-250	350	400
Shark fins						
Putih	15,000	20,000-30,000	45,000-55,000	60,000	60,000-75,000	75,000
Tanggungan	n.d.	n.d.	n.d.	45,000	50,000	45,000
Karanggan	n.d.	n.d.	n.d.	35,000	30,000	40,000
Unyil	n.d.	n.d.	30,000	27,000	30,000-35,000	n.d.
Gandenan(pres)	8,000	10,000-20,000	30,000-40,000	30,000	30,000-35,000	n.d.
Gandenan(coak)		n.d.	37,500	n.d.	n.d.	
Super(pres)		n.d.	25,000-32,000	25,000-27,000	32,000	38,000
Super(coak)		n.d.	37,500	40,000	53,000	67,000
BA I(pres)	6,000	15,000	20,000-22,500	20,000-23,000	23,000	28,000
BA I(coak)	n.d.	n.d.	n.d.	30,000	22,000-25,000	37,500
BA II(pres)	3,500	10,000	15,000-17,500	15,000-20,000	18,000-20,000	23,000
BA II(coak)	n.d.	n.d.	n.d.	n.d.	23,000-25,000	30,000
Plen	2,500	5,000	7,000	6,000	6,000	7,000

Key: Putih 30->40cm Tanggungan: 20-30cm; Unyil: <20cm a *Rhinobatos typus* fins Karanggan: 20-30cm *Rhina anclyostoma;* Gandenan: *Sphyrna* spp.; Super>30cm; BA 1: 20-30cm; BA: II 15-20cm; Plen: <15cm all dorsal fin length
pres = flat cut shark fin
coak = crescent cut shark fin
n.d.: no data available.
Source: based on author's field research and trader's account DOOKS.

Table 5. Selling prices (rupiahs) of shark fins to exporters.

Shark fins	1987	1988	1989	1990	1991
Putih I	64,000	77,000	81,000-103,000	85,000-110,000	n.d.
Putih II	60,000	65,000	65,000	81,000	103,000
Tanggungan	45,000	52,000	52,000-57,000	62,000	78,000
Karanggan	n.d.	60,000	68,000	68,000	77,500
Unyil	n.d.	n.d.	n.d.	n.d.	63,000
Gandenan(pres)	31,000-33,000	n.d.	n.d.	n.d.	n.d.
Gandenan(coak)	n.d.	n.d.	n.d.	85,000	100,000-103,000
Super(pres)	28,000-31,000	50,000	n.d	.n.d.	64,000
Super(coak)	50,000	60,000-70,000	65,000-70,000	69,000-77,500	77,500-100,000
BA I(pres)	20,000-24,000	36,000	n.d.	38,000	42,000
BA I(coak)	36,000	47,500	47,500	47,00-48,500	63,000
BA II(pres)	13,000-14,000	26,000	n.d.	28000	33,000
BA II(coak)	26,000	37,500	37,500	38,500	48,000
Plen	7,000-7,500	13,500	15,000	12,000	10,000

Key: Putih I: >40cm; Putih II: 30-40cm; Tanggungan: 20-30cm; Unyil: <20cm all *Rhinobatos typus;* Karanggan: fins of *Rhina anclyostoma* 20-30cm; Gandenan: *Sphyrna* spp. >30cm; Super: >30cm; BA I: 20-30cm; BA II: 15-20cm; Plen: <15cm
pres = flatcut fin
coak = crescent cut fin
n.d.: no data available.
Source: based on author's field research and trader's account books.

Surabaya, from where it was transported by truck to the village.

The long line gear was set two or three times per day, with large fish or dolphin meat used as bait. When caught, the shark was split open and salted and the innards removed.

Types of shark fin and prices

Shark fins were handled in sets a set consisted of one dorsal fin, the pair of ventral fins, and one lower caudal fin, except for the guitarfishes, in which case a set also included the second dorsal fin and the upper caudal fins. A dorsal fin with the cartilage intact, removed with a straight cut keeping it straight, is called *pres*, whilst a fin removed by a crescent-shaped cut with the cartilage cut off is called *coak*, and commanded a higher price per kg.

Fins were also divided into two types, white and black. The fins of the guitar fishes Rhinobatidae and the wedgefish Rhynchobatidae were both white. Those of the giant guitarfish commanded the highest prices. The black group included sharks such as hammerheads (Sphyrnidae spp.), the fins of which were particularly valuable (Table 4).

The buying and selling prices for shark fins rose twice between the first and second halves of 1987 and continued to rise steadily after that, so that by 1991 the price was double that of the latter half of 1987 (Table 5).

The catch

Table 6 shows the catch from three fishing expeditions in 1989 by boats owned by, or under contract to, one of the traders in the village. Eight boats took part in the first and second expeditions, but only six in the third. Because of a poor catch, one captain left his boat before the voyage, and one of the other boats was being repaired.

Catches varied substantially. The average catch from these 22 boat-voyages was 690kg of salted shark and ray meat and 16.6kg of shark fin (18.9 kilograms if the small-size *plen* fins (<15cm long) are included). The salted shark and ray meat was worth 290,000 rupiah, the shark fins 470,000 rupiah (not including the small-size *plen)* for a total average from the catch of 760,000 rupiah per boat per trip. The fins accounted for as much as 61% of the value of the catch (Table 6).

Operating costs

A boat set out carrying 700kg of salt, 200kg of rice, 2001 of fuel oil, oil, hooks, rope and other equipment, and just before leaving port the owner gave the captain a cash advance to buy supplies, some of which may have been used for the living expenses of the crews' families in the village.

The average operating cost in 1989 per trip was 530,000 rupiah. The advance of 200,000 rupiah accounted for 40% of the cost, followed by fuel oil (20%), rice (12.6%) and salt (10.8%). In 1987 the average trip cost about 300,000 rupiah. By 1991 this had risen to more than 600,000 rupiah.

Sharing system

After all overheads were covered, any remaining money from the catch was divided between the boat owner and the crews. First, the trader deducted the local tax and the cost of shipping the catch; then operating costs were deducted from the remainder. The owner got 50% of what remained, the captain 20%, and each of the crew 10%. The small-size *plen* shark fins were bought directly by the trader, for which the crew members were paid in the form of a bonus.

The catches (gross receipts) and operating costs for the 25 boat-voyages, the net receipts (obtained from deducting operating costs from the value of the catch, without

Table 6. Results (catch shown as volume in kg) of 22 boat-voyages in 1989.

Captain's name	DM	SD	DK	GD	TB	KM	MD	NM	Total	Average
1ST VOYAGE										
voyage period	28/5-15/7	25/5-13/7	24/5-13/7	20/5-4/7	21/5-4/7	25/5-11/7	18/5-6/7	25/5-26/6		
days	49	50	51	45	46	48	50	32	437	49
meat (kg)										
shark	1,153.0	700.0	470.0	157.0	275.0	1,000.0	1,180.0	70.0	5,573.0	619.2
ray	19.0	45.0	0.0	0.0	0.0	140.0	0.0	0.0	284.0	31.6
others	80.0	135.0	0.0	0.0	0.0	0.0	0.0	0.0	215.0	26.9
sub-total I	**1,252.0**	**880.0**	**470.0**	**157.0**	**275.0**	**1,140.0**	**1,180.0**	**70.0**	**6,073.0**	**674.8**
shark fins (kg)										
Putih	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.4
Karanggan I	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	5.7	0.7
Karanggan II	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	1.6	0.2
Tanggungan	0.0	0.0	0.0	0.0	0.5	0.0	1.8	0.0	2.3	0.3
Unyil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kikir	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Super(pres)	0.0	14.0	4.3	1.9	1.5	24.0	0.0	0.0	55.1	6.9
Super(coak)	19.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	31.0	3.9
Gandenan	0.0	0.0	4.0	0.0	0.0	4.0	0.0	0.0	8.0	1.0
BA I	5.0	1.7	2.2	0.0	1.9	5.3	0.0	0.8	18.8	2.3
BA II	1.5	3.8	3.1	1.2	1.0	1.7	0.0	0.7	20.4	2.5
others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
sub-total II	**27.0**	**21.1**	**13.6**	**3.1**	**4.9**	**35.0**	**21.1**	**1.5**	**146.0**	**18.1**
Plen	0.0	0.0	1.0	0.0	1.5	0.0	0.0	0.5	4.0	0.4
others	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.9	0.2
2ND VOYAGE										
voyage period	20/7-16/9	24/7-29/9	28/7-14/9	24/7-25/9	8/8-30/9	24/7-16/9	19/7-15/9	8/8-21/9		
days	59	68	49	64	54	55	59	45	529	61
meat (kg)										
shark	820.0	635.0	965.0	240.0	410.0	958.0	730.0	529.0	5,735.0	650.8
ray	55.0	68.0	0.0	0.0	40.0	0.0	35.0	50.0	508.0	56.4
others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
sub-total I	**875.0**	**703.0**	**965.0**	**240.0**	**450.0**	**958.0**	**765.0**	**579.0**	**6,243.0**	**708.0**
shark fins (kg)										
Putih	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Karanggan I	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	1.3	0.2
Karanggan II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tanggungan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unyil	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	1.3	0.2
Kikir	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.9	0.1
Super(pres)	16.0	11.0	26.0	3.3	0.0	8.1	0.0	8.0	73.4	8.2
Super(coak)	0.0	0.0	0.0	0.0	0.0	0.0	8.6	0.0	8.6	1.1
Gandenan	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	4.0	0.5
BA I	6.4	2.3	4.1	0.0	0.0	6.0	2.6	1.2	25.3	3.0
BA II	3.3	2.4	4.4	0.9	1.9	8.0	1.8	1.0	28.3	3.4
others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
sub-total II	**25.7**	**15.7**	**34.5**	**5.5**	**3.2**	**26.1**	**13.9**	**10.2**	**143.1**	**16.6**
Plen	0.0	3.5	4.0	0.9	2.6	4.3	**2.5**	1.7	21.0	2.4
others	0.0	5.5	0.0	0.0	0.0	0.0	0.0	4.8	10.7	0.7
3RD VOYAGE										
voyage period	23/9-24/10	4/10-24/11	24/9-31/10	-	_	26/9-26/10	23/9-24/10	28/9-6/11		
days	55	52	49	-	-	31	32	40	304	43
meat (kg)										
shark	990.0	792.0	843.0	-	-	580.0	530.0	530.0	4,445.0	635.0
ray	230.0	40.0	0.0	-	-	63.0	130.0	42.0	505.0	72.1
others	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0	0.0
sub-total I	**1,210.0**	**832.0**	**843.0**	**-**	**-**	**643.0**	**660.0**	**572.0**	**4,940.0**	**705.7**

Table 6... continued Results (catch shown as volume in kg) of 22 boat-voyages in 1989.										
Captain's name	**DM**	**SD**	**DK**	**GD**	**TB**	**KM**	**MD**	**NM**	**Total**	**Average**
3RD VOYAGE ... continued										
shark fins (kg)										
Putih	0.0	0.0	0.0	-	-	0.0	0.0	1.3	2.6	0.4
Karanggan I	0.0	0.0	0.0	-	-	0.0	0.5	0.0	1.5	0.2
Karanggan II	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0	0.0
Tanggungan	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0	0.0
Unyil	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0	0.0
Kikir	1.0	0.0	0.0	-	-	0.0	0.0	0.0	1.0	0.1
Super(pres)	17.4	14.5	14.0	-	-	7.0	10.5	7.7	72.3	10.3
Super(coak)	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0	0.0
Gandenan	6.3	0.0	0.0	-	-	0.0	0.0	0.0	6.3	0.9
BA I	2.9	3.7	5.7	_	-	1.7	1.0	3.0	18.7	2.7
BA II	3.4	3.5	4.2	-	_	4.0	2.7	2.8	21.6	3.1
others	0.0	1.5	0.0	-	-	0.0	0.0	0.0	1.5	0.2
sub-total II	**31.0**	**23.2**	**23.9**	**-**		**12.7**	**14.7**	**14.8**	**125.5**	**17.9**
Plen	**4.3**	**4.0**	**0.0**	_	_	**2.0**	**1.0**	**1.6**	**14.0**	**2.0**
others	**1.7**	**0.0**	**0.0**	**-**	-	**0.0**	**1.0**	**0.0**	**5.5**	**0.8**

	Grand total	**Average**
days	1,270.0	50.8
meat (kg)		
shark	0.0	0.0
ray	1,297.0	51.9
others	215.0	8.6
sub-total I	**17,265.0**	**690.6**

	Grand total	**Average**
days	1,270.0	50.8
shark fins (kg)		
Putih	5.7	0.2
Karanggan I	8.5	0.3
Karanggan II	1.6	0.1
Tanggungan	2.3	odd
unyil	1.3	
Kikir	1.9	
Super(pres)	200.8	8.0
Super(coak)	39.6	1.6
Gandenan	18.3	0.7
BA I	62.8	2.5
BA II	70.3	2.8
others	1.5	0.1
sub-total II	**414.6**	**16.6**
Plen	39.0	1.6
others	18.1	0.7

Key: Putih I:40cm; Putih II: 30-40cm Tanggungan 20-30cm, Unyil:<20cm; all *Rhinobatos typus* Karanggan fins of *Rhina anclyostoma;* Kikir: Rhinobatidae fin; Gandenan: *Sphyrna* spp.; Super:>30cm; BA I: 20-30cm; BA II:15-20cm; Plen <15cm.
pres: flatcut fin
coak: crescent cut fin
Source: based on author's field research and boat owner/trader account books.

including shipping costs and local tax) came to approximately 226,000 rupiah. Of this, the boat owner got 113,000 rupiah, the captain 45,000 rupiah and the crew members 22,500 rupiah each (Table 6).

In eight of the 22 boat-voyages, the value of the catch was less than the operating costs. A crew member on a boat under a good captain could make about 100,000 rupiah per year, but one on a boat with poor catches may have got practically nothing. The skill of the captain determines the trader's profit, and what the crew members are paid.

Most captains and crew members borrowed money from the boat owner for their families' living expenses when they left port or during the voyage. If their pay from a voyage was small, they returned only part of what they had borrowed, the remainder of the loan being carried over until the next voyage. Likewise, the shortfall when the income from the catch was less than the operating costs was added to the operating costs of the next voyage. So unless the next catch was quite good, nobody got paid and the loans could not be paid back.

Trader/boat owners sometimes had to cover such losses from their shark fin sales profits, but they were usually not likely to be able to recover their losses. Thus they went to great pains to get skilled and experienced chief fishermen, giving the latter houses or paying them the equivalent of their own pay from the catch if they bring in big catches two or three times.

Profits from the catch

The selling price of shark fins rose every year, and the buying price was set on average at between 50% and 65%

Table 7. Results showing income (loss) in rupiah) of 22 boat-voyages in 1989.

Captain's name	DM	SD	DK	GD	TB	KM	MD	NM	Total	Average
1ST VOYAGE										
voyage period	28/5-15/7	25/5-13/7	24/5-13/7	20/5-4/7	21/5-4/7	25/5-11/7	18/5-6/7	25/5-26/6		
days	49	50	51	45	46	48	50	32	437	49
meat (rupiah)										
shark	576,500	350,000	235,000	78,500	137,500	500,000	590,000	35,000	2,786,500	309,611
ray	3,800	11,250	0	0	0	0	0	0	31,050	3,450
others	28.000	54,000	0	0	0	49,000	0	0	131.000	14,556
sub-total I	**608,300**	**415,250**	**235,000**	**78,500**	**137,500**	**549,000**	**590,000**	**35,000**	**2,948,550**	**327,617**
sharlc fins (rupiah)										
Putih	0	0	0	0	0	0	0	0	0	0
Karanggan I	82,500	96,000	0	0	0	0	0	0	178,500	19,833
Karanggan II	0	0	0	0	0	0	199,500	0	199,500	22,167
Tanggungan	0	0	0	0	0	0	40,000	0	40,000	4,444
Unyil	0	0	0	0	15,000	0	108,000	0	123,000	13,667
Kikir	0	0	0	0	0	0	0	0	0	0
Super(pres)	0	0	0	0	0	0	0	0	0	0
Super(coak)	0	420,000	107,500	57,000	45,000	600,000	0	0	1,464,500	162,722
Gandenan	760,000	0	0	0	0	0	540,000	0	1,300,000	144,444
BA I	0	0	120,000	0	0	120,000	0	0	240,000	26,667
BA II	150,000	34,000	44,000	0	38,000	106,000	0	13,600	423,600	47,067
others	30,000	57,000	46,500	18,000	15,000	25,500	0	8,400	311,400	34,600
sub-total II	**1,022,500**	**607,000**	**318,000**	**75,000**	**113,000**	**851,500**	**887,500**	**22,000**	**4,280,500**	**475,611**
Plen	0	0	0	0	0	0	0	0	0	0
others	0	0	0	0	0	0	0	0	0	0
total (gross receipts)	**1,630,800**	**1,022,250**	**553,000**	**153,500**	**250,500**	**1,400,500**	**1,477,500**	**57,000**	**7,229,050**	**803,228**
operation costs	638,545	521,610	374,500	459,130	502,370	502,780	573,790	573,000	4,623,035	513,671
net receipts	992,255	500,640	178,500	(305,630)	(251,870)	897,720	903,710	(516,000)	2,606,015	289,557
share of boat owner	496,128	250,320	89,250	(152,815)	(125,935)	448,860	451,855	(258,000)	1,303,008	144,779
share of captain	198,451	100,128	35,700	(61,126)	(50,374)	179,544	180,742	(103,200)	521,203	57,911
share of crew	99,226	50,064	17,850	(30,563)	(25,187)	89,772	90,371	(51,600)	260,602	28,956
2ND VOYAGE										
voyage period	20/7-16/9	24/7-29/9	28/7-14/9	24/7-25/9	8/8-30/9	24/7-16/9	19/7-15/9	8/8-21/9		
days	59	68	49	64	54	55	59	45	529	61
meat (rupiah)										
shark	348,500	254,000	386,000	96,000	164,000	407,150	292,000	212,000	2,325,050	258,339
ray	13,750	0	0	0	10,000	0	8,750	8,400	105,900	11,767
others	0	17,000	0	0	0	0	0	0	17,000	1,889
sub-total I	**362,250**	**271,000**	**386,000**	**96,000**	**174,000**	**407,150**	**300,750**	**220,400**	**2,447,950**	**271,994**
shark fins (rupiah)										
Putih	0	0	0	0	0	0	0	0	0	0
Karanggan I	0	0	0	0	0	0	0	0	0	0
Karanggan II	0	0	0	0	58,500	0	0	0	58,500	6,500
Tanggungan	0	0	0	0	0	0	0	0	0	0
Unyil	0	0	0	0	0	0	0	0	0	0
Kikir	0	0	0	35,000	0	0	0	0	35,000	3,889
Super(pres)	0	0	0	0	0	0	31,500	0	31,500	3,500
Super(coak)	448,000	297,000	728,000	89,000	0	218,700	0	216,000	2,024,700	224,967
Gandenan	0	0	0	0	0	0	344,000	0	344,000	38,222
BA I	0	0	0	0	0	120,000	0	0	120,000	13,333
BA II	140,800	50,600	82,000	0	41,800	132,000	78,000	26,400	613,700	68,189
others	49,500	35,700	66,000	13,500	49,600	120,000	36,000	15,000	458,900	50,989
sub-total II	**638,300**	**383,300**	**876,000**	**137,500**	**149,900**	**590,700**	**489,500**	**257,400**	**3,686,300**	**409,589**
Plen	0	0	0	0	0	0	0	0	0	0
others	0	0	0	0	0	0	0	0	0	0
total (gross receipts)	**1,000,550**	**654,300**	**1,262,000**	**233,500**	**323,900**	**997,850**	**790,250**	**477,800**	**6,134,250**	**681,583**
operation costs	709,000	522,250	542,850	453,450	466,115	502,030	651.600	508,175	4,898,400	544,267
net receipts	291,550	132,050	719,150	(219,950)	(142,215)	495,820	138,650	(30,375)	1,235,850	137,317
share of boat owner	145,775	66,025	359,575	(109,975)	(71,108)	247,910	69,325	(15,188)	617,925	68,658
share of captain	58,310	26,410	143,830	(43,990)	(28,443)	99,164	27,730	(6,075)	247,170	27,463
share of crew	29,155	13,205	71,915	(21,995)	(14,222)	49,582	13,865	(3,038)	123,585	13,732

Table 7 ... continued. Results (showing income (loss) in rupiah) of 25 boat-voyages in 1989.

Captain's name	DM	SD	DK	GD	TB	KM	MD	NM	Total	Average
3RD VOYAGE										
voyage period	23/9-24/10	4/10-24/11	24/9-31/10		-	2679-26/10	23/9-24/10	28/9-6/11		
days	55	52	49			31	32	40	304	43
meat (rupiah)										
shark	396,000	316,000	337,000		-	232,000	212,000	212,000	1,777,000	253,857
ray	46,000	8,000	0			12,600	26,000	8,400	101,000	14,429
others	0	0	0			0	0	0	0	0
sub-total I	**442,000**	**324,000**	**337,000**		**-**	**244,600**	**238,000**	**220,400**	**1,878,000**	**268,286**
shark fins (rupiah)										
Putih	0	0	0			0	0	0	0	0
Karanggan I	0	0	0			0	0	84,500	169,000	24,143
Karanggan II	0	0	0			0	15,000	0	60,000	8,571
Tanggungan	0	0	0			0	0	0	0	0
Unyil	0	0	0			0	0	0	0	0
Kikir	0	0	0			0	0	0	0	0
Super(pres)	30,000	0	0			0	0	0	30,000	4,286
Super(coak)	578,000	493,000	448,000		-	210,000	376,000	246,400	2,393,400	341,914
Gandenan	0	0	0			0	0	0	0	0
BA I	204,000	0	0			0	0	0	204,000	29,143
BA II	72,500	92,500	131,000			37,400	23,000	69,000	442,900	63,271
others	68,000	70,000	75,600			72,000	48.000	50,400	404,000	57,714
sub-total II	**952,500**	**655,500**	**654,600**		**-**	**319,400**	**462,000**	**450,300**	**3,703,300**	**529,042**
Plen	0	18,000	0			0	0	0	18,000	2,571
others	0	0	0			0	0	0	0	0
total (gross receipts)	**1,394,500**	**997,500**	**991,600**		**-**	**564,000**	**700,000**	**670,700**	**5,599,300**	**799,900**
operation costs	653,540	584,010	508,775		-	539,610	599,050	504,080	3,794,765	542,109
net receipts	740,960	413,490	482,825		-	24,390	100,950	166,620	1,804,535	257,791
share of boat owner	370,480	206,745	241,413			12,195	50,475	83,310	902,268	128,895
share of captain	148,192	82,698	96,565			4,878	20,190	33,324	360,907	51,558
share of crew	74,096	41,349	48,283			2,439	10,095	16,662	180,454	25,779

	Grand total	Average of 22 boats
days	1,270	51
meat (rupiah)		
shark	6,888,550	275,542
ray	237,950	9,518
others	148,000	5,920
sub-total I	**7,274,500**	**290,980**
shark fins (rupiah)		
Putih	0	0
Karanggan I	347,500	13,900
Karanggan II	318,000	12,720
Tanggungan	40,000	1,600
Unyil	123,000	4,920
Kikir	35,000	1,400
Super(pres)	61,500	2,460
Super(coak)	5,882,600	235,304
Gandenan	1,644,000	65,760
BA I	564,000	22,560
BA II	1,480,200	59,208
others	1,174,300	46,972
sub-total II	**11,670,100**	**466,804**

	Grand total	Average of 22 boats
days	1,270	51
Plen	18.000	720
others	0	0
total (gross receipts)	**18,962,600**	**758,504**
operation costs	13,316,200	532,648
net receipts	5,646,400	225,856
share of boat owner	2,823,200	112,928
share of captain	1,129,280	45,171
share of crew	564,640	22,586

Key: Tanggungan: 20-30cm; Unyil: <20cm all *Rhinobatos typus;* Karanggan: fins of *Rhina anclyostoma;* Gandenan: *Sphyrna* spp. >30cm; Super; BA I: 20-30cm; BA II: 15-20cm; Plen: <15cm.
pres: flatcut fin
coak: crescent cut fin
Source: author's field research and boat owner/trader account books.

of the selling price. The larger the shark fin, the higher price it commanded and the larger the selling profit.

For the 22 boat-voyages that took place from June to July, 184kg were taken, and sold for a profit of 3.26 million rupiah (shipping costs not included), or 360,000 rupiah per boat. By contrast the 6t of salted shark and ray meat from the catch sold for 550 rupiah and 250 rupiah per kilo respectively, bringing a profit of only 50 rupiah per kilo, or 300,000 rupiah overall.

Traditional social norms in the fishing village

The efforts by trader/boat owners to secure the best chief fishermen cannot be explained in purely economic terms. For instance, when the boats were in and the crews had no income, the trader/boat owners usually lent them money for living expenses. They were supposed to pay this back from out of the wages they received from the next fishing voyage. But when unable to do so - as was usually the case - the traders did not often press them to repay. If they did, the fishermen would not want to work on their boats anymore and would switch to another trader's boat, without paying off their former employer.

During the sea festival and at Ramadan, at the end of the Muslim fast, the traders gave the crew rice and T-shirts and paid for the bands or theatre groups that came to the village to provide entertainment. That was considered to be their social responsibility.

These outlays could sometimes become quite a large economic burden. But such customs can be seen in terms of the trader redistributing wealth among the fishermen from the profits from the sale of shark fins, rather than monopolising it for himself.

Conclusions

The leap in the price of shark fins on the international market transformed shark fishing in Karangsong.

Although continually rising market prices for shark fins underpin this industry, the salted shark meat which accounted for 40% of the value of the catches cannot be ignored. The development from the 1970s of drift gillnet fishing, *ngawa,* which netted shark as the principle catch, and the opening up of domestic markets for salted shark meat by the fish traders, laid the foundations for the development of the longline shark fishing industry in this village.

Shark fins formed 60% of the value of the catch in this study. If the market price should stabilise or drop, or if the volume of the catch should decline due to the loss of fishing grounds, or a decrease in shark resources, the industry could be financially very vulnerable. Whilst the market price of salted shark meat is also rising, the profits would be insufficient to maintain the fishing industry at this level. The increase in the value of the catch brought about by the rise in the price of shark fins was cancelled out by operating costs, which doubled between 1987 and 1991. This led to a levelling off, or even a drop, in the returns to the chief fishermen and crews on the boats. Given the fierce competition over resources, it is thought unlikely at the time of writing that the longline shark fishing industry will be able to keep growing, even if the price for shark fins continues to rise.

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The Status of Shark Fisheries in Zanzibar

M.A. Shehe
Community Development and Environmental Conservation Zanzibar, P.O. Box 201, Zanzibar, Tanzania
N.S. Jiddawi
Institute of Marine Sciences, P.O. Box 668, Zanzibar, Tanzania

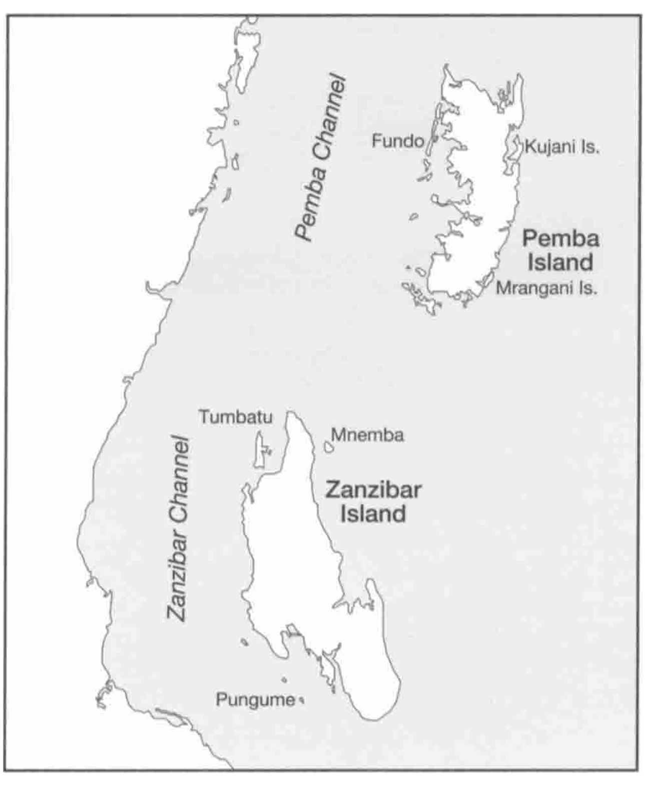
The conservation and management of chondrichthyan fishes (sharks, rays and chimaeras) is a concern, particularly of sharks. There are limited population data, making status assessment difficult for Zanzibar. Sharks form a major food source for Zanzibar's growing human population. Some species are of conservation concern, several are considered vulnerable to extinction. Threats come from unregulated fishing, and increasing commercial demand for sharks. Although fishing practices are still traditional, catches are declining. While external factors may be partly responsible, it is possible that the traditional fishery is unsustainable. Marine fisheries laws have recently been revised, but need further revision to provide sufficient protection for marine species.

The paper summarises the status of shark fisheries in Zanzibar. Basic information on shark fisheries obtained from a literature review, interviews, informal discussions and observations at landing stations and fish markets, indicates the pattern of seasonal catches. The common species caught by the fishermen are listed, some of which are threatened by overexploitation. Fisheries laws and regulations exist, but adequate monitoring of fisheries is lacking. Steps to improve the current position are outlined.

Introduction

Zanzibar is rich in marine resources and these are an important protein source. The fishing industry is mainly unmechanised, and is one of the main coastal occupations. It directly involves more than 15,000 people plus others in supporting activities such as boat building, gear manufacture and fish trading, with fisheries contributing 4%-10 % of the total Gross Domestic Product (GDP) (Haji 1990). They are the major source of protein, with per capita consumption of about 20kg per annum at the time of writing. This mainly comes from demersal coral reef fish and small pelagic fish.

Figure 1. Map of the Zanzibar study area.



The conservation and management of sharks, rays and chimaeras is of increasing concern to many people, as their status becomes better understood. Once considered 'under-utilised' resources, increasing numbers of shark populations worldwide now face over-exploitation and depletion as markets for shark meat, fins and cartilage expand (Camhi *et al.* 1998).

Data for sharks in Zanzibar are limited, making assessments of status difficult. Nonetheless, the size of the shark and ray catches appears to be declining. This paper discusses the status of sharks in the Zanzibar fisheries, the species of economic importance and threatened species, trends, seasonality of shark trade and potential and actual management measures.

Methodology

Basic information was gathered through interviews, a literature review, observations and informal discussions. Interviews were conducted with fishers, exporters, government officials and consumers. Additional information was obtained from the Fisheries statistics section of the Sub Commission of Fisheries (SCF) Zanzibar, and from data collected at two landing stations in Zanzibar by the Institute of Marine Sciences. Standardised questions were used for interviews, relating to shark catches, species most commonly caught or rarely seen, the shark fin trade, gears used and other related information.

Results

Sharks are caught the whole year round. Landings declined from 1994 to 1996 (Figure 2). Peak catches were recorded in April, July and October (Figure 3). Shark fin exports are given in Figure 4. About 2.2t were exported annually. This is declining, and in 1995 exports were only 0.3t. In 1996 sharks made up 4.5% of all fish caught.

Catches varied between districts (Figure 5). The central district was the main source of shark landings followed by North A. Observations of artisanal fish landings at Matemwe and Mkokotoni by IMS in 1996 estimated shark catches to be approximately 6t and 0.25t respectively (IMS CIDA project, in progress, 1997).

All shark species identified by fishermen are listed in Table 1. The most common were angel sharks *Squatina africana* and four species were reported as rarely seen.

Discussion

Catch trends

The available statistics indicate that catches of all fish landed in Zanzibar have declined from around 20,000t in the 1980s to about 10,000t in 1995 (Jiddawi *el al.* 1992). Sharks statistics show a similar trend. Fishermen interviewed said the catches have declined to such an extent that, in a landing station, only one fisherman is likely to have ashark in his catches. People relate this sharp decrease to overfishing. This may be the result of the increase in number of fishermen, and poor fishing methods. Sharks are vulnerable to overfishing because of their slow growth, late maturity, and low reproductive capacity (Camhi *et al.* 1998). Even though sharks are rarely taken as target species, and more usually as bycatch, numbers continue to decline. Accidental harvesting of immature specimens may affect numbers recruited into the adult population.

Species

In the early 1980s the FAO carried out a study on commercial marine and brackish water species of Tanzania (Bianchi 1985), identifying 26 species of sharks. The study did not indicate status. Results from interviews carried out for the present study, revealed that all the 26 species are commonly observed (Table 1). The most common species belong to the family Carcharhinidae. Other species were observed that were not included in the FAO manual, such as the whale shark *Rluncodon typus.* Many fishermen have reported that they normally see a very big fish of up to 10 *pimas* (one *pima* is approximately 2m). The same has been reported by travellers crossing the Zanzibar channel.

No official statistics are available to indicate status or threat. Fishers interviewed reported that one or two

Figure 2. Annual trend of tonnage of sharks and rays caught in Zanzibar, 1989-1996.

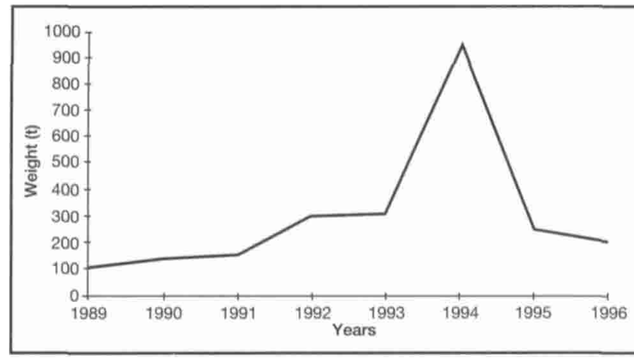


Figure 3. Mean monthly catch of sharks and rays from selected regions in Zanzibar, 1995-1996.

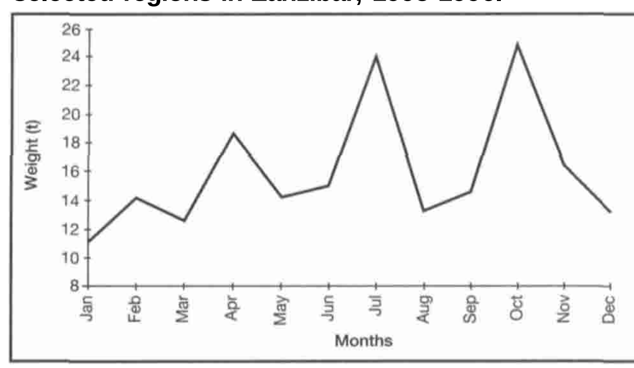


Figure 4. Annual export of shark fins from 1989-1995 in Zanzibar.

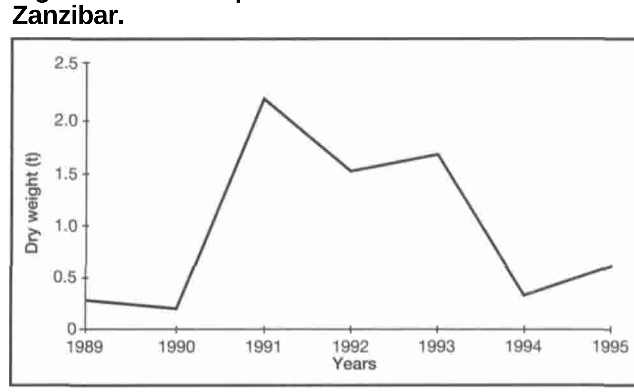


Figure 5. Total tonnage of sharks caught in Zanzibar by district, 1996.

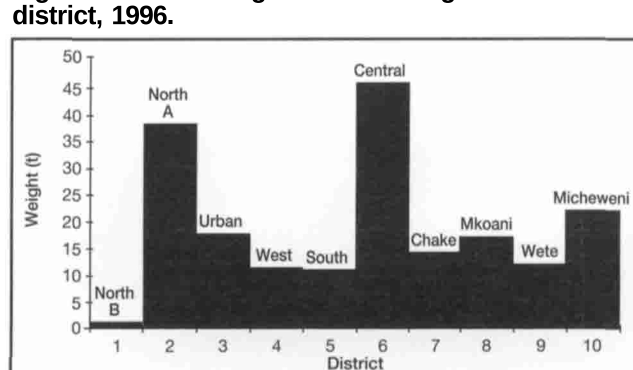


Table 1. Some of the shark species caught in Zanzibar, ranked according to occurrence in landings.

Species name	Common name	Local name	%	rank
Carcharhinusfalciformis	Silky shark	Dhamirime	52	10
Galeocerdocuvier	Tiger shark	Papa madebe	76	3
Carcharhinusalbimarginatus	Silvertip shark	Sangani//Marimbe	52	10
Carcharhinusmelanopterus	Blacktip reef shark	Papa	40	18
Carcharhinussealei	Blackspot shark	Mambwe	52	10
Carcharhinusamblyrhynchos	Gray reef shark	Mambwe	23	22
Carcharhinusmacloti	Hardnose shark	Papa mwamba	52	10
Carcharhinusplumbeus	Sandbar shark	Madebe tumbo	28	24
Carcharhinussorrah	Spottail shark	Kinengo mambwe	48	15
Loxodon macrorhinus	Sliteye shark	Sasareni mtobwe	56	8
Negaprionacutidens	Sharptooth lemon shark	Papa ngozi	40	18
Rhizoprionodonacutus	Milk shark	Papa nyama	48	15
Scoliodon laticaudatus	Spadenose shark	Papa sumbwii	44	17
Triaenodonobesus	Whitetip reef shark	Papa siruanzi	28	24
Pseudoginglymostoma brevicaudatum	Shorttail nurse shark		84	2
Hemipristiselongata	Snaggletooth shark	Papa mwamba	32	22
Isurusoxyrinchus	Shortfin mako	Nyarani	76	3
Sphyrnalewini	Scalloped hammerhead	Papa pingusi	36	21
Sphyrnamokarran	Great hammerhead	Papa pingusi	60	7
Centrophorusmoluccensis	Smallfin gulper shark	Papa	28	26
Dalatiaslicha	Kitefin shark	Papa	40	18
Squatinaafricana	African angelshark	Kirimawe	96	1
Stegostomafasciatum	Zebra shark	Papachindi	76	3
Hypogaleushyugaensis	Blacktip topeshark	Papa upinde	56	8
Alopias vulpinus	Thresher shark	Sangani	28	26

Source: interviews with local fishermen

species are rarely seen. They were not able to provide us with enough details to accurately identify these species. The African angelshark was the commonest species caught and the thresher shark *Alopias vulpinus,* smallfin gulper shark *Centrophorus moluccensis* and whitetip reef shark *Triaendon obesus* were the rarest caught species.

Seasonality

Sharks catches are seasonal (Figure 2). The fishers indicated that sharks migrate to the coastal areas from deep waters, and the return migration is due to changes in wind direction. Some reported that sharks move to the shallow waters as the wind blows from the south and return to deep waters when the wind changes to come from the north. Therefore, fishing grounds in Zanzibar are selected according to wind direction, and accessibility is determined by the ability of the vessels to sail with the wind (most vessels are sail-driven). Good fishing areas are those protected by the coral reef barriers, where fishing is possible throughout the year (Jiddawi *et al.* 1992). Shark migration has a clear effect on catches.

Social and economic factors affecting sharks

Although cheaper, sharks are not the most popular food fish. One kg can cost up to 800 Tanzania Shillings (US$1.33), while preferred types may cost up to 1,300 Tanzania Shillings (US$2.17). Nonetheless, sharks remain an important source of protein in Zanzibar. Shark fins have long been exported to the Far East, especially Hong Kong. Between 1919 and 1929 shark fins were chiefly exported to China (Last 1929). In 1923 it was reported that 6.56t were exported annually. Currently only 2.2t are exported annually

Conservation and management measures

Recently, the Zanzibar administration has been concerned with enhancing the conservation and management of marine resources, and has revised its fisheries legislation, providing a good legal basis for marine resource conservation. All forms of destructive fishing methods, e.g. dynamite fishing, catching of under-aged fish, use of poison in fishing operations and destruction of marine habitat, are prohibited. In addition, Zanzibar has taken several steps towards establishment of marine protected areas and community-based management. The aim is to comply with Chapter 17 section lc and 1d of the United Nations Conference on Environment and Development (UNCED 1992).

Despite this, fishing continues to be unsustainable, and some shark species may be vulnerable or even endangered in Zanzibar. To change the position will require a change in public perception of both sharks and the implications of over-exploiting finite marine resources.

Conclusion and recommendations

The current decline in shark numbers needs prompt action to limit the possibility of some species going extinct. One way would be to educate the public of the importance of sharks, both ecologically and economically. The development of localised conservation and management strategies has been tested and proven successful in some areas of Zanzibar, the best example being at Fumba village.

Institutionally, it will be necessary to develop well-resourced fisheries administrations. As a part of institutional reform, administrations at the local level should be allowed to fully assume management roles, as resource constraints limit the efficient working of central administrations. In addition, greater transparency is needed on issues affecting the marine environment and fishery resources. This will make people aware of the dangers linked to resource degradation, and allow them to participate fully in making decisions regarding resource conservation and management. It is also recommended that the institutions concerned should try to develop strategies that will lead to the development of plans for domestic shark management, and conduct more research on sharks and other elasmobranchs in Zanzibar. Data collection to improve public knowledge of the biology of shark species, the scale of fisheries landings and trade both locally and internationally will need improvement too. For all this to work properly, laws need to be fully enforced.

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Preliminary Report on Taiwan's Whale Shark Fishery

Che-Tsung Chen
National Kaohsiung Institute of Marine Technology, 142 Haichuan Road, Nantzu, Kaohsiung, Taiwan
Kwang-Ming Liu and Shoou-Jeng Joung
National Taiwan Ocean University, 2 Pei-Ning Road, Keelung 20224, Taiwan

This study collected information on catch and distribution of whale sharks *Rhincodon typus* around Taiwan by interviews with 32 captains of harpoon vessels and 58 owners/operators of set-nets. The main fishing methods for whale shark in Taiwan are harpoon and set-net, with gillnet and longline playing a minor role. Man had the highest annual catch rate for set-nets with 2.35 animals per set-net per year. Miaoli had the lowest catch rate with 0.83 animals per set-net per year. The average estimated annual catch per year was: Man, 61.1; Hualien, 46.8, Taitung, 25.3; Pingtung, 14; Hsinchu, 5.17; Miaoli, 3.33; Penghu, 2. The annual catch by set-nets was estimated to be 158 individuals. The estimated total catch for harpoon fisheries in Hungchung, Taitung and llan were 33.6, 62.4 and 17.8, respectively. The total annual catch for harpoon fisheries in Taiwan was estimated to be 114 individuals. Whale sharks seem to have an extremely low reproductive capacity and high vulnerability to over-exploitation. Creation of a successful management system for whale shark fisheries will require further research into the species' life history, population structure, behaviour, migration patterns and genetics.

Introduction

The whale shark *Rhincodon typus* is the largest fish in the world, growing to a length of almost 14m (Pauly, this volume). However, little is known of the species' biological history, its ecological role, or its conservation status. There is increasing concern that heavy, and largely unregulated, trade in shark species in general is contributing to a decline in global shark stocks. Efforts by the IUCN/SSC Shark Specialist Group and relevant national and international authorities to gauge the current level of threat for many species and effects on individual species are hindered by a lack of data (Camhi *et al.* 1998). Although the whale shark is listed in the IUCN 'data deficient' category (IUCN 1997), there is growing concern that trade may be depleting stocks of this fish.

In Taiwan, there appears to be no dedicated whale shark fishery and the species is caught mainly as a bycatch of harpoon and set-net fisheries. Referred to as the 'tofu shark' in Taiwan on account of its soft white flesh, the species has recently emerged as a delicacy. The last five or six years have seen much interest among Taiwan's media in whale shark landings, particularly in details such as the shark's large size, capture methods, its high price, and whether or not the animal poses a danger to humans. Little attention has been paid, however, to potential conservation problems for the species resulting from increasing domestic consumption.

The survey described below was conducted as a first step in collecting information on the distribution and catch of whale sharks around Taiwan, as well as in gathering market and trade information for future use as a reference in developing management and conservation strategies. The data compiled here supplements information on the history and trends in Taiwan's shark fisheries in Chen *et al.* 1996. The report hopes to contribute towards other regional research and monitoring efforts, such as WWF's 1996 investigation into the whale shark fishery in the Bohol Sea (Philippines) (Alava *et al.*, this volume) and research into the migratory patterns of the species through electronic tagging of specimens in north-west Australia (Newman *et al.*, this volume).

Methods

Initial research for this project was conducted from February to July 1996. Information was primarily based on interviews with the crews and owners of harpoon and set-net vessels, from which whale sharks are caught as a bycatch: 58 of a total of 97 set-net fishermen (60%) and 32 captains of98 harpoon vessels (32.7%) operating in Taiwan were interviewed. Questions covered catch volumes, size of specimens caught, capture locations, whale shark behaviour, and migratory routes.

Data on numbers of set-nets and harpoon vessels in operation were collected from the Taiwan Fishery Bureau, as well as from regional and local fishers' associations. Local fishers' associations are responsible for the collection of fisheries catch and sales data in Taiwan. Available data for whale shark catch and sales were limited, however, for reasons explained below.

Regional catches were calculated from the average catch per unit of set-net or harpoon vessel, as reported in interviews, and multiplied by the total number of set-nets and harpoon vessels in operation. Figures for the estimated total annual catches of whale sharks may not accurately reflect the catches of those set-net operators and harpoon fishers who were not interviewed. Furthermore, catch effort data for the two types of fishery were not collected **for** this preliminary report.

Results

Biology and distribution

Whale sharks live in epipelagic (waters to a depth of 200m), oceanic and coastal areas of tropical and subtropical regions, including the western and eastern Atlantic, west Indian, central Pacific and eastern Pacific oceans (Compagno 1984). In the western Pacific, the species is commonly found along the Kuroshio Current. Although no tagging or marking studiesdocumenting their migration routes have been published at the time of writing, whale sharks are believed to be highly migratory, their movements corresponding to plankton blooms and blooms associated with coral spawning, and the changing temperatures of water masses. They are associated with schools of pelagic fishes, especially mackerel Scombridae (Compagno 1984). Examination of the stomach contents of landed whale sharks revealed small fish such as anchovy and shrimp, as well as plankton.

Joung *et al.* (1996) found that the whale shark is ovoviviparous (the female produces live offspring from

Figure 1. Map of Taiwan with black areas along the coastal line showing set-net operations.

eggs hatched in the uterus) and found one gravid female, 16t and 10.6m long, containing 300 embryos. This level of fecundity is possibly the highest among elasmobranchs (sharks, skates and rays). However, even female whale sharks in the 15-34t range are rarely found to be carrying offspring, which may indicate an extremely late sexual maturity, low reproductive capacity, and high vulnerability to over-exploitation.

Taylor (1994) suggested that whale sharks do not reach maturity until they are over 30 years of age, at a size of 9m. Given the size of a full-term whale shark foetus (0.7kg and 60cm) (Joung *et al.* 1996), such a lengthy maturation period is possible. The gestation period is unknown. The species is thought to grow to a maximum length of 18m (Compagno 1984); however, in March 1987, two of the authors recorded one specimen in Lotung fish market (Ilan county), which was approximately 20m in length and weighed 34t. This is believed to be the largest whale shark ever caught in Taiwan.

Limited population data exist for Taiwan's whale sharks. Figures collected for set-nets indicate that the species is distributed around Taiwan's coastal area, particularly off the eastern coast (Figure 1), and specimens have been sighted around the island year-round, with winter (December to February) and summer (June to August) being the peak seasons. The fish follow the Kuroshio Current north along the coastline, and are known to enter the waters of southern Japan in spring. The duration and route of their migration south is not known.

Fishing methods

In Taiwan, whale sharks are caught accidentally by set-net or on an opportunistic basis by harpoon; catches by gillnets and longlines are less common. Set-nets are nets which are suspended vertically from floats at a fixed location. These are used to target seasonally migratory fish including mackerel (genus *Scomber),* scad (family Carangidae), tuna (genus *Tlnmnus),* barracuda *Sphyraena japonica,* bigeye *Priacanthus macracanthus* and bonito (genus *Auxis).* Whale sharks occasionally swim close to the coastline while in pursuit of prey, and blunder into set-nets, making them an easy catch for set-net operators.

Harpoon fishers, using three-prong or spear-headed weapons, target billfish (Istiophoridae, including *Istiophorus platypterus, Makaira mazara, Makaira indica* and *Tetrapturus audax).* Because of the difficulty of handling such large animals, harpoon fishers have previously avoided catching whale sharks. However, this situation is changing following the growing demand for this fish and the correspondingly high price it fetches. The animal's docility, combined with its habit of swimming slowly and near the surface, makes it an easy target for harpoon fishers. After it has been harpooned, the whale shark is towed to the harbour.

Catch volumes

Figure 1 shows the area of operation for set-nets in the Hsinchu, Ilan, Hualien, Taitung, Pingtung and Penghu coastal regions. All but three of the 58 set-net operators interviewed have recorded the capture of whale sharks. As no set-nets or harpoon vessels operate between Hsinchu in the north-west and Pingtung in the south-west, there are no capture records for Taiwan's western coastal region except for the Penghu area. However, the authors believe that whale sharks occur in this region.

It is difficult to estimate the actual catch from local fish market data, as the majority of landed whale sharks are sold outside the regular fish market system to avoid incurring market fees. Only the markets at Chengkung and Suao have recorded landing data for whale sharks.

A wholesaler in Suao who specialises in whale shark meat estimated that about 250 whale sharks are landed in Taiwan annually (Y.S. Yu, pers. comm., August 1995). He also estimated that landed specimens range in weight from several hundred kilograms to as much as 30t.

Set-net catches

Table 1 shows the distribution for set-nets based on data collected from the Taiwan Fishery Bureau and regional fishermen's associations. A total of 97 set-nets were in operation in Taiwan's inshore area; 58 set-net fishermen (60%) were interviewed. The main fishing areas for set-nets were Taitung, Hualien and Ilan, comprising 84.9% of the total annual catch of whale sharks. Ilan had the highest annual catch rate for set-nets, with 2.35 animals per set-net per year, and Miaoli had the lowest, with 0.83 per set-net per year (Table 1). Taking the average annual catch per year in each region, and multiplying it by the number of nets gave the estimated total catch of whale sharks by set-net as 158 specimens.

Harpoon catch

Harpoon fisheries operate in the Hongchun, Taitung and Ilan coastal areas, with the harpoon-equipped vessels in each region numbering 20, 46 and 32 respectively (Table 2). Based on catch information provided by the harpoon fishermen interviewed (32 of 98 or 32.7%), the total annual catch of whale sharks for harpoon fisheries in Taiwan was estimated to be 114 individuals. Three captains of harpoon vessels who were interviewed in the Aoti region had never captured whale sharks.

Total combined catch

The current combined annual catch of whale sharks from set-net and harpoon fisheries was estimated by the authors to be 272 individuals (158 for set-net; 114 for harpoon). This estimate is close to that of 250 specimens mentioned by the wholesaler in Suao. Figures for the estimated total annual catches of whale sharks may not completely reflect the catches of those set-net operators and harpoon fishers who were not interviewed, given a variety of factors including differing sizes and designs for set-nets and harpoon vessels.

Table 1. Set-net distribution in Taiwan and estimated minimum number of whale sharks caught by set-net each year.

	Taitung	Hualien	Ilan	County Hsinchu	Miaoli	Pingtung	Penghu	Total
No. of set-nets in operation[1,2]	11	32	26	12	4	7	5	**97**
No. of operators interviewed[3]	5	14	17	12	3	2	5	**58**
Average annual catch per set-net[3]	2.3	1.46	2.35	0.43	0.83	2.0	0.4	**1.63**
Estimated total annual catch based on interviews[3]	25.3	46.8	61.1	5.17	3.33	14.0	2.0	**157.7**

Sources: 1. Taiwan Fisheries Bureau; 2. Regional fishers' associations; 3. Interviews with fishers.

Table 2. Distribution of harpoon fisheries in Taiwan and estimated minimum number of whale sharks caught by harpoon each year.

	Hongchun	County Taitung	Ilan	Total
No. of harpoon vessels in operation[1]	20	46	32	**98**
No. of interviewed[2] captains	14	7	11	**32**
Average annual catch per vessel[2]	1.68	1.36	0.56	**1.22**
Estimated total annual catch based on interviews[2]	33.64	62.43	17.78	**113.85**

Sources: 1. Regional fishers' associations; 2. Interviews with fishers.

Insufficient information exists to estimate catch trends for Taiwan's whale shark fishery. However, information provided by the fishers indicated that, in the mid-1980s, harpoon fishers from Hongchun harbour were able to harvest between 50 and 60 specimens from the waters south of Penghu each spring. Over the last decade, the catch has declined gradually to approximately 10 individuals annually. Fewer than 10 were captured in this area in 1994 and 1995. The apparent decline in whale shark numbers could be attributed to environmental factors, including changes in water temperature, abundance of prey, or the flow of the Kuroshio Current. Changes in catch effort could also be a factor.

Sale, marketing and utilisation of whale sharks

Sale

After being towed to the fishing harbour, the whale shark is weighed before auction (the weight of large specimens can only be estimated). The auctions usually take place at Suao, Chengkung or Anping fish markets; however, this procedure usually takes place outside the official fish market system in order to avoid market fees, which, being a proportion of the total price (0.4%), could result in a substantial amount of money for large specimens. The whole animal, including the fins, is sold intact to one buyer and, in the case of specimens too large to weigh, the price is based on estimated weight.

After auction, the specimen is transported either whole or cut into several pieces, with fins and viscera removed, to processors. The major processing centres for whale shark in Taiwan are located in Ilan County at Lotung, Ilan and Suao. Smaller numbers of whale sharks are landed in Chengkung and Hongchun. Whale sharks landed in Chengkung are processed there. Specimens landed in Hongchun are processed in Anping. Processors handle a range of products and are not specifically set up to handle whale shark.

Table 3. Range of shark prices in Taiwan's fish markets, 1995.

Species	Price range per kg NTS	USS
Whale shark *Rhincodon typus*	70-180	2.56-6.59
Shortfin mako *Isurus oxyrinchus*	50-80	1.83-2.93
Scalloped hammerhead *Sphyrnalewini*	50-70	1.83-2.75
Pelagic thresher *Alopias pelagicus*	35-70	1.28-2.56
Silvertip shark *Carcharinusalbimarginatus*	50-60	1.83-2.20
Dogfish sharks *Squalidae* spp.	30	1.10
Blue shark *Prionace glauca*	15-20	0.55-0.73

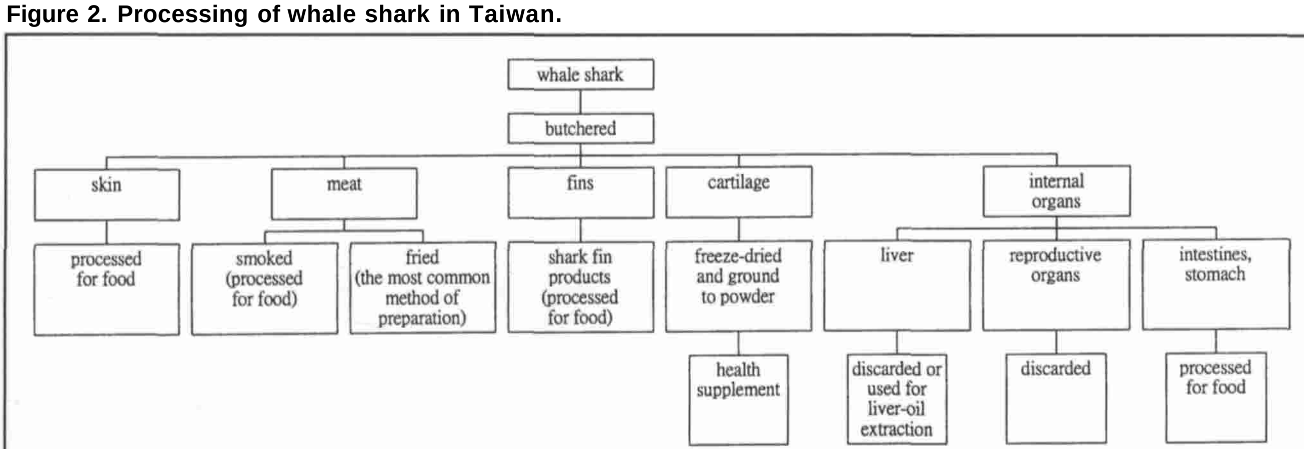
Exchange rate: US$1 = NT$27.322
Source: Chen *et al.,* 1996

Marketing and utilisation

In the past, the meat of the whale shark was less popular than it is today and the price relatively low: prior to 1985, a specimen weighing several tonnes would fetch between (New Taiwan Dollars) NT$5,500and NT$8,200 (US$200 and US$300) (currency conversions correct at time of writing) at auction. Since the late 1980s, however, the wholesale price of a gutted whale shark has increased to roughly NT$190 (US$7) per kg (total price divided by estimated weight) and is now the most expensive of the shark meats available. A small whale shark of 2,000kg could fetch NT$360,000 (US$14,000) while a larger specimen of 10,000kg could sell for NT$1.9 million (US$70,000). Because of the high price of larger specimens, the number of wholesalers who purchase whale sharks is small.

For comparative purposes, Table 3 summarises the landing price of seven shark species caught by Taiwan's coastal and offshore Fisheries. Prices are those paid at auction after landing at fishery markets (production sites) for whole specimens, including fins and internal organs.

Figure 2. Processing of whale shark in Taiwan.



The price of shark meat in the market varies according to season and freshness, with prices highest in winter (December-February).

Following processing, the meat is distributed to retail outlets, supermarkets and restaurants around the island. The retail price of whale shark meat in local fish markets is currently about NT$400 (US$15) per kg. Non-meat products of whale sharks are sold by the buyer to individuals who deal in shark viscera and other byproducts.

Meat comprises about 45% of the body weight of a whale shark. The fins, skin, stomach and intestines are also used for food. As with other shark species, its cartilage can be processed and exported for use in health supplements. The processing system is illustrated in Figure 2.

Discussion

Traditionally, Taiwan has utilised the body parts (fins, meat, skin, cartilage, for example) of a variety of shark species. Taiwan's whale shark fishery is a more recent development. The increasing popularity, and high price, of whale shark meat, however, has made this species a valuable catch for fishers. This preliminary study has documented a significant annual take of whale sharks by Taiwan's fishers. Although information is too sketchy to conclude with any certainty that whale shark populations off Taiwan are declining, anecdotal evidence, paired with recent information on the species' reproductive patterns, gives cause for concern. As with a number of other shark species which may be vulnerable to over-exploitation, there is a need for more comprehensive, long-term monitoring of whale shark populations and catch.

Currently, no international fishery, trade or conservation regime exists for shark fisheries. In Taiwan, whale sharks are caught for local consumption predominantly by set-net and harpoon. Under these circumstances, a domestic management system based on size limits or a quota system should be established. However, a successful management system for whale shark fisheries will require further research into the life history of the species, its population structure, behaviour, migration patterns, and genetics as well as more in-depth research into current fisheries practices.

Recommendations

The authors would like to make the following recommendations to further the management and conservation of whale sharks in Taiwan.

1. **Education** Fishermen and the general public should be better informed about the behaviour, ecology, limited reproductive capacity, and conservation status of the whale shark, by means of the media, public seminars, etc.
2. **Establishment of catch and trade databases** Reporting of whale shark catch and landing data should be made mandatory. Portside monitoring should be improved. All trade should be required to go through the market system and destinations of catches should be documented. Attention should be paid to possible international trade, both legal and illegal. All data should be made available to scientists for future study.
3. **Scientific research** Further research into the whale shark's life history, population structure, behaviour, migration patterns and genetics should be considered of high priority, as should cooperation with other scientists internationally.
4. **Development of a domestic management system** The relevant fisheries agencies in Taiwan should compile and analyse the information gathered from the implementation of the second and third recommendations. The results should be used to develop a whale shark management plan taking account of both the conservation needs of the species and the economic needs of local fishermen. It is comparatively straightforward to establish size and catch limits for whale shark catches by the harpoon fishery, which is targeted. Regulation of set-nets is more difficult to control and requires further study, particularly the feasibility of releasing live specimens caught in excess of a quota.

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Freshwater and Estuarine Elasmobranch Surveys in the Indo-Pacific Region: Threats, Distribution and Speciation

L.J.V. Compagno
Shark Research Centre, Division of Life Sciences, South African Museum, 25 Queen Victoria St., P.O. Box 61, Cape Town 8000, South Africa

The tropical Indo-West Pacific is the world centre of chondrichthyan diversity, with a varied marine and freshwater fauna. The inshore marine fauna, from the intertidal to 50m depth, and the freshwater fauna is especially rich, and comprises approximately 245 species of elasmobranchs and no chimaeroids (which occur on the tropical slopes in the Indo-West Pacific). This includes about 41 % sharks and 59% rays, with approximately 86% endemicity. The elasmobranchs that occur in fresh water include approximately 12% of the total inshore-freshwater fish fauna. This includes a poorly-known category of marginal species (6% total) which occur in estuaries and river mouths and have a limited penetration of fresh water, and an inadequately-known category of euryhaline and obligate freshwater elasmobranchs (8% total). Euryhaline and obligate species include sharks of the genera *Carcharhinus* and *Glyphis* (family Carcharhinidae), sawfishes of the genus *Pristis* and possibly *Anoxypristis* (family Pristidae), and stingrays of the genera *Dasyatis* (fringetail stingrays), *Himantura* (whiprays), and *Pastinachus* (cowtailed rays) (family Dasyatidae). The shark genus *Glyphis* is endemic to the tropical Indo-West Pacific and, as with many other regional freshwater elasmobranchs, is poorly known. A tentative checklist of tropical inshore and freshwater elasmobranchs of the Indo-West Pacific is presented in the paper. Threats to the survival of freshwater elasmobranchs in the area include biological limitations of elasmobranchs in general and freshwater elasmobranchs in particular, coupled with human-induced problems including over-exploitation and habitat modification and destruction.

Introduction

This paper surveys the biodiversity of the inshore elasmobranch fauna of the tropical Indo-West Pacific, from South Africa and the Red Sea to Australia and southern Japan with special emphasis on freshwater elasmobranchs and on threats to their survival. It builds on previous work on freshwater elasmobranchs of the region by Compagno (1984,1988), Compagno and Roberts (1982), Compagno and Cook (1995a, b, c, d), Ishihara *et al.* (1991), Roberts and Karnasuta (1987), Last and Stevens (1994), Monkolprasit and Roberts (1990), Taniuchi (1979), Taniuchi and Shimizu (1991), Taniuchi *et al.* (1991a) and Taniuchi *et al.* (1991b).

Analyses were performed and graphs prepared with spreadsheets in Quattro Pro, maps with VersaMap, PhotoStyler and Corel PhotoPaint, and graphics developed with CorelDraw on an IBM PC clone.

Taxonomic diversity

The tropical Indo-West Pacific is the world centre of marine chondrichthyan diversity. This is especially apparent in the inshore and freshwater elasmobranch fauna (Campagno 1984). Table 1 is a checklist of tropical inshore and freshwater elasmobranchs of the Indo-West Pacific, prepared from checklists of elasmobranchs and of elasmobranch distribution maintained by the author. Principal references from the literature in addition to the above include Annandale (1908, 1909, 1910), Bass *et al.* (1973, 1975a, b, c, d), Bigelow and Schroeder (1948, 1953), Bessednov (1969), Chen (1963), Chu *et al.* (1963), Compagno *et al.* (1997), Cook and Compagno (1996), Dingerkus and DeFino (1983), Fowler (1941), Garman (1913), Garrick (1982,1985), Herre (1927,1953,1955,1958),Mongkolprasit (1977, 1984), Shen *et al.* (1995), Smith (1945), Teng (1962), and Wallace (1967a,b). Also refer to three papers in this volume (Taniuchi, Last, Manjaji). The area includes obligate freshwater species, euryhaline species, marginal freshwater species, and inshore and offshore marine species that occur on the continental and insular shelves close inshore, from the intertidal to approximately 50m depth. Many of the species occur in deeper water than 50m, and some extend into the oceanic zone or onto the continental slopes. Some species have wide habitat ranges while others are strictly confined to the inshore zone, or occur only in fresh water. Many of the inshore species occur in estuaries, and some of them are marginal freshwater species. The inshore-freshwater fauna includes approximately 245 species, of which 41% (100 species) are sharks and 59% (145 species) are rays. Approximately 86% of the species of elasmobranchs that occur in the inshore Indo-West Pacific, and adjacent lakes and rivers, are endemic to this vast area. Approximately 75% of the sharks and 93% of the rays are endemic to the Indo-West Pacific. Taxonomically the inshore shark fauna

Table 1. Checklist of inshore, estuarine and freshwater elasmobranchs in the tropical Indo-West Pacific. Species occurring in the Indo-West Pacific tropics including the Red Sea and Persian Gulf, from northern South Africa (KwaZulu-Natal) and Mozambique to tropical Australia, China, Taiwan and southernmost Japan, on the continental and insular shelves from the intertidal to 50 and including estuarine and freshwater species.

Family	Scientific name	Common name
LIVING SHARKS		
HEXANCHIDAE	*Notorynchus cepedianus*	Broadnose sevengill shark?
HETERODONTIDAE	*Heterodontus japonicus*	Japanese bullhead shark?
	Heterodontus zebra	Zebra bullhead shark
	Heterodontus sp. A	Oman bullhead shark?
BRACHAELURIDAE	*Heteroscyllium colcloughi*	Bluegray carpetshark
ORECTOLOBIDAE	*Eucrossorhinus dasypogon*	Tasselled wobbegong
	Orectolobus japonicus	Japanese wobbegong
	Orectolobus maculatus	Spotted wobbegong?
	Orectolobus ornatus	Ornate wobbegong
	Orectolobus wardi	Northern wobbegong
	Orectolobus sp. A	Western wobbegong
	Sutorectus tentaculatus	Cobbler wobbegong?
HEMISCYLLIIDAE	*Chiloscyllium arabicum*	Arabian carpetshark
	Chiloscyllium burmensis	Burmese bambooshark
	Chiloscyllium griseum	Gray bambooshark
	Chiloscyllium hasselti	Indonesian bambooshark
	Chiloscyllium indicum	Slender bambooshark
	Chiloscyllium plagiosum	Whitespotted bambooshark
	Chiloscyllium punctatum	Brownbanded bambooshark
	Hemiscyllium freycineti	Indonesian speckled carpetshark
	Hemiscyllium hallstromi	Papuan epaulette shark
	Hemiscyllium ocellatum	Epaulette shark
	Hemiscyllium strahani	Hooded carpetshark
	Hemiscyllium trispeculare	Speckeled carpetshark
GINGLYMOSTOMATIDAE	*Nebrius ferrugineus*	Tawny nurse shark
	Pseudoginglymostoma brevicaudatum	Shorttail nurse shark
STEGOSTOMATIDAE	*Stegostoma fasciatum*	Zebra shark
RHINCODONTIDAE	*Rhincodon typus*	Whale shark
ODONTASPIDIDAE	*Carcharias taurus*	Sand tiger, spotted raggedtooth, or gray nurse shark
ALOPIIDAE	*Alopias pelagicus*	Pelagic thresher
	Alopias superciliosus	Bigeye thresher
	Alopias vulpinus	Thresher shark
CETORHINIDAE	*Cetorhinus maximus*	Basking shark
LAMNIDAE	*Carcharodon carcharias*	Great white shark
	Isurus oxyrinchus	Shortfin mako
SCYLIORHINIDAE	*Atelomycterus macleayi*	Australian marbled catshark
	Atelomycterus marmoratus	Coral catshark
	Aulohalaelurus kanakorum	New Caledonia catshark
	Cephaloscyllium sufflans	Balloon shark
	Cephaloscyllium umbratile	Japanese swellshark?
	Cephaloscyllium sp.	Dwarf oriental swellshark
	Cephaloscyllium sp.	New Guinea swellshark
	Halaelurus buergeri	Darkspot, blackspotted, or Nagasaki catshark?
	Halaelurus lineatus	Lined catshark
	Halaelurus natalensis	Tiger catshark
	Haploblepharus sp.	Natal shyshark
TRIAKIDAE	*Hemitriakis japanica*	Japanese topeshark
	Hemitriakis leucoperiptera	Whitefin topeshark
	Hemitriakis sp.	Ocellate topeshark
	Mustelus griseus	Spotless smoothhound
	Mustelus manazo	Starspotted smoothhound
	Mustelus cf. *manazo*	
	Triakis scyllium	Banded houndshark
HEMIGALEIDAE	*Chaenogaleus macrostoma*	Hooktooth shark
	Hemigaleus microstoma	Sicklefin weasel shark
	Hemigaleus sp. cf. *microstoma*	Australian weasel shark

Table 1… continued. Checklist of inshore, estuarine and freshwater elasmobranchs in the tropical Indo-West Pacific.

Family	Scientific name	Common name
	Hemipristiselongatus	Snaggletooth shark
	Paragaleusleucolomatus	Whitetip weasel shark
	Paragaleusrandalli	Slender weasel shark
	Paragaleustengi	Straighttooth weasel shark
CARCHARHINIDAE	*Carcharhinusalbimarginatus*	Silvertip shark
	Carcharhinusamblyrhynchoides	Graceful shark
	Carcharhinusamblyrhynchos	Gray reef shark?
	Carcharhinusamboinensis	Pigeye or Java shark
	Carcharhinusborneensis	Borneo shark
	Carcharhinusbrachyurus	Bronze whaler
	Carcharhinusbrevipinna	Spinner shark
	Carcharhinuscautus	Nervous shark
	Carcharhinusdussumieri	Whitecheek shark
	Carcharhinusfitzroyensis	Creek whaler
	Carcharhinushemiodon	Pondicherry shark
	Carcharhinusleiodon	Smoothtooth blacktip?
	Carcharhinusleucas	Bull shark
	Carcharhinuslimbatus	Blacktip shark
	Carcharhinusmacloti	Hardnose shark
	Carcharhinusmelanopterus	Blacktip reef shark
	Carcharhinusobscurus	Dusky shark
	Carcharhinusplumbeus	Sandbar shark
	Carcharhinussealei	Blackspot shark
	Carcharhinussorrah	Spottail shark
	Carcharhinustilsoni	Australian blacktip shark
	Carcharhinus sp.	False smalltail shark
	Galeocerdocuvier	Tiger shark
	Glyphisgangeticus	Ganges shark
	Glyphisglyphis	Speartooth shark
	Glyphis sp. A	Bizant river shark
	Glyphis sp. B	Borneo river shark
	Glyphis sp. C	New Guinea river shark
	Lamiopsistemmincki	Broadfin shark
	Loxodon macrorhinus	Sliteye shark
	Negaprionacutidens	Sharptooth lemon shark
	Rhizoprionodon acutus	Milk shark
	Rhizoprionodonoligolinx	Gray sharpnose shark
	Rhizoprionodontaylori	Australian sharpnose shark
	Scoliodon laticaudus	Spadenose shark
	Triaenodonobesus	Whitetip reef shark
SPHYRNIDAE	*Eusphyrablochii*	Winghead shark
	Sphyrnalewini	Scalloped hammerhead
	Sphyrnamokarran	Great hammerhead
	Sphyrnazygaena	Smooth hammerhead?
LIVING BATOIDS (RAYS)		
PRISTIDAE	*Anoxypristis cuspidata*	Knifetooth, pointed, or narrow sawfish
	Pristisclavata	Dwarf or Queensland sawfish
	Pristis microdon	Greattooth or freshwater sawfish
	Pristis pectinata	Smalltooth or wide sawfish?
	Pristiszijsron	Green sawfish
RHINIDAE	*Rhinaancylostoma*	Bowmouth guitarfish or sharkray
RHYNCHOBATIDAE	*Rhynchobatusaustraliae*	Whitespotted shovelnose ray
	Rhynchobatusdjiddensis	Whitespotted wedgefish or giant guitarfish
	Rhynchobatuslaevis	Smoothnose wedgefish
	Rhynchobatus sp.	Broadnose wedgefish
	Rhynchobatus sp.	Roughnose wedgefish
RHINOBATIDAE	*Aptychotrema rostrata*	Eastern shovelnose ray
	Aptychotremavincentiana	Southern shovelnose ray
	Rhinobatosannandalei	Bengal guitarfish

Table 1 . . . continued. Checklist of inshore, estuarine and freshwater elasmobranchs in the tropical Indo-West Pacific.

Family	Scientific name	Common name
	Rhinobatos formosensis	Taiwan guitarfish
	Rhinobatos granulatus	Sharpnose guitarfish
	Rhinobatos halavi	Halavi guitarfish
	Rhinobatos holcorhynchus	Slender guitarfish
	Rhinobatos hynnicephalus	Ringstraked guitarfish
	Rhinobatos leucospilus	Greyspot guitarfish
	Rhinobatos lionotus	Smoothback guitarfish
	Rhinobatos microphthalmus	Smalleyed guitarfish
	Rhinobatos obtusus	Widenose guitarfish
	Rhinobatos petiti	Madagascar guitarfish
	Rhinobatos punctifer	Spotted guitarfish
	Rhinobatos salalah	Salalah guitarfish
	Rhinobatos schlegelii	Brown guitarfish
	Rhinobatos thouin	Clubnose guitarfish
	Rhinobatos typus	Giant shovelnose ray
	Rhinobatos zanzibarensis	Zanzibar guitarfish
	Rhinobatos sp.	Tanzanian guitarfish
	Trygonorrhina sp. A	Eastern fiddler ray
PLATYRHINIDAE	*Platyrhina limboonkengi*	Amoy fanray
	Platyrhina sinensis	Fanray
	Zanobatus sp.	Indian panray?
NARCINIDAE	*Narcine brevilabiata*	Shortlip electric ray
	Narcine brunnea	Brown electric ray
	Narcine lingula	Rough electric ray
	Narcine maculata	Darkspotted electric ray?
	Narcine prodorsalis	Tonkin electric ray
	Narcine timlei	Blackspotted electric ray
	Narcine westralensis	Banded numbfish
	Narcine sp. A	Ornate numbfish?
	Narcine sp.	Bigeye electric ray
	Narcine sp.	Indian electric ray
	Narcine sp.	Whitespot electric ray
NARKIDAE	*Heteronarce bentuvai*	Elat electric ray
	Heteronarce? sp.	Ornate sleeper ray (Southern Africa)
	Narke dipterygia	Spottail electric ray
	Narke japonica	Japanese spotted torpedo
	Narke sp. A	Thailand sleeper ray
	Narke sp. B	Taiwan dwarf electric ray
	Temera hardwickii	Finless electric ray
HYPNIDAE	*Hypnos monopterygius*	Coffin ray or crampfish
TORPEDINIDAE	*Torpedo fuscomaculata*	Blackspotted torpedo
	Torpedo panthera	Leopard torpedo
	Torpedo polleni	Reunion torpedo?
	Torpedo sinuspersici	Gulf torpedo
	Torpedo suissi	Red Sea torpedo?
	Torpedo zugmayeri	Baluchistan torpedo?
	Torpedo sp.	Comoro red torpedo
	Torpedo sp.	Mauritius torpedo
	Torpedo sp.	Seychelles torpedo
	Torpedo sp. ?	Kenyan spotted torpedo?
UROLOPHIDAE	*Trygonoptera personalis*	Masked stingaree
	Trygonoptera testacea	Common stingaree
	Urolophus armatus	New Ireland stingaree?
	Urolophus javanicus	Java stingaree
POTAMOTRYGONIDAE	*Taeniura lymma*	Ribbontailed stingray, Bluespotted ribbontail or fantail ray
	Taeniura meyeni	Fantail stingray, round ribbontail ray, speckled stingray
DASYATIDAE	*Dasyatis akajei*	Red stingray
	Dasyatis annotata	Plain maskray

Table 1… continued. Checklist of inshore, estuarine and freshwater elasmobranchs in the tropical Indo-West Pacific.

Family	Scientific name	Common name
	Dasyatis bennetti	Bennett's cowtail or frilltailed stingray
	Dasyatis brevicaudata	Shorttail or smooth stingray?
	Dasyatis fluviorum	Estuary stingray
	Dasyatis kuhlii	Bluespotted stingray or maskray.
	Dasyatis laevigata	Yantai stingray
	Dasyatis laosensis	Mekong freshwater stingray
	Dasyatis leylandi	Painted maskray
	Dasyatis microps	Thickspine giant stingray
	Dasyatis navarrae	Blackish stingray
	Dasyatis sinensis	Chinese stingray
	Dasyatis thetidis	Thorntail or black stingray?
	Dasyatis zugei	Pale-edged stingray?
	Dasyatis sp. B	Chinese freshwater stingray
	Himantura alcocki	Palespot whipray
	Himantura bleekeri	Whiptail stingray
	Himantura chaophraya	Giant freshwater stingray or whipray
	Himantura draco	Dragon stingray?
	Himantura fai	Pink whipray
	Himantura fluviatilis	Ganges whipray
	Himantura gerrardi	Sharpnose stingray, Bluntnose whiptail ray or whipray, banded whiptail ray
	Himantura granulata	Mangrove whipray
	Himantura imbricata	Scaly stingray or whipray
	Himantura jenkinsii	Pointed-nose stingray or golden whipray
	Himantura marginata	Blackedge whipray
	Himantura microphthalma	Smalleye whipray
	Himantura oxyrhyncha	Marbled freshwater whipray
	Himantura pareh	Plain-edged whipray
	Himantura pastinacoides	Round whipray
	Himantura signifer	White-edge freshwater whipray
	Himantura toshi	Blackspotted whipray or coachwhip ray
	Himantura uarnacoides	Whitenose whipray
	Himantura uarnak	Honeycomb or leopard stingray or reticulate whipray [species complex]
	Himantura undulata	Leopard whipray [= *H. fava]*
	Himantura walga	Dwarf whipray
	Himantura sp. A.	Brown whipray
	Pastinachus gruveli	Thailand stingray
	Pastinachus sephen	Feathertail or cowtail stingray
	Pastinachus sp. A	Narrowtail stingray or flagray
	Urogymnus asperrimus	Porcupine ray
GYMNURIDAE	*Aetoplatea tentaculata*	Tentacled butterfly ray
	Aetoplatea zonura	Zonetail butterfly ray
	Gymnura australis	Australian butterfly ray
	Gymnura bimaculata	Twinspot butterfly ray
	Gymnura japonica	Japanese butterfly ray
	Gymnura natalensis	Diamond ray
	Gymnura poecilura	Longtail butterfly ray
MYLIOBATIDAE	*Aetobatus flagellum*	Longheaded eagle ray
	Aetobatus narinari	Spotted eagle ray or bonnetray
	?Aetobatus guttatus	Indian eagle ray
	Aetomylaeus maculatus	Mottled eagle ray
	Aetomylaeus milvus	Ocellate eagle ray or vulturine ray
	Aetomylaeus nichofii	Banded or Nieuhof's eagle ray
	Aetomylaeus vespertilio	Ornate or reticulate eagle ray
	Myliobatis aquila	Common eagle ray or bullray?
	Myliobatis australis	Southern eagle ray
	Myliobatis hamlyni	Purple eagle ray?
	Myliobatis tobijei	Kite ray
	Pteromylaeus bovinus	Bullray or duckbill ray
FAMILY RHINOPTERIDAE	*Rhinoptera adspersa*	Rough cownose ray

Table 1…continued. Checklist of inshore, estuarine and freshwater elasmobranchs in the tropical Indo-West Pacific.		
Family	**Scientific name**	**Common name**
	Rhinoptera hainanensis	Hainan cownose ray?
	Rhinoptera javanica	Javanese cownose ray or flapnose ray
	Rhinoptera jayakari	Oman cownose ray?
	Rhinoptera neglecta	Australian cownose ray
	Rhinoptera sewelli	Indian cownose ray?
MOBULIDAE	*Manta birostris*	Manta
	Mobula eregoodootenkee	Pygmy devilray or oxray
	Mobula japanica	Spinetail devilray
	Mobula kuhlii	Shortfin devilray
	Mobula tarapacana	Sicklefin devilray
	Mobula thurstoni	Bentfin or smoothtail devilray

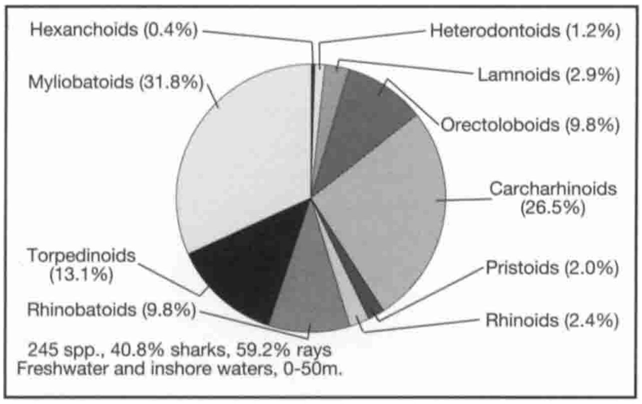

Figure 1. Pie graph showing relative diversity of higher groups of sharks and rays in the inshore tropical Indo-West Pacific.

is dominated by orectoloboids and carcharhinoids, and the ray fauna by myliobatoids, rhinobatoids, rhinoids and torpedinoids. (Figure 1), with virtually no representation from primarily offshore or deepwater groups such as hexanchoid, squaloid, pristiophoroid and squatinoid sharks, rajoids (skates) and chimaeroids. Sawfish (Pristidae) are essentially confined to the inshore and freshwater environment, while rhinoids, rhinobatoids, and many groups of myliobatoid stingrays are most diverse inshore.

Estuarine and freshwater elasmobranchs

The rough classification of Compagno and Cook (1995c) of freshwater elasmobranchs into Marginal, Brackish, Euryhaline and Obligate species is followed here, see p.52 (Compagno, this volume). There are no known brackish species, but there is a rich estuarine fauna in the region that might include such species, as well as marginal freshwater elasmobranchs. The occurrence of species of elasmobranchs in estuaries and at river mouths in possibly reduced salinities is not well-known for most parts of the tropical Indo-West Pacific. It may include many of the inshore species listed above in Table 1. Several of the species in Table 1 occur close inshore, but favour coral or rocky reefs, and are not estuarine or seldom found in estuaries or at river mouths. Many Indo-Pacific species occur in shallow bays and estuaries. Their abilities to tolerate fresh or brackish water are for the most part not known.

Marginal freshwater elasmobranchs

At least 15 Indo-West Pacific species (6% of the total inshore-freshwater fauna) are possibly marginal freshwater elasmobranchs, and may occur in fresh water but may not travel up rivers to any great extent (Table 2). These are mostly requiem sharks, family Carcharhinidae, and whiptailed stingrays, family Dasyatidae, but a few members of other families have been recorded as marginal freshwater species.

Euryhaline and obligate freshwater elasmobranchs

The greatest diversity of freshwater elasmobranchs in the Indo-West Pacific occurs from the Indian Subcontinent

Table 2. List of marginal freshwater elasmobranchs from the Indo-West Pacific.

HEMISCYLLIIDAE	*Chiloscyllium indicum*
STEGOSTOMATIDAE	*Stegostoma fasciatum*
CARCHARHINIDAE	*Carcharhinus amboinensis* *Carcharhinus hemiodon* *Carcharhinus melanopterus* *Carcharhinus plumbeus* *Carcharhinus obscurus* *Rhizoprionodon acutus* *Scoliodon laticaudus*
RHYNCHOBATIDAE	*Rhynchobatus* cf. *djiddensis*
PRISTIDAE	*Pristis clavata*
DASYATIDAE	*Dasyatis thetidis* *Himantura imbricata* *Himantura toshi*
GYMNURIDAE	*Gymnura* sp.
MYLIOBATIDAE	*Aetobatus narinari*

Table 3. List of euryhaline and obligate freshwater elasmobranchs from the Indo-West Pacific.	
CARCHARHINIDAE	
Carcharhinus leucas	Euryhaline.
Glyphis gangeticus	Obligate freshwater?
Glyphis sp. A	Euryhaline?
Glyphis sp. B	Obligate freshwater?
Glyphis sp. C ? = *G. glyphis*	Euryhaline? or Obligate freshwater?
PRISTIDAE	
Anoxypristis cuspidata?	Euryhaline or Marginal?
Pristis microdon	Euryhaline
Pristis pectinata	Euryhaline, records need confirmation
Pristis zijsron	Euryhaline
DASYATIDAE	
Dasyatis fluviorum?	Euryhaline or Marginal?
Dasyatis laosensis	Obligate freshwater
Dasyatis sp. (China)	Obligate freshwater?
Himantura chaophraya	Obligate freshwater or Euryhaline?
Himantura oxyrhyncha (= *H. krempfi)*	Obligate freshwater
Himantura signifer	Obligate freshwater?
Himantura cf. *chaophraya* (New Guinea)	Obligate freshwater?
Himantura fluviatilis	Euryhaline or Obligate freshwater?
Himantura uarnak	Euryhaline or Marginal?
Pastinachus sephen	Euryhaline?

to tropical Australia. It is second only to tropical South America in diversity of freshwater species. Like South America, stingrays are the most important freshwater component of the Indo-West Pacific fauna. These are members of the family Dasyatidae instead of the Potamotrygonidae. Euryhaline and obligate freshwater elasmobranchs occur in fresh water far from the sea, with the former also occurring in marine coastal waters. The latter are confined to fresh water. At least 19 species of euryhaline and obligate freshwater elasmobranchs (8% of the total inshore-freshwater fauna) occur in the area. A tentative list of euryhaline and obligate freshwater species from the Indo-West Pacific is provided (Table 3). Some species on this list are known to be euryhaline, but many species recorded only from freshwater are too poorly known to be sure if they are obligate freshwater or euryhaline species. Individual species are discussed below.

Freshwater sharks

Euryhaline and possibly obligate freshwater sharks are exclusively members of the family Carcharhinidae as presently known.

Gray sharks (genus *Carcharhinus)*

The bull shark *Carcharhinus leucas.* This large (to approximately 3.4m) euryhaline shark is possibly the widest-ranging of all freshwater elasmobranchs (rivalled only by *Pristis microdon* and its relatives), being found in numerous tropical river systems in both hemispheres as well as on the continental shelves in inshore environments, including shallow bays, river mouths, estuaries, and even hypersaline lakes. In the Indo-West Pacific it occurs in numerous rivers from South Africa to Australia, and has been recorded in a few freshwater lakes (see Compagno and Cook 1995c for an extensive list of localities and references). The bull shark should be expected in any warm-temperate and tropical river and lake with sea access little altered by human activities.

The ubiquity of *C. leuc*as a riverine shark, and the vast confusion in the past over identification of Indo-Pacific carcharhinids, tends to mask the presence of other sharks in rivers in the area, particularly other species of *Carcharhinus* that are marginal freshwater species and the river sharks of the genus *Glyphis.* Over the last century the bull shark was generally confused with the true Ganges shark *Glyphis gangeticus*, the pigeye shark *Carcharhinus amboinensis,* and a number of other species including possibly *C. melanopterus* and *C. hemiodon.* This makes many riverine records of sharks in the area impossible to sort out taxonomically unless adequate illustrations, descriptions, or specimens are available to confirm the records.

River sharks, genus *Glyphis*

These relatively rare, and enigmatic, tropical sharks are confined to the Eastern Indian Ocean and West-Central Pacific, and may include both euryhaline and obligate freshwater species. They are generally known from few specimens with inadequate locality and habitat data. There may be at least four or five species of river shark, separable by subtle differences in external morphology, dentitional morphology and meristics, and morphometrics, and by considerable differences in vertebral counts. They have often been confused with the bull shark, which may occur in some rivers along with them. River and bull sharks cohabit the Ganges system, the Kinabatangan River in Sabah (Manjaji, this volume, b), and rivers in Northwest Territory and Queensland, Australia. A species from Thailand *(Carcharias (Prionodon) siamensis* Steindachner, 1896) may be a *Glyphis* or *Carcharhinus* but its status is uncertain from its original description and its holotype (if extant) needs to be re-examined (Garrick 1982, Compagno 1988).

Ganges shark *Glyphis gangeticus*

This shark is known from at least three existing museum specimens including two syntypes (stuffed specimen in Zoologisches Museum, Humboldt University, Berlin, alcohol-preserved specimen in the Museum National d'Historie Naturelle, Paris, and an alcohol-preserved specimen in the Zoological Survey of India, Calcutta). They were collected during the 19th century from the Ganges river system in India. The Ganges shark is only known from fresh water, with no confirmed records from inshore marine waters or estuaries. A few recently caught specimens were located by Dr Tyson R. Roberts (pers. comm.) in 1996 in India in the Ganges River, after an extensive search over the past decade. It is a large species, with adults between 2 and 3m long. There is also a record of this shark, or a close relative, from Karachi, Pakistan (named as a separate species, *Carcharias murrayi* Giinther 1887). Its exact locality, habitat and taxonomic status are uncertain, and the only known specimen (stuffed) is apparently lost or misplaced in the British Natural History Museum. In the Indian literature, prior to the 1980s, the bull shark was usually confused with the Ganges shark, and many records of this species are based on bull sharks and other species. The Ganges shark is ranked as Endangered on the IUCN Red List (www.redlist.org).

Bizant or Queensland river shark *Glyphis* sp. A (Last and Stevens 1994), *Glyphis* sp. 1 (Compagno and Cook 1995c)
This stocky species is known from two juvenile specimens from the lower reach of the Bizant River in Queensland, Australia (Compagno 1988, Last and Stevens 1994), where it occurs along with the bull shark. It is apparently quite distinct from other *Glyphis* species. It was collected in possibly brackish water and may be euryhaline.

Borneo river shark *Glyphis* sp. B.
This species is known from a specimen from "Borneo" (no further information recorded) in the Naturhistorisches Museum, Vienna (Dr Ernst Mikschi, Curator of Fishes pers. comm., 1997). Recently, several small *Glyphis* sharks have been collected in the Kinabatangan River by members of the Darwin Initiative Sabah Project, but it remains to be seen if they are conspecific with *Glyphis* sp. B (Manjaji, this volume, b).

New Guinea river shark *Glyphis* sp. C, Adelaide river shark *Glyphis* sp. 2 (Compagno and Cook 1995c), **and speartooth shark *Glyphis glyphis*** (see Compagno 1984, 1988)
The New Guinea river shark is known from two juvenile specimens (examined, measured and radiographed by J.A.F. Garrick but subsequently destroyed according to P. Kailola pers. comm.) and five sets of jaws with little data from Port Romilly, Bainuru, and the upper reaches of the Fly River, Papua New Guinea (Compagno 1988, L.J.V. Compagno and J.A.F. Garrick unpublished data, P. Kailola pers. comm.). It may be conspecific with the Adelaide river shark, collected in the Adelaide River near Rum Jungle, Northern Territory, Australia (Taniuchi and Shimizu 1991, Taniuchi *et al.* 1991b, Compagno and Cook 1995c, Last, this volume). Another similar river shark was caught in 1996 in fresh water about 60km upstream from the mouth of the South Alligator River, Northern Territory, but although the jaws were saved, and the shark was photographed, the shark itself was eaten by the angler that caught it! (J. Stevens and P. Last pers. comm., 1996). *Glyphis glyphis*, the speartooth shark, was described without a locality. It most closely resembles the New Guinea river shark in its dentition (see Compagno 1984, 1988). The holotype, and only known specimen, a stuffed specimen in the Zoologisches Museum, Humboldt University, Berlin, was thought to be lost (Garrick 1982, Compagno 1984, 1988) but was relocated (Paepke and Schmidt 1988) along with the stuffed Berlin syntype of *G. gangeticus* (H.-J. Paepke pers. comm.). It needs to be re-examined determining vertebral counts if possible for comparison with other *Glyphis* species.

Freshwater sawfish

Sawfish (family Pristidae) are well-known from fresh water, and several species are recorded in tropical rivers and lakes in the Indo-West Pacific. All sawfish seem to be euryhaline or marginal freshwater species, with *Pristis microdon*, and relatives, breeding in fresh water and spending much of their lives in rivers and lakes, while apparently retaining the ability to traverse coastlines in shallow marine waters. The taxonomic arrangement used here follows Compagno and Cook (1995c). Sawfishes are apparently declining worldwide, and listed as Vulnerable or Endangered by the IUCN Shark Specialist Group.

Knifetooth sawfish *Anoxypristis cuspidata*
This moderately large, distinctive, wide-ranging Indo-West Pacific species is known from brackish waters in Papua New Guinea. It has been nominally recorded from rivers in India, Burma, Malaysia and Thailand. Its status as a euryhaline species needs to be verified, and it could be marginal in fresh water.

Queensland sawfish *Pristis clavata*
This little-known and possibly dwarf sawfish is known from tropical northern Australia (Western Australia, Northern Territory and Queensland) but may be more wide-ranging in the Indo-West Pacific (Last and Stevens 1994). It occurs some distance up rivers and can tolerate brackish waters, and may be euryhaline rather than marginal.

Greattooth sawfish *Pristis microdon*
This large, wide-ranging Indo-West Pacific euryhaline sawfish is close if not identical to *P. perotetti* of the Atlantic and Eastern Pacific. It is the most wide-ranging species of sawfish in fresh water in the area, often occurring in the same river systems as *Carcharhinus leucas*. It is known to extend far up rivers and breeds in them. Young specimens are generally found in fresh water, while large individuals occur in shallow coastal waters as well. It is recorded from rivers and lakes of South Africa, Mozambique, Zimbabwe, India, Thailand, Cambodia, Malaysia (including the Kinabatangan River in Sabah, Borneo), Philippines, Indonesia (Sumatra, Kalimantan), Papua New Guinea and northern Australia (Western Australia, Northern Territory and Queensland).

Smalltooth sawfish *Pristis pectinata*
A large, euryhaline, wide-ranging sawfish with uncertain status in the Indo-West Pacific. Although there are numerous records of the species from the Atlantic, its distribution in the Indo-West Pacific is poorly understood. There are numerous nominal marine records of this species from the area, and a freshwater record from the Ganges river. It is possible that at least some of the records of this species are based on *P. zijsron,* as appears to be true for most southern African records of P. *pectinata.* There are recent photographic records assigned to this species from the Gulf of Carpentaria (Last and Stevens 1994). Descriptions of sawfish from the Bay of Bengal may be based on this species (Annandale 1909).

Green sawfish *Pristis zijsron*
A large, euryhaline, wide-ranging Indo-West Pacific sawfish, with freshwater records from Thailand, Malaysia, Indonesia (Kalimantan, Borneo, and on Java and Ternate), and from various rivers in Queensland and New South Wales, Australia. It may not penetrate rivers as far beyond their mouths as *P. microdon.*

Freshwater stingrays

Whiptailed stingrays of the family Dasyatidae are highly diverse in the Indo-West Pacific, with numerous species in inshore marine waters (Table 1). Freshwater stingrays are relatively diverse in the eastern Indo-West Pacific, from the Indian Subcontinent to South East Asia, Indonesia, Philippines, and tropical Australasia. There appear to be three groups of obligate freshwater or euryhaline whiptailed stingrays that have separately colonised fresh water in the Indo-West Pacific, with close relatives that are inshore marine or marginal species: Fringetail stingrays, genus *Dasyatis;* whiprays, genus *Himantura;* and cowtail stingrays, genus *Pastinachus.*

Mekong freshwater stingray *Dasyatis laosensis*
This small, obligate, freshwater stingray is restricted to the Mekong River of Laos and the Mekong and Chao Phraya in Thailand. It seems to be close to the red stingray *Dasyatis akajei,* of the Western Pacific, which, in turn, is either marginal or euryhaline. Freshwater stingrays have been reported from Chinese rivers (including the Hsi or West river near Naning in the Guangxi Autonomous Region, People's Republic of China) as *D. akajei* but may be distinct.

Marbled freshwater whipray *Himantura oxyrhyncha*
Formerly termed *H. krempfi* (Chabanaud 1923), this is a junior synonym (P. Last pers. comtn.). This little-known, apparently obligate, freshwater stingray has a restricted distribution in South East Asia from Pnom Penh and the Grand Lac, Cambodia, and from the Mekong, Bangpakong, Chao Phraya, and possibly the Mae Nam Nan Rivers of Thailand. A live freshwater stingray, possibly referable to this species, was seen and photographed by Sid Cook, Sarah Fowler and the author at the fisheries station at Chai Nat on the Chao Phraya River in 1993.

White-edged freshwater whipray *Himantura signifer*
This distinctive, apparently obligate, freshwater stingray is moderate-sized and was described from a series of specimens from the Kapuas River of western Kalimantan, Borneo, Indonesia (Compagno and Roberts 1982). Stingrays from the Indragiri River of Sumatra, the Perak River of Malaysia, and the Mekong, Tapi and Chao Phraya Rivers of Thailand (Taniuchi 1979, Compagno and Roberts 1982, Monkolprasit and Roberts 1990) have been tentatively referred to this species. Two live specimens of a freshwater stingray close to this species were seen and photographed by Sid Cook, Sarah Fowler and the author at the fisheries station at Chai Nat on the Chao Phraya River in 1993. These had a light-edged pectoral disk similar in shape to that of the type series of *H. signifer,* but differed in having a dark, rather than white, tail and well-developed pearl spines on the middle of the disk. It is possible that these specimens represent a separate (undescribed) species from *H. signifer,* along with a small Thai specimen examined by Compagno and Roberts and tentatively referred to *H. signifer* but which also had a large pearl spine. They were similar also to *H. pareh* from Java, but had a somewhat different coloration and disk morphology.

Giant freshwater whiprays, *Himantura fluviatilis* complex, including *H. fluviatilis, H. chaophraya* and *H. polylepis* (Bleeker 1852)
These long-snouted distinctive rays include some of the largest living stingrays, and are confined to the eastern Indian Ocean and Western Central Pacific. It is uncertain how many species are represented in the complex, or whether these rays are euryhaline, or if some are obligate freshwater elasmobranchs. Changes in disk morphology with growth are apparent. *Himantura fluviatilis* itself is known from India, in fresh water in the Ganges River (where it is said to reproduce) and inshore off Madras and in the Bay of Bengal. *H. chaophraya* was described by Monkolprasit and Roberts (1990) from the Chao Phraya, Mae Nam Nan, Mekong, Mae Nam Bangpakong, Mae Nam Tachin, and Tapi Rivers of Thailand. It is also provisionally recorded from the Mahakam Basin of Kalimantan, Borneo, from the Kinabatangan River of Sabah, Borneo, possibly from the Fly River basin and Lake Murray in Papua New Guinea, and from many large, tropical rivers of North Australia (including Western Australia, Northern Territory, and Queensland) (Taniuchi *et al.* 1991, Last, this volume). *H. polylepis* was described from the sea off Jakarta, Java. *Himantura fluviatilis* has a chequered nomenclatural history, but may be available as the oldest species name for members of the complex

(Compagno and Cook 1995c). *H. polylepis* is the next available species name (P. Last pers. comm.). Several live specimens of *H. chaophraya,* including young, moderate sized individuals and large adult specimens, were seen and photographed by Sid Cook, Sarah Fowler and the author at the fisheries station at Chai Nat on the Chao Phraya River in 1993.

Cowtail or feathertail stingrays, *Pastinachus sephen* (formerly in genus *Hypolophus)* and relatives.
This large, distinctive euryhaline stingray has a wide Indo-West Pacific range ascribed to it from inshore waters of the Indo-West Pacific from South Africa and the Red Sea to Japan and Australia. It has been recorded from freshwater in the Ganges system of India (where it apparently breeds), from Burma, from the Chao Phraya River and possibly the Tal Sap lake of Thailand, from Malaysia (Peninsular Malaysia and Sarawak, Borneo), Indonesia (Java and Sumatra) and tropical Australia. Ongoing taxonomic studies on the genus by P. Last suggest that there is more than one species of dark-tailed *Pastinachus,* including *P. sephen,* as well as a light-tailed species tentatively ascribed to *P. gruveli.* The identity of freshwater species of cowtail stingrays needs to be confirmed. Apparently there is a need for a neotype for *P. sephen* (originally described from the Red Sea) to be named to help sort out the problems.

Threats to freshwater elasmobranchs in the Indo-West Pacific

Compagno and Cook (1995c) give a comprehensive, if not exhaustive, discussion of limitations and threats faced by freshwater elasmobranchs, which by extension can be partly applied to estuarine marine elasmobranchs that share habitats with marginal and euryhaline freshwater species in the Indo-West Pacific.

Limitations of freshwater elasmobranchs

1. Limited biological flexibility of freshwater elasmobranchs to cope with major human-induced habitat problems, compared with some other, better-adapted, freshwater vertebrates. This is relative, and dependent on the severity of the problem. Freshwater elasmobranchs have all the biological limitations of inshore marine elasmobranchs: they are large and relatively few in numbers of individuals, and make big, easy targets for fishing gear which is easier to work in lakes and rivers (and in protected coastal environments) than in the open sea. They are sensitive to pollutants, such as chlorinated hydrocarbons, and probably cannot live in highly polluted environments downstream from large cities and major agricultural areas. They have few natural predators, and low fecundity, and can be differentially fished out in bycatch fisheries and in targeted fisheries.
2. Limited environmental flexibility. Freshwater elasmobranchs must cope with physically limited, more variable, more vulnerable environments and with being marginally adapted to them as big downstream river and sea-run lake dwellers. They cannot aestivate, cannot breathe air, cannot climb out of the water when it goes bad or dries up, and cannot survive as eggs or adults in mud.
3. Very limited knowledge of fisheries for freshwater elasmobranchs in the area.
4. Limited knowledge of the biology of freshwater elasmobranchs in the area.
5. Limited research interest in freshwater elasmobranchs by biologists and fisheries managers in the area.
6. Little interest in conservation of freshwater elasmobranchs by researchers, fisheries officers, and the general public until very recently (last two years). More recently still, there has been active resistance to conservation measures affecting elasmobranchs by large fisheries interests and their governmental and scientific allies.
7. Little importance to human affairs. Chondrichthyan fisheries worldwide are less than 1% of total fisheries catches, which probably is even lower in fresh water in most places. Chondrichthyans are often regarded negatively by people, and their problems are exacerbated by the media fixation on shark attack.

Problems faced by freshwater elasmobranchs

1. An exponentially expanding human population worldwide and in the area, which increasingly places stress on the environment, particularly freshwater habitats in countries with burgeoning human populations, in numerous ways. *Homo sapiens* is the only large animal with a world population of 5.5 billion individuals and with a doubling time of 28 years. World fisheries are not tracking this increase (Figure 2).
2. Expanding commercial and artisanal fisheries in the area, in inshore marine and freshwater environments, with commensurate increase in sophistication of fisheries. There is ongoing overfishing of cartilaginous fishes, caught mostly as bycatch of fisheries for more fecund marine animals, and limited management. Most fisheries that land elasmobranchs are essentially uncontrolled and are unstoppable from the standpoint of the elasmobranch catches.
3. Expanding pollution of freshwater environments in the area, including pollution from industrial waste, agricultural chemicals, urban and rural sewage, touristic development, wastes from mining and oil drilling (including oil, heavy metals, cyanide and radioactive

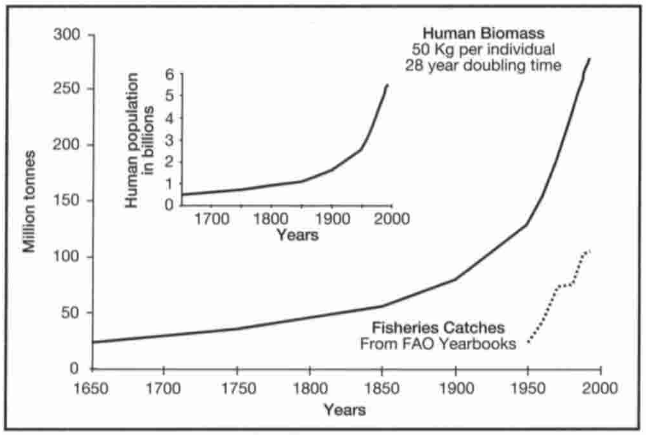

Figure 2. Human population, biomass and world fisheries levels. Data on human population levels from UN via S. Cook (pers. comm.). Biomass estimate with assumption that average *Homo sapiens* weighs 50kg.

isotopes), and the physical effects of conflicts such as the Gulf and Vietnam wars.

4. Expanding freshwater habitat destruction and modification in the area, including that caused by deforestation, hydroelectric and flood-control dams, barrages and water impoundments, flooding, lowering of the water table, siltation, microclimate modification, interruption of migration routes and cutting off of euryhaline species from the sea.
5. Expanding globalisation, with increasingly powerful and essentially autocratic economic entities following a policy of short-term gain in profits from non-renewable harvesting of the world's natural resources. Their economic and political power, both individually and in cooperation with powerful First World governments, can overwhelm conservation efforts in the area, and the efforts of local governments in preserving ecosystems.
6. Unidirectional increase of wealth in the North or First World, and poverty in the South or Third World where most of the freshwater elasmobranchs live.
7. Political instability, strife and war. As parts of the area get more impoverished, and political problems occur, sensitive environments can be damaged and conservation efforts halted.

Where do we go from here?

Down the river? We can face the prospect of extinction of many freshwater elasmobranchs in tropical riverine habitats worldwide. Obligate freshwater elasmobranchs with limited geographic ranges are the most vulnerable. There can be local victories in conserving some areas, as refuges for populations of freshwater elasmobranchs, much as game parks exist for the ever-decreasing Pleistocene megafauna. However, the ongoing juggernaut of blind human population growth and development may not be stopped in our lifetimes. It is evident from the latest round of CITES (10th Conference of the Parties, June 1997), that even highly popular animals such as elephants and rhinos are vulnerable to the needs of local governments beset by economic and demographic problems, and by the needs of international economic interests eager for profits. Freshwater elasmobranchs are, by comparison, obscure, not loved, not furry and cuddly, and are much more difficult to manage and conserve. Still, the effort should be made, and should be based on increasing knowledge of the species involved, preservation or conservation of habitat and sensitive and rational education of people where these animals occur, as well as national and international policies for sustaining the health of the earth and its human and nonhuman residents. A tall order, but the alternatives are increasingly non-viable for the long-term benefit of humanity and everything else that must share the earth with this most fearsome and destructive of species.

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Outline of Field Surveys for Freshwater Elasmobranchs Conducted by a Japanese Research Team

Toru Taniuchi
Department of Marine Sciences and Resources, Ninon University, Kameino 1866, Fujisawa-shi, Kanagawa 252-8510, Japan

Field surveys for freshwater elasmobranchs were conducted in South East Asia (November 1976-February 1977), South America (August-October 1980), West Africa (December 1985-February 1986), Oceania (August-September 1989, August-September 1990), Mexico and Central America (July 1993, December 1993-January 1994), and Thailand, Laos, India and Bangladesh (November 1996, March 1997; another survey was planned for August-September 1997). Two species of sharks (Carcharhinidae), six species of stingrays (Dasyatidae), and at least eight species of river stingrays (Potamotrygonidae) were examined. Over 200 specimens were collected and examined for a variety of research projects.

Introduction

Elasmobranchs have evolved by adapting their ecology and physiology to marine environments since their first appearance in the Devonian Era. However, they have frequently been reported in fresh water. Zorzi (1995) and Compagno and Cook (1995) have reviewed systematics and some ecological and physiological aspects of freshwater elasmobranchs (also see Compagno, this volume).

The author participated in field surveys for freshwater elasmobranchs conducted by the Japanese Research Team in rivers and lakes in South East Asia, South America, West Africa, Oceania, and Central America. Further field surveys in India, Bangladesh, Laos and Thailand took place in 1997. Some results have been published in journals and reports of related institutes. Three volumes of internal reports, two written in Japanese and one in English, were submitted to the Monbusho; the Ministry of Culture, Science, Sports and Education in Japan, who provided research funds. The reports are for restricted circulation. This paper summarises the freshwater elasmobranchs surveys carried out by the Japanese Research Team.

This paper is based mainly on the three internal reports and one published report as described below:

- Research Team of the University of Tokyo for Freshwater Sharks. December 1977. Studies on Adaptability and Evolution of Freshwater Sharks. Interior Report of Overseas Scientific Research Program Supported by the Monbusho - I, 83pp. In Japanese.
- Research Team of the University of Tokyo for Freshwater Elasmobranchs. March 1982. Studies on Adaptability and Evolution of Freshwater Elasmobranchs. Interior Report of Overseas Scientific Research Program Sponsored by the Monbusho - II, 125pp. In Japanese.
- Investigation Committee of Freshwater Elasmobranchs, Nagasaki University. March 1987. Studies on Adaptability and Evolution of Freshwater Elasmobranchs–III. Report of the Overseas Scientific Investigation in Africa, 82pp.
- Shimizu, M. and Taniuchi, T. (eds). 1991. Studies on Elasmobranchs Collected from Seven River Systems in Northern Australia and Papua New Guinea. The University Museum, The University of Tokyo, Nature and Culture No. 3, 109pp.

Reports of field surveys were also described in the Reports of Japanese Society for Elasmobranch Studies as follows: Taniuchi 1979, Mizue 1980, Taniuchi 1990, Tanaka 1990, Ishihara 1990, Taniuchi 1992, Taniuchi 1993, Tanaka 1994 and Taniuchi 1997.

Methods, results and discussion

The surveys for freshwater elasmobranchs consisted of three stages: preliminary and full investigations, and preparation for publication.

The purpose of the preliminary investigation was to collect detailed information on the distribution of freshwater elasmobranchs; that is, to find out where and when to stay, and to look for counterparts familiar with the geography, catching methods, transportation, and facilities in the remote areas. Usually a pair of scientists visited many places where elasmobranchs have been reported in freshwater or brackish water. For example, the author visited 10 countries from Canada to Panama during the preliminary investigation for North America.

The next stage was a full investigation at sites selected by the preliminary visit. Usually five or six scientists from

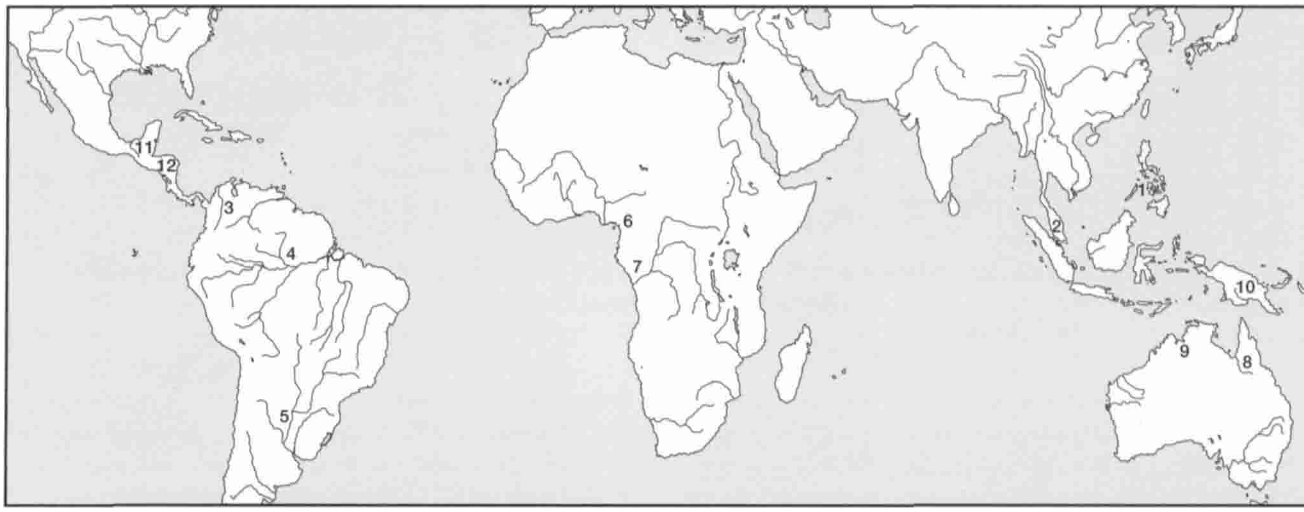

Figure 1. Sampling sites of freshwater elasmobranchs. 1. Lake Naujan, Philippines; 2. Perak River, West Malaysia and Indragiri River, Sumatra, Indonesia; 3. Magdalena River, Colombia; 4. Amazon River Basin; 5. Parana River, Argentina; 6. Sanaga River, Cameroon; 7. Congo River, Democratic Republic of Congo; 8. Gilbert River, Australia; 9. Adelaide River, Australia; 10. Sepik River, Papua New Guinea; 11. Usumacinta River, Mexico; 12. Lake Nicaragua and San Juan River System, Nicaragua and Costa Rica.

differing fields took part, for example, taxonomy, ecology, environmental biology, physiology, biochemistry and genetics. We tried to collect fresh specimens, and for each to examine their physiology and biochemistry. The results of the first two stages were submitted to the Monbusho. Subsequently, papers were also submitted to refereed journals, including those by Teshima *et al.* 1987, Taniuchi 1979b, Ogawa and Hirano 1982, Teshima and Hara 1983, Taniuchi and Ishihara 1990, Taniuchi 1991, Kan and Taniuchi l99l,Teshima and Tekashita l992 and Kitamura *et al.* 1996.

Survey areas are shown in Figure 1. In South Eest Asia, surveys were conducted in Lake Naujan, the Philippines, Perak River, Malaysia, and Indragiri River. Initially, only sharks were covered targeted by the survey, as noted by the title of the first internal report. The preliminary investigation had indicated the likelihood that live sharks could be caught by longlines or gillnets, particularly in Lake Naujan. Failure to catch sharks during the course of field surveys led to the inclusion of rays, including sawfish and stingrays. Stingrays and sawfish were collected in the Perak River and Indragiri River, both of which flow into the Maraca Straits.

In South America, the Magdalena River basin near San Cristabal, the Amazon River system near Manaus, Brazil, and Iquitos, Peru, and the Parana River near Santa Fe, Argentina were surveyed. Many specimens of freshwater stingrays were caught in the Magdalena and Amazon River basins, but none from the Parana River, probably due to a cold season when the stingrays may migrate upstream or inhabit deeper waters in the river.

In West and Central Africa, field surveys were undertaken in the Sanaga River, Cameroon, and Congo River, Democratic Republic of Congo. Stingrays were collected from the Sanaga basin near Edea, in freshwater 15km from its river mouth. Although we failed to catch stingray in the Congo River near Boma, an angler provided us with several photos of a stingray, characteristic of *Dasyatis ukpam.*

In Oceania, field surveys were conducted in the freshwater section of Mitchell and Gilbert River, Queensland, and the Daly and Adelaide River, Northern Territory, Australia. A river shark provided by the staff of Fisheries Research, Primary Industry and Fisheries, Northern Territory, was found to be an undescribed species after dissection, unfortunately too late to reconstruct its original state.

In Mexico, several sharks were collected from the Usumacinta River basin and the west coast of Mexico near Mazatlan. In Lake Nicaragua and San Juan River system, we carried out extensive surveys for freshwater elasmobranchs because the bull shark *Carcharhinus leucas* and sawfish were believed to be indigenous to the river system, but we fear that both species may be near extinction in the lake. Sharks were collected from the mouth of the Colorado River, a tributary of the San Juan River, and from the coastal area of San Juan de Norte.

Field surveys in Thailand, Laos, India, and Bangladesh took place in 1997. This included the collection of a number of specimens of stingrays from the Chaophraya and Mekong River. We also confirmed the occurrence of several species of stingrays by examining specimens collected from the Ganges River near Bahgarpur above the Farraca Barrage. The preliminary results were submitted to the Ministry of Education in October 1998.

The species name and the number of specimens collected in each survey are shown in Table 1. Twenty-seven species ofelasmobranch were examined during these field surveys. Of these, two species of sharks, *Carcharhinus leucas* and *Glyphis* sp., six species of stingrays (Dasyatidae), eight species of river stingrays (Potamotrygonidae) and two species of sawfishes (Pristidae) were collected from freshwater. Over 200 specimens of freshwater elasmobranchs were collected and examined for various scientific purposes. Whilst freshwater elasmobranchs are generally not very difficult to collect, it is very difficult to obtain fresh specimens of elasmobranchs in some areas where fisheries and other activities have led to over-exploitation and environmental deterioration, such as in Lake Nicaragua.

Elasmobranch populations are also endangered if they are not free to recruit from the sea. Physical barriers, such as harbour facilities, prevent migration to and from the sea. Shrimp fisheries employing gill nets entrap elasmobranchs in river mouths, hindering upriver migration. In Lake Nicaragua, freshwater fishers believe that gill nets for shrimps set at the river mouth of San Juan

Table 1. Species name and number of specimens captured in each locality.

Locality	Species name	No. of specimens	Remarks
Lake Naujan (Philippines)	*Carcharhinus melanopterus*		freshwater, identified by photos
Perak River (Malaysia)	*Chiloscyllium indicum*	X 2	collected in fish market
	Rhizoprionodon acutus	W 6	
	Scoliodon laticaudus	W 1, X 6	
	Rynchobatus djiddensis	X 1	
	Dasyatis bennetti	X 1	freshwater
Indragiri River (Sumatra, Indonesia)	*Dasyatis bennetti* ?	X 2	freshwater
	Pastinachus sephen	X 1	
	Pristis microdon	W 2, X 3	
Magdalena River (Colombia)	*Potamotrygon magdalenae*	W 44, X 74	freshwater
Amazon River (Manaus, Brazil)	*Potamotrygon histrix*	W 1, X 1	freshwater
	Potamotrygon motoro	W 2	
	Potamotrygon signata	W 1, X 1	
	Potamotrygon circularis	W 2	
	Potamotrygon scobina	W 1	
	Potamotrygon sp.	X 1	
	Paratryon thayeri	W 3, X 1	
Amazon River (Iquitos, Peru)	*Potamotrygon histrix*	W 2	freshwater
	Potamotrygon motoro	W 3, X 1	
	Potamotrygon laticeps	X 1	
	Disceus thayeri	X 2	
Sanaga River (Cameroon)	*Dasyatis garouaensis*	W 14, X 21	freshwater
	Dasyatis ukpam	X 1	
Congo River (Dem. Rep. of Congo)	*Dasyatis margarita*	W 4, X 3	brackish water
Gilbert River (Australia)	*Pristis microdon*	W 2, X 3	freshwater
Adelaide River (Australia)	*Carcharhinus leucas*	W 1, X 1	freshwater
	Glyphis sp.	X 1	
Daly River (Australia)	*Carcharhinus leucas*	W 1, X 1	freshwater
	Pristis microdon	W 2, X 2	
	Himantura chaophraya	X 1	
Pentecoste River (Australia)	*Pristis clavata*	W 5, X 5	salt water
Sepik River (Papua New Guinea)	*Carcharhinus leucas*	W 4	freshwater
	Pristis microdon	W 8, X 4	
Lake Murray (Papua New Guinea)	*Pristis microdon*	W 12, X 11	freshwater
Oriomo River (Papua New Guinea)	*Anoxypristis cuspidatas*	W 1	brackish water
	Pristis microdon	W 1	
	Himantura uarnak	X 1	
Usumacinta River (Mexico)	*Carcharhinus leucas*	W 3, X 2	freshwater
Lake Nicaragua (Nicaragua)	*Pristis perotteti*	W 1	freshwater
Colorado River (Costa Rica)	*Carcharhinus leucas*	W 1, X 1	freshwater

River prevent elasmobranchs from coming up the river. In contrast, freshwater stingrays were relatively easy to obtain from a fish dealer on the Chaophraya River, Thailand. Before the survey, we had been told that *Himantura chaophraya* was an endangered species, but we have already examined several specimens of this stingray. It is important that better data are available for freshwater elasmobranchs, allowing a proper assessment of status.

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Freshwater and Estuarine Elasmobranchs of Australia

P.R. Last
CSIRO, Division of Fisheries Research, G.P.O. Box 1538, Hobart, Tasmania 7001, Australia

Only a decade ago, the freshwater and estuarine elasmobranch fauna of Australia was considered to be insignificant in size and diversity. Surveys funded by Australian and Japanese agencies in the 1990s have significantly changed this impression. At least 7 species from the families Carcharhinidae, Pristidae, Rajidae and Dasyatidae, are now thought to be obligate within these habitats, while many others breed or occur seasonally in estuaries. Our understanding of their biology remains poor and this may have serious conservation consequences. The undescribed Bizant river shark, *Glyphis* sp., which is known from only two specimens taken more than 15 years ago, may now be extinct. The freshwater sawfish, *Pristis microdon,* appears to be restricted to freshwater. This species, which is Australia's largest freshwater fish, is taken in the dry season from waterholes by gill nets and its numbers appear to be declining. So serious is this situation, that this species may be eliminated from the region before its biology is understood. Similarly, an undescribed skate *Dipturus* sp. confined to two Tasmanian estuaries is the world's only known obligate estuarine skate. Once again, little is known of its life history but its small population and extremely restricted range make it highly vulnerable to extirpation. Conservation issues applying to Australian elasmobranchs also apply elsewhere in the Indo-Pacific.

Introduction

Australia's fish fauna with more than 4,000 species (Yearsley *et al.* 1997) is among the world's largest yet with less than 150 obligate species its freshwater component is decidedly depauperate. Only a few of the 300 or so Australian elasmobranchs (Last and Stevens 1994) are confined to local drainages but a significant suite of species occur periodically in euryhaline brackish water at the mouths of rivers and estuaries. Despite their size and general public interest there have been few studies targeting this fauna. Prior to the 1980s, data on elasmobranchs in freshwater was based mainly on ad hoc observations and anecdotes.

In 1989, the Japanese Research Council funded the first two dedicated surveys of elasmobranchs in freshwater systems of tropical Australasia (Taniuchi and Shimizu 1991; Taniuchi *et al.* 1991 and Taniuchi this volume). In the initial survey, the Japanese/Australian research team led by Dr Toru Taniuchi (University of Tokyo) sampled the Gilbert and Mitchell Rivers (northern Queensland), the Daly River (Northern Territory), and the Fly and Sepik River basins (New Guinea). During the second survey, the elasmobranch faunas of rivers and upper estuaries of northern Western Australia and the Bonaparte Gulf were investigated. In both surveys important discoveries were made of this poorly defined fauna and formed the basis of information included in a review of the entire Australian chondrichthyan fauna published soon after (Last and Stevens 1994).

The major features of the Indo-Pacific freshwater and estuarine elasmobranch fauna have been presented by Compagno earlier in this volume. This paper focuses on the key features of the Australian component of the fauna, much of which has direct relevance to the broader region.

Methods

A classification of estuarine/freshwater dependence is based on a scheme proposed by Compagno and Cook (1995) which includes three high level categories of dependence: obligate freshwater; euryhaline; and brackish marginal species. An additional marginal marine species group is further divided into subcategories to discriminate between marine species that occur regularly, and those that are rare in these habitats. These are as follows: common marginal species (primarily coastal marine fishes that are seasonal residents or frequently occur in meso- and euhaline brackish waters, sometimes venturing well up rivers and estuaries); occasional marginal species (marine fishes, often as juveniles, that occur occasionally in euryhaline brackish waters, such as the lower reaches of large river estuaries and estuarine bays); vagrant species (marine species that are known from but which are rarely recorded from estuaries); and possible vagrant species (marine species presently unrecorded from these habitats but which live in nearby coastal habitats and as such could venture into estuaries). Photographs are provided of the dependent species. Those with a collection acronym have been deposited in the CSIRO Fish Collection, Hobart.

The fauna

At least 118 species, about 40% of the Australian elasmobranch fauna, are either known or likely to live or venture into fresh or brackish water (Table 1). Of these, 90 species have been confirmed within these habitats, but only 22 are considered to occur commonly. Based on their

Table 1. Freshwater/estuarine dependence of Australian elasmok>ranchs.

	Scientific name	Common name
Obligate freshwater species	*Glyphis* sp. A	Bizant river shark
	Glyphis sp. C	Adelaide river shark
Brackish marginal species	*Pristis microdon*	Freshwater sawfish
	Dipturus sp. L	Maugean skate
	Himanturachaophrya	Giant freshwater whipray
Estuarine species	*Carcharhinusleucas*	Bull shark
	Dasyatisfluviorum	Estuary stingray
Marginal marine species - common in brackish/freshwater	*Notorynchuscepedianus*	Broadnose sevengill shark
	Squalusacanthias	Piked dogfish
	Cephaloscylliumlaticeps	Australian swellshark
	Mustelusantarcticus	Gummy shark
	Pristisclavata	Dwarf sawfish
	Hypnosmonopterygius	Coffin ray
	Okamejeilempheri	Australian thomback skate
	Trygonopteratestacea	Common stingaree
	Trygonoptera sp. B	Eastern shovelnose stingaree
	Urolophus cruciatus	Banded stingaree
	Dasyatisbrevicaudata	Smooth stingray
	Dasyatisthetidis	Black stingray
	Himantura sp. A	Brown whipray
	Pastinachussephen	Cowtail stingray
	Myliobatisaustralis	Southern eagle ray
Marginal marine species - occasionally occurring in brackish/freshwater	*Galeorhinus galeus*	Tope shark
	Carcharhinusamboinensis	Pigeye shark
	Carcharhinusbrachyurus	Bronze whaler
	Carcharhinusbrevipinna	Spinner shark
	Carcharhinusfitzroyensis	Creek whaler
	Carcharhinusmelanopterus	Blacktip reef shark
	Carcharhinussorrah	Spot-tail shark
	Galeocerdocuvier	Tiger shark
	Negaprionacutidens	Sharptooth lemon shark
	Prionaceglauca	Blue shark
	Rhizoprionodonacutus	Milk shark
	Sphyrnalewini	Scalloped hammerhead
	Rhynchobatusaustraliae	Whitespotted shovelnose ray
	Aptychotrema rostrata	Eastern shovelnose ray
	Rhinobatos typus	Giant shovelnose ray
	Trygonorrhinafasciata	Southern fiddler ray
	Narcinetasmaniensis	Tasmanian numbfish
	Rajawhitleyi	Melbourne skate
	Trygonopteramucosa	Western shovelnose stingaree
	Urolophusgigas	Spotted stingaree
	Urolophuspaucimaculatus	Sparsely-spotted stingaree
	Taeniuralymma	Bluespotted fantail ray
	Dasyatiskuhlli	Bluespotted maskray
	Himanturagranulata	Mangrove whipray
	Himanturauarnak	Reticulate whipray
	Himanturaundulata	Leopard whipray
	Manta birostris	Manta
Marine species - vagrant in brackish/freshwater	*Hexanchusgriseus*	Bluntnose sixgill shark
	Squalusmegalops	Shortnose spurdog
	Pristiophorusnudipinnis	Shortnose sawshark
	Squatinaaustralis	Australian angelshark
	Heterodontusportusjacksoni	Port Jackson shark
	Parascylliumferrugineum	Rusty carpetshark
	Parascylliumvariolatum	Necklace carpetshark
	Brachaeluruswaddi	Blind shark
	Heteroscylliumcolcloughi	Bluegray carpetshark

Table 1 ... continued. Freshwater/estuarine dependence of Australian elasmobranchs.

	Scientific name	Common name
Marine species - vagrant in brackish/freshwater ... continued	*Eucrossorhinus dasypogon*	Tassled wobbegong
	Orectolobus maculatus	Spotted wobbegong
	Orectolobus ornatus	Ornate wobbegong
	Nebrius ferrugineus	Tawny nurse shark
	Carcharias taurus	Gray nurse shark
	Alopias vulpinus	Thresher shark
	Carcharodon carcharias	Great white shark
	Isurus oxyrinchus	Shortfin mako
	Asymbolus vincenti	Gulf catshark
	Carcharhinus amblyrhynchoides	Graceful shark
	Carcharhinus amblyrhynchos	Gray reef shark
	Carcharhinus limbatus	Blacktip shark
	Carcharhinus obscurus	Dusky shark
	Carcharhinus plumbeus	Sandbar shark
	Triaenodon obesus	Whitetip reef shark
	Sphyrna zygaena	Smooth hammerhead
	Anoxypristis cuspidata	Narrow sawfish
	Pristis zijsron	Green sawfish
	Rhina ancylostoma	Sharkray
	Aptychotrema vincentiana	Southern shovelnose ray
	Trygonorrhina sp. A	Eastern fiddler ray
	Dipturus sp. A	Longnose skate
	Urolophus circularis	Circular stingaree
	Urolophus sp. A	Kapala stingaree
	Taeniura meyeni	Fantail stingray
	Dasyatis leylandi	Painted maskray
	Himantura fai	Pink whipray
	Himantura toshi	Black-spotted whipray
	Pteroplatytrygon violacea	Pelagic stingray
	Gymnura australis	Australian butterfly ray
	Aetobatus narinari	Spotted eagle ray
	Rhinoptera neglecta	Australian cownose ray
Marine species - likely vagrants in brackish/freshwater	*Pristiophorus cirratus*	Longnose sawshark
	Orectolobus wardi	Northern wobbegong
	Sutorectus tentaculatus	Cobbler wobbegong
	Chiloscyllium punctatum	Broadbanded bambooshark
	Hemiscyllium ocellatum	Epaulette shark
	Hemiscyllium trispeculare	Speckled carpetshark
	Stegostoma fasciatum	Zebra shark
	Asymbolus analis	Grey spotted catshark
	Furgaleus macki	Whiskery shark
	Carcharhinus cautus	Nervous shark
	Carcharhinus dussumieri	Whitecheek shark
	Carcharhinus macloti	Hardnose shark
	Carcharhinus tilstoni	Australian blacktip shark
	Loxodon macrorhinus	Sliteye shark
	Rhizoprionodon oligolinx	Gray sharpnose shark
	Rhizoprionodon taylori	Australian sharpnose shark
	Eusphyra blochii	Winghead shark
	Sphyrna mokarran	Great hammerhead
	Rhynchobatus sp.	Broadnose wedgefish
	Narcine westraliensis	Banded numbfish
	Pavoraja nitida	Peacock skate
	Trygonoptera ovalis	Striped stingaree
	Trygonoptera personata	Masked stingaree
	Urolophus lobatus	Lobed stingaree
	Dasyatis annotatas	Plain maskray
	Urogymnus asperrimus	Porcupine ray
	Aetomylaeus nichofii	Banded eagle ray
	Mobula eregoodootenkee	Pygmy devilray

known distributions and/or centres of abundance, only seven species are considered to be primary inhabitants of freshwater or estuaries of Australia (specific information is provided below for these species). Two species appear to be obligate in freshwater: *Glyphis* spp. (two species - sensu Compagno this volume). Three species are classified as brackish marginal species: *Dipturus* sp. (as *Raja* sp. L *sensu* Last and Stevens, 1994), *Himantura chaophraya* and *Pristismicrodon.* Two species are thought to be euryhaline: *Carcharhinus leucas* and *Dasyatis fluviorum.* Fifteen marginal marine species are considered to be common in rivers and estuaries with a further 27 occurring occasionally. Another 69 species are either confirmed or likely to be transient in these habitats.

River sharks (Carcharhinidae)

River or speartooth sharks belong to the genus *Glyphis.* The taxonomy of this group of Indo-Pacific freshwater requiem sharks has been hampered by a universal lack of specimens from across the region. Two species are thought to occur in Australian rivers (Compagno, *pers. comm.*): an eastern Australian species known only from the Bizant River (provisionally referred to as *Glyphis* sp. A); and an undescribed species from the Northern Territory *(Glyphis* sp. C) that may also occur in New Guinea. Only four specimens have ever been identified locally: two juveniles of *Glyphis* sp. A - both taken in 1982 from east of the Queensland divide about 17km up the Bizant River; and two specimens of *Glyphis* sp. C from the Northern Territory - an immature female taken about 100km up the Adelaide River in 1989 (Taniuchi *et al.* 1991b), and an adult male taken some 60km up the South Alligator River in 1996 (Stevens, in press). Although Compagno and Cook (1995) provisionally classified *Glyphis* species as marginal, their level of dependence on riverine systems is likely to be higher (Compagno, this volume). The Australian specimens were taken well upstream in the Northern Territory where the water, although not analysed for its salinity, was undoubtedly fresh. Similarly, salinity levels 17km inland at the tail of the rainy season in the shallow, unstratified Bizant River is well above tidal influence (J. Johnson pers comm.). Despite considerable collecting and fishing activities along the tropical Australian coastline, no specimens have ever been found in marine or estuarine habitats.

The largest river whalers appear to reach more than 2m as adults (the largest local specimen was 145cm total length) and are amongst the largest fishes found in Australia's drainages. Field surveys of tropical rivers using electrofishing gear and some nets have failed to take more specimens. How animals of this size can remain relatively undetected in such relatively small drainages remains a mystery. It is possible that the Queensland river shark has already succumbed to fishing pressures in the Bizant River, although it may still exist in larger nearby rivers. A comprehensive field program using a combination of anecdotal information and targeted surveys using hook and lines and coarse mesh nets is needed to obtain a more accurate coverage of their likely distributions and abundance throughout northern Australia.

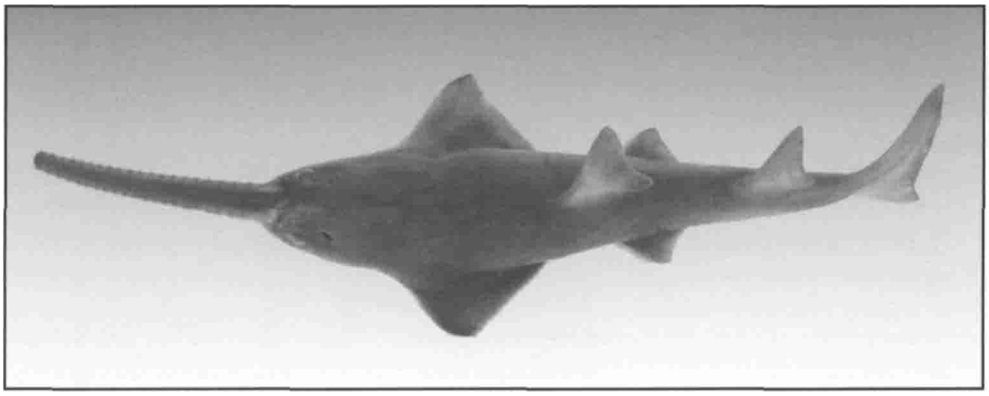
Bull shark (Carcharhinidae)

The bull shark *Carcharhinus leucas* is frequently reported from rivers and estuaries of warm temperate and tropical Australia. It has rarely been identified from the nearby open coast, but this could be due to problems of identification with other coastal whaler species. It is considered to be the main culprit in attacks on humans and domestic pets in the man-made waterways of southern Queensland and the muddy channels and inlets around Sydney (Last and Stevens 1994). It is probably the most common elasmobranch in rivers and penetrates well upstream. Small specimens of less than a metre total length have reportedly nipped at the ankles of swimmers more than 100km up rivers of Cape York, northern Queensland.

Sawfishes (Pristidae)

Sawfishes have a strongly k-selected lifestyle and are considered to be among the most threatened of all elasmobranchs. Compagno and Cook (in press) noted that sawfishes have virtually disappeared from commercial catches where they were a fairly common catch item and may face extirpation in the wild in the next few decades. Two sawfish species occur in tropical Australian estuaries andrivers: *Pristis microdon and P. clavata* (Last and Stevens 1994). Possibly the most seriously threatened of these is *P. microdon,* the largest fish found in Australia's freshwater. It has been suggested that this 'marine' species breeds in freshwater (Merrick and Schmida 1984). So far there are no validated records of this fish from Australian seas, although old records and detached rostral saws taken from freshwater specimens are numerous (Taniuchi *et al.* 1991). Saws of adult *P. clavata,* a coastal marine species, appear to have been confused with those of *P. microdon* in the past. These species have similarly shaped rostral saws and tooth counts. The likely restriction of *P. microdon* to Australian rivers and lakes has important conservation implications (Compagno, this volume).

The local range of *P. microdon* now appears to be extremely restricted (known from a handful of northern Australian river basins). Its vulnerability to fishing, and the extent of illegal netting in its catchments, means that without intervention, it is a primary candidate for local extinction within Australia. The possibility of dams planned within its drainages may accelerate this process. Most of the rivers in which it occurs fragment into a series of ponds in the dry season, further reducing its available habitat,



Freshwater sawfish
Pristis microdon.

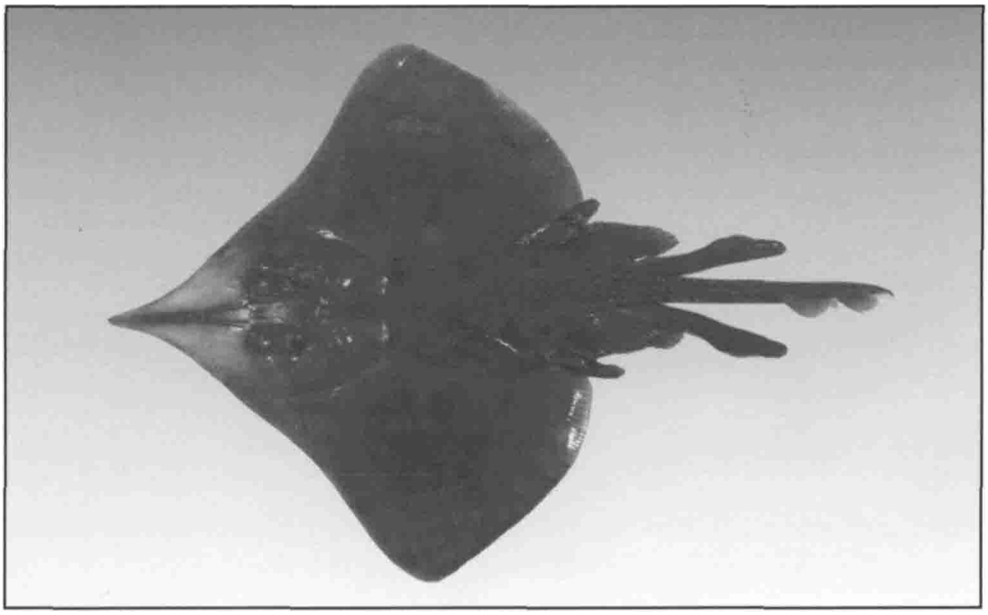
CSIRO Division of Marine Research/ G. Johnson

making it more vulnerable to capture and elimination from these ponds by net fishermen. The snout of the sawfish can become heavily entangled in the gill-net meshes while they feed on the bottom. Handling large, active sawfish is difficult and can be dangerous. According to a newspaper report (Tasmanian Mercury March, 1997), a Vietnamese fishermen (Serepoc River, Dak Lak Province) was mortally wounded attempting to kill with a knife an 80kg sawfish that had become entwined in his net. Consequently, it is not unsurprising that sawfish are considered a pest to fishermen and, when caught, are usually killed and the saws removed for curios.

Other species of sawfish, particularly *P. clavata,* enter the lower reaches of estuaries and rivers from the sea. Like the freshwater sawfish, there are serious concerns regarding their conservation. In inshore areas of Asia, where anecdotal evidence suggests that sawfish were once most common, they are now extremely rare for example specimens have either not been seen for more than a decade (e.g. Sri Lanka, Thailand) or are now extremely rare (e.g. India, Indonesia).

Maugean skate (Rajidae)

The extremely long snout of the Maugean skate resembles that of *Dipturus* species found on silty bottoms of the deep continental slopes. However, the Maugean skate is unlike all other Australian skates being most closely related to inshore skates found off New Zealand (i.e. *Dipturus (Zearaja) nasuta)* and South American *(Dipturus (Zearaja) chilensis)* (Last and Yearsley in press). This skate is unique in being the only rajid confined to an estuarine habitat. It was discovered in 1988 by an ecologist, Dr Graham Edgar, while surveying the biota of Bathurst Harbour at the headwaters of the remote Port Davey estuarine system in south-west Tasmania. Before then, the skate was probably confused with the marine thornback skate *Okamejei lemprieri* that frequents the lower reaches of Bathurst Channel. In 1994, it was found in nearby Macquarie Harbour by CSIRO scientist Mark Lewis who collected several specimens when handlining in the upper estuary at Kelly Basin near the entrance of the Gordon River. Additional specimens were collected during an



Maugean skate *Dipturus* sp. L.

CSIRO Division of Marine Research/ T. Carter environmental survey of this estuary in 1995 (Anon. 1996). However, despite a spate of surveys and continuous commercial fishing operations in the nearby sea since the late 1970s, no marine specimens have been captured.

Port Davey, a deep, stratified ria estuary, is located in the heart of the Tasmanian world heritage wilderness. The benthos is highly unusual, with communities of invertebrates that normally occur in deep offshore habitats near the shelf break or beyond. Light penetration in this estuary is extremely low due to a dark tannin stain emanating from nearby button grass plains. A similar physical habitat probably exists in Macquarie Harbour, which is the only other large bay estuary off western Tasmania. The skate's range within these systems has not been fully defined, but it appears to prefer the low salinities of the upper estuaries. Its available habitat is no more than a few tens of km^2. Preliminary survey data suggests that its population is likely to be small (probably in the order of 1,000 individuals or so). The isolation of Bathurst Harbour, and high conservation status of southwestern Tasmania, offers natural protection for this species. However, its other population lives in an estuary, heavily polluted by prolonged mining operations, subject to pressures from recreational gill netting. Both populations are in otherwise scenic and important recreational areas facing increasing pressure from tourism.

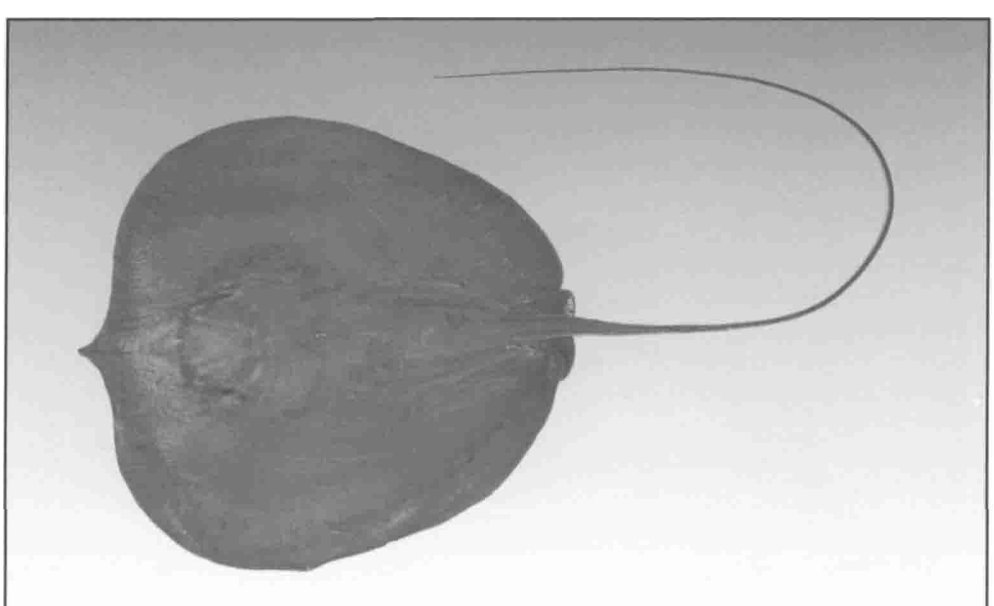
Giant freshwater whipray (Dasyatidae)

Illustrated by Merrick and Schmida (1984) as *Dasyatis fluviorum,* the giant freshwater whipray *Himantura chaophraya* was first accurately identified from the region in 1989 from the Daly River, Northern Territory (Taniuchi *et al.* 1991). It is know known to occur in the Ord and Pentecost rivers (Western Australia), the Alligator River (Northern Territory) and the Gilbert River (Queensland). Only three Australian specimens of *H, cluiophraya* are held in museums, although additional sightings have been made from these rivers. It appears to be most abundant in the brackish lower and middle sections of these rivers, but has been observed well upstream above tidal influence. No specimens have been sighted seaward of the estuaries of these rivers.

Himantura chaophraya, which was described from specimens from major river systems of Indo-China (Monkolprasit and Roberts 1990), appears to belong to a species complex. Asian populations are amongst the largest stingrays reaching 200cm in disc width and a weight of 600kg. Australian individuals are much smaller, with the largest known specimen only 100cm disc width (Last and Stevens 1994). Taniuchi *et al.* (1991) noted some differences in measurements and counts between the Asian and Australian populations, and the two morphotypes may not be conspecific. Other names exist for similar forms within this complex: *H. fluviatilis* (Hamilton-Buchanan, 1822) from the Ganges River, India (although *H. fluviatilis* has been synosymised with *Pastinachus sephen,* Roberts, in press), and *H. polylepis* (Bleeker, 1852) from Java. More research is required to resolve the taxonomy of this complex.

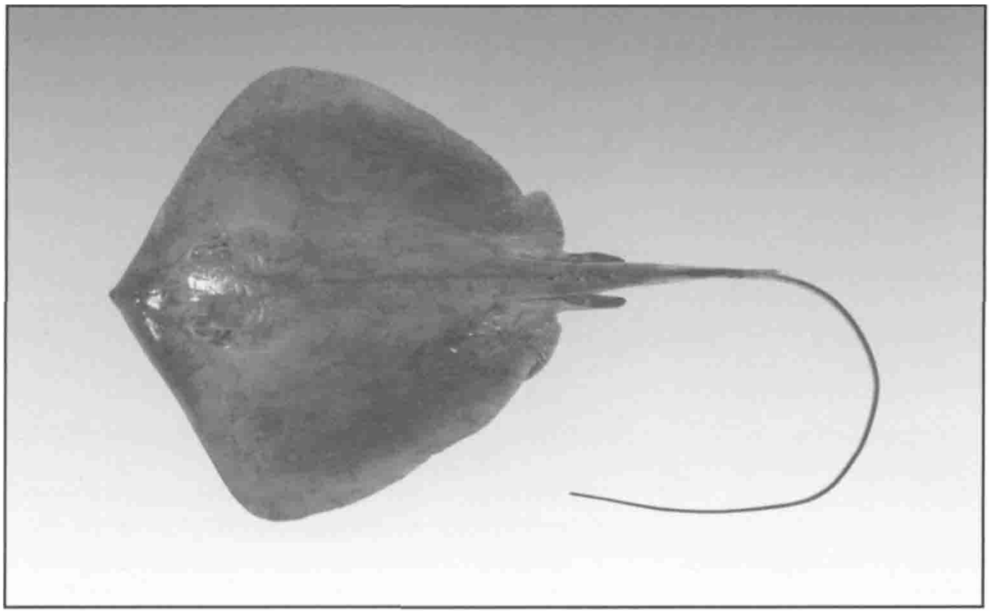
Estuarine stingray (Dasyatidae)

The little known estuarine stingray *Dasyatis fluviorum* was first described by Ogilby in 1908, but a ray (referred to as *Trygon pastinaca* by 19th century naturalist William Saville-Kent) observed feeding on oysters in a Queensland estuary was probably this species (Whitley 1940). Its range was initially thought to extend from the Brisbane



Giant freshwater whipray
Himatura chaophraya.

CSIRO Division of Marine Research/ G. Johnson



Estuarine stingray
Dasyatis fluviorum.

CSIRO Division of Marine Research/ T. Carter

River in southern Queensland to Port Jackson in central New South Wales (McCulloch 1915; Munro 1956; Grant 1978), where it was considered to be a common inhabitant of estuaries (Marshall 1982; Grant 1991) ascending rivers virtually into freshwater (Grant 1978). Grant (1991) refers to groups of 20 individuals feeding over shallow sand banks on soldier crabs *Myctyris* spp. and yabbies (presumably *Alpheus* spp). However, based on general observations and limited survey data, this species is no longer common within this region. Its conservation status urgently needs to be evaluated. It has been observed over mangrove flats in marine habitats (J. Johnson, perscomm.) and in the sea off the mouths of large estuaries (K. Graham, pers comm.).

Merrick and Schmida (1984) stated that *"D. fluviorum* is not confined to New South Wales as previously reported". They included drainages of northern Australia and the Timor Sea within its range which was in part followed by Larson and Martin (1989) and Last and Stevens (1994). However, more recent investigations suggest that the species may be confined to estuaries of central eastern Australia and that northern observations appear to be misidentifcations of *Himantura chaopliraya.*

Marginal and transient marine species

Marine elasmobranch species rarely venture into freshwater, although some occur commonly in the oligohaline and mesohaline regions of estuaries. Stingrays (four species) and stingarees (three species) are the most diverse of the 10 families regularly frequenting these habitats. This assemblage comprises *Pristis clavata, Himantura* sp. A. and *Pastinachus sephen* in the tropics, *Hypnos, Dasyatis brevicaudata, D. thetidis,* and *Trygonoptera lestacea* in warm temperate latitudes, and *Notorhynchus cepedianus, Squalus acanthias, Cephaloscyllium laticeps, Mustelns antarcticus, Okamejei lemprieri, Urolophus cruciatus* and *Myliobatis australis* in the cool temperate estuaries along the southern coast. *Pastinachus sephen* ventures well upstream with several accounts beyond tidal reach (Compagno and Cook, 1995). *Squalus acanthias* is considered to be essentially stenohaline (Thorson, 1983), but in the estuarine bays of southwestern Tasmania this species lives in mixed brackish water all year around. Some species (e.g. *Urolophus cruciatus)* clearly make use of large bay estuaries (such as the Derwent River) for pupping, but the use of estuaries by most elasmobranchs is not well understood.

The whaler sharks (11 species), and stingrays and stingarees (eight species) dominate the 27 species considered to be occasional visitors of estuaries. The occurrences, and penetration, of vagrants in estuaries seems to be dependent on seasonal and several physical factors such as the system size, depth, runoff and salinity structure. These elasmobranchs are most prevalent in large, deep, stratified estuaries with euryhaline water during dry periods.

Conservation considerations

The estuarine and freshwater chondrichthyan fauna of Australia is relatively complex on an international scale. Our knowledge of the distribution of these species, let alone their biology remains far from adequate. Similarly, knowledge of issues specific to elasmobranchs and their conservation seems not to be fully appreciated. For example, Wager (1993) in a review of the distribution and conservation status of freshwater fishes in Queensland classified *P. microdon* (as *P. pristis)* as common/secure on the basis that it is 'considered to be found over a large range including many relatively undisturbed estuaries and rivers'. In the same document, Wager makes no mention of *Glyphis* (possibly one of the most threatened Queensland freshwater fish) or *Himantura chaophraya,* and states that the single stingray, *Dasyatis fluviorum,* is probably widespread throughout the northern Queensland drainages. Wager's comments reflect our poor understanding of the basic issues confronting conservation scientists and mangers. An improved baseline constructed from a comprehensive, strategically planned, survey of Australia's drainages using interactive skills of State and Federal agencies is urgently needed to redress this situation.

Acknowledgements

I wish to thank Jeff Johnson (Queensland Museum) and G. McPherson (QDPI) for obtaining data and information on the distribution of elasmobranchs in Queensland. John Stevens kindly made useful comments on this manuscript and provided photographs of *Glyphis* spp. R. Daley provided scans of *Glyphis* photographs and S. Riddoch assisted with the acquisition of specimen data. Also I wish to express my gratitude to the many fisheries officers, fishermen and field technicians who have contributed to distributional information on sharks and rays of this region.

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Elasmobranchs Recorded from Rivers and Estuaries in Sabah

Bernadette Mabel Manjaji
Borneo Marine Research Institute, Universiti Malaysia Sabah, Locked Bag 2073,
88999 Kota Kinabalu, Sabah, Malaysia

Sabahan villagers and fishermen have traditionally known that elasmobranchs (sharks, rays and sawfish) occur in several large rivers in Sabah. However, prior to the initiation of this study, no species had ever been recorded during scientific surveys, or reported in the literature. As a result of this study, there are now definite records from Sabah rivers of two shark species: *Glyphis* sp., (provisionally named the Borneo river shark) and the bull shark, *Carcharhinus leucas,* and three batoids: the giant freshwater stingray *Himantura chaophraya,* and the sawfishes *Pristis microdon* and P. *zijsron,* (although the latter is known only from a saw). Local fishermen also confidently described other species of fresh or brackish water elasmobranchs, which are yet to be seen by scientists. As a result of these findings, it is hoped more can be learned about the biology of these species, which is presently very poorly understood. Additionally, strategies for the conservation and management of critical freshwater, estuarine and near-shore areas should be better developed and supported.

Background

Sabahan villagers and fishermen living along several major river systems on the eastern coast have traditionally known that elasmobranchs (sharks, rays and sawfishes) occur in their rivers. They were able to distinguish several ray species and to generally describe the declining trend of this fauna, particularly in the case of the sawfishes. However, the occurrence of elasmobranchs has never been reported in scientific literature, or recorded from previous scientific surveys in Sabah (Lim and Wong 1994; Inger and Chin 1962).

In adjacent landmasses and other areas of the region, elasmobranchs have been captured and recorded from freshwater systems: Kalimantan in Western Borneo, Indonesia (Roberts 1989); Perak in the Malay Peninsula; Sumatra in Indonesia and Mindoro Island in the Philippines (Taniuchi 1979).

Study approach

A preliminary field survey of the Labuk Bay/estuary and Kinabatangan River, and in addition, visits to several coastal fish markets in the state, was carried out in January 1996 by members of the IUCN Shark Specialist Group (SSG) (Figure 1). The aim was to draw up recommendations for a freshwater and marine inshore elasmobranch project (Cook and Compagno 1996). During this initial visit, no sharks or rays were caught from the river, but the team collected several dried parts and were thus able to confirm the existence of elasmobranchs in rivers, namely, one species of shark: the bull shark *Carcharhinus leucas* and two species of sawfish: the freshwater sawfish *Pristis microdon* and green sawfish *P. zijsron.* (The latter is so far still known only from a dried saw of undetermined age). With funding from the UK government's Darwin Initiative for the Survival of Species and support from several organisations within Sabah, a project was established with the aim of studying the elasmobranchs of the region, with emphasis on those caught in the river systems (Fowler, this volume; Manjaji, this volume).

In the following months, further river sampling and interviews with local people were carried out, along with regular visits to coastal fish markets, by project team members and local staff from the Fisheries Department. Attempts were made by both the research team and local fishermen to catch the riverine elasmobranchs using longlines and gill nets. Areas surveyed included Segama River and Labuk Bay, although the emphasis was on the Kuamut-Bukit Garam-Abai section of the Kinabatangan River (Figure 1). The main reason more emphasis was given to this particular section is that there were more recent reports of elasmobranchs (particularly the stingrays) having been caught here, and concentrating sampling effort in this area was practical, given the limited available research period of 18 months.

Methods and materials

Fishing gear

Fishermen along the Kinabatangan river use three types of fishing gears: lines (consisting of longline or *'rawai'*, and hook and line or *'panting');* nets (consisting of gill net or *'pukat insang'* and cast net or *'rambat')* and traps

Figure 1. Map of Sabah, Malaysia, showing Kinabatangan River, Kinabatangan District and Segama River, Lahad Datu District on the north-eastern coast of Sabah, and the Padas River, Beaufort District on the south-western coast of Sabah.

(consisting of fish trap or *'bubu ikan'* and prawn trap or *'bubu udang')*. The project team constructed fishing gears similar to the ones used by the villagers. The materials used to construct longlines were polyethylene and polyamiline tilivion (3mm in diameter for the main line and the extensions or gangions).

During the project, one sampling trip lasting up to one week approximately every two months was carried out, despite the unfavourable river conditions. Each outing on the river took place from 0700-1900 hrs, and up to three longlines, each with about 13-15 size 3 and 5 fishing hooks were set per sampling time. The longlines were set across as well as along the river, and in tributaries and oxbow lakes. Rebaiting could only be done in the daylight. We lost several longlines due to flashfloods and to a lesser extent to theft.

The monofilament gill nets used had mesh sizes between 8.5-10cm and these were set at an angle to the river, parallel to the water flow.

Other equipment

A fish finder or sonar (Hummingbird series) was used to assist in our sampling. This plotted the profile of the river-bed *in-situ* and helped us find suitable locations for setting the gear. The fish finder and the fishing equipment were set both on the main river and in tributaries and oxbow lakes.

Alternative sampling approach

During the sampling time available in 1996, the river was severely flooded, hampering the fieldwork and lowering the chances of getting specimens. It was not possible for the team to be permanently based by the river, and the decision was made to leave several tanks containing fixative (10% formalin) in villages, as elasmobranchs get caught occasionally by the villagers even during the flood. Tanks were left in Abai, Bukit Garam and Kuamut. Villagers

Table 1. Position of longlines.

Station	Relative position	GPS reading	PH	Salinity (ppt)	°C
1	downstream Sukau	5°30'48"N, 118°17'83"E	8.1	0	28.6
2	downstream Sukau	5°30'48"N, 118°17'83"E	8.1	0	28.6
3	upstream Sukau	5°30'51"N, 118°17'11"E	8.1	0	28.6
4	Danau Kelandaun	5°29'18"N, 118°15'72"E	8.3	0	28.3
5	Danau Kelandaun	5°29'50"N, 118°15'20"E	8.3	0	28.3
6	upstream Danau Kelandaun	5°28'28"N, 118°15'32"E	8.2	0	28.2
7	upstream Danau Kelandaun	5°29'28"N, 118°15'32"E	8.2	0	28.2

were paidthe current market price for any sharks and rays they caught and subsequently preserved for us. Single-use cameras were also left with the villagers in the event that a specimen was too large to be stored in a tank. In 1997, conditions improved and the flooding subsided, and members of the project team accompanied villagers on their fishing trips on several occasions.

Measuring water parameters

Water parameters (pH, salinity and temperature) were measured (Table 1) on only one occasion (8-12 October 1996), when a meter was made available for the project to use. Saline water was not detected on this occasion but it is suspected that weak salt wedges might occur up to Kampong Sukau (which is approximately 50km from sea), judging from the breadth of the river. Variable salinities were measured in the area in 1998 (Compagno *et al.,* in prep.).

Results and discussion

River profile

A diverse range of aquatic microhabitats and the changing patterns of natural vegetation along the entirety of the Kinabatangan were observed. In the upper section of the river (from Bukit Garam up to Kuamut), the sides are very high and slope steeply down to a rocky bottom. In the lower sections (from Batu Putih to Abai) the sides are very low and slope gradually down to a generally flat and muddy bottom. There are also many tributaries, such as Sungai (river) Tenegang (5°27'17"N, 118°15'15"E) near Sukau, with a maximum depth of up to 6m. Depths of 6-7.2m were measured in the main river itself but at the meanders, the bottom may reach up to 14m. In oxbow lakes, the maximum depth measured was 7.5m. However, relatively few measurements were taken and there are indications that there may be deeper areas (Mycock and Cavanagh pers. comm.). Depths can also increase considerably during flooding. Current land-based activities especially agriculture, are seen as the main factor in the detrimental modification of these natural habitats.

Species composition

Several species of marine elasmobranchs, known to range into estuarine waters, were recorded from the coastal fish market surveys. These were *Carcharhinus sorrah* and *Rhizoprionoclon acutus* from the family Carcharhinidae, and seven species of batoids from three families: *Rhinobatos typus,* family Rhinobatidae; *Himantura uarnakoides, H. walga* and *Pastinachus sephen,* family Dasyatidae; and *Anoxypristis cuspidatus, P. microdon* and *P. zijsron,* family Pristidae (Table 2).

The bull shark *Carcharhinus leucas,* was identified from a set of dried fins shown to the team by a villager in

Table 2. Species list of elasmobranchs recorded from Sabah, and known to range into rivers and estuaries.

Family/Species	Common name	Local name	Location*
CARCHARHINIDAE			
Carcharhinusleucas	Bull shark	yu/ yu sungai	Kampong Sukau, Kinabatangan, Sandakan, Lahad Datu, Semporna, Tuaran, Kota Kinabalu
Carcharhinussorrah	Spottail shark	yu	Sandakan, Lahad Datu, Beluran, Tuaran, Kota Kinabalu, Papar, Kuala Penyu
Glyphis sp.	Borneo river shark (pending confirmation) (Compagno, this volume)	yu sungai	Kinabatangan area
Rhizoprionodonacutus	Milk shark	yu	Sandakan, Lahad Datu, Beluran, Tuaran, Kota Kinabalu, Papar, Kuala Penyu
PRISTIDAE			
Anoxypristiscuspidatus	Narrow sawfish	ikan parangan/ bilas	Sandakan (identified from a fin set)
Pristis microdon	Freshwater sawfish	ikan parangan/ bilas	Labuk Bay area, Kinabatangan area, Segama area
Pristis zijsron (saw only)	Green sawfish	ikan parangan/ bilas	Labuk Bay area, Kinabatangan area
RHINOBATIDAE			
Rhinobatostypus	Giant shovelnose stingray	yu kemejan	Kota Kinabalu, Beluran, Sandakan
DASYATIDAE			
Himanturachaophraya	Giant freshwater stingray	pari sungai	Kinabatangan area
Himanturauarnacoides	Whitenose whipray	pari	Sandakan, Kota Kinabalu, Kinabatangan area?
Himanturawalga	Dwarf whipray	pari	Sandakan, Kota Kinabalu, Kuala Penyu
Pastinachussephen	Cowtail stingray	pari	Sandakan, Lahad Datu, Beluran, Tuaran, Kota Kinabalu, Papar, Kuala Penyu

* It should be noted that when locations other than Kinabatangan, Labuk and Segama are mentioned, the samples were from fish markets.

Table 3. Tooth counts of dried rostrums of sawfishes donated to the project.

Scientific name	Length of rostrum (mm)	No. of teeth on left-hand side	No. of teeth on right-hand side	Where rostrum was obtained
Pristiszijsron	265	24	26	Kampong Tetabuan in Labuk Bay (donated by the Ketua Mukim or head of the area)
Pristis microdon	480	19	19	Kampong Tetabuan in Labuk Bay (donated by the Ketua Kampung or village head)
Pristis microdon	250	19	20	Kampong Batu Putih in Kinabatangan (donated by a villager)
Pristismicrodon	230	23	22	Kampong Tomanggong in Segama (donated by a villager)

Kampong Sukau. This appeared to be the only record from the river. Other records of this species were made from observations of fresh specimens in the coastal markets and from the teeth of dried jaws shown to us by fish-sellers at the markets.

Dried rostrums (or saws) of sawfish shown to the team from several villages on the banks of the Kinabatangan and from a fishing village in Labuk Bay were identified as *P.microdon* and *P.zijsron.* The villagers, who had kept them for cultural purposes, willingly donated some of the saws to the project when they understood the objectives of this study. Tooth counts for dried rostrums donated are shown in Table 3. Information from interviews with many elderly villagers indicated a downward trend in sawfish captures. Villagers remembered them as abundant in the 1970s, declining sharply in the 1980s and most of them could not recall catching even one in the past five to 10 years. It is a good sign however, that in May 1996, a fisherman from Kampong Sukau caught a 900mm (total length) freshwater sawfish *P.microdon* on one of his longlines. Due to miscommunication however, only photographs were taken, although the fins and rostrum were saved. The capture of this young sawfish proved that sawfish do still exist in the river, although in small numbers and highly endangered.

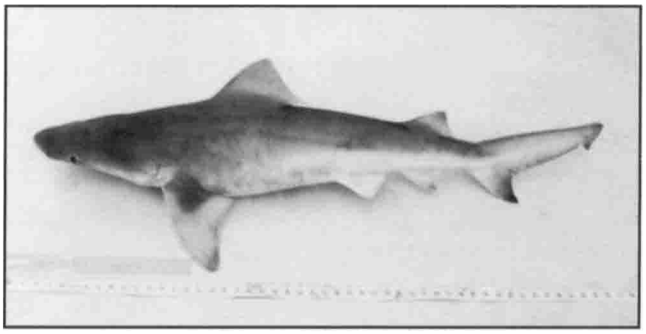
The same fisherman had also caught a river ray (on another longline), which he photographed. From the photos, it was identified as *H. chaophraya,* the giant freshwater stingray. Later, in October 1996 the first specimen of *H. chaophraya* was obtained for the project collection, also caught by a fisherman from Kampong Sukau. This specimen was an immature male, measuring 360mm disc width, with its tail chopped off. In the following months, two more specimens were caught and preserved by the villagers. The first of these was an immature male from Bukit Garam with a disc width of 52.6cm; the second was an immature female from 3 miles upriver of Kuamut, 141.1cm total length weighing 7.8kg. More recently, in June 1997, the project was informed (via the Fisheries Office) of a freshwater ray caught from the Padas River in Beaufort District, southwestern Sabah (Figure 1). A fisherman from a village there caught it with a hook and line. This specimen was a female approximately 159cm in total length, and 61.8cm disc width, weighing 7kg. This form looked similar to those caught from the Kinabatangan, although the disc shape was more circular rather than having 'high shoulders'.

Another form of *H. chaophraya* was observed at the Sandakan coastal fish market with the following description: the same disc shape as described in Last and Stevens (1996), sand-coloured dorsally with small dark speckles, pale ventrally with pale blotches at the disc margin. The entire dorsal surface was granular, with the largest denticles along the dorsal midline, becoming thorny towards the tail. The thorns extended dorsally and ventrally along entire tail and there were two spines. The specimen was a male at maturity stage 3 with a total length of 262.5cm, and a disc width of 121cm (Cavanagh and Mycock 1997).

On a sampling trip on the Kinabatangan river in March 1997, a family living in Kampong Abai who were key contacts for the project, had saved a shark they caught in December 1996 (plate). This was later confirmed as *Glyphis* sp. (river shark) and was the first of several more sharks of this species caught and saved for the project, by the same family.

The only other known specimen *of Glyphis* from Borneo (exact location unknown) was caught almost a century ago, and is stored in a museum in Vienna, Austria. This

Borneo river shark *Glyphis* sp. caught in March 1997 by fishermen on the Kinabatangan River.



Scott Mycock and Rachel Cavanagh

old specimen is identical to the recent specimens found during this project, thus the presence of this shark in the Kinabatangan River is a highly significant finding. Very little is known about species in this genus, and the recent specimens collected will provide new understandings about its biology (Compagno, pers. comm.). Work is now underway on this shark, provisionally called the Borneo river shark, to determine its species identity (Compagno *et al.* in prep.; Compagno, this volume).

Apart from the current records, there may be other species of fresh or brackish water elasmobranchs unknown to science, as experienced and knowledgeable fishermen living along the Kinabatangan and Segama rivers confidently describe other forms. Examples of these include a form of guitarfish, either *Rhynchobatus* sp. or *Rhinobatus* sp., and the cowtail stingray, *Pastinachus* sp.

Conclusion

There are now definite records of elasmobranchs from freshwater sections of Sabah rivers. These findings and the knowledge that freshwater elasmobranchs are very vulnerable by the nature of their biology and habitat requirements, lend support to current conservation efforts for these rivers. Strategies for the conservation and management of critical freshwater, estuarine and near-shore areas can now be better developed and supported.

Acknowledgements

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Growth and Mortality of the Basking Shark *Cetorhinus maximus* and their Implications for Management of Whale Sharks *Rhincodon typus*

Daniel Pauly
Fisheries Centre, University of British Columbia, 2204 Main Mall, Vancouver, B.C., Canada V6T 1Z4,

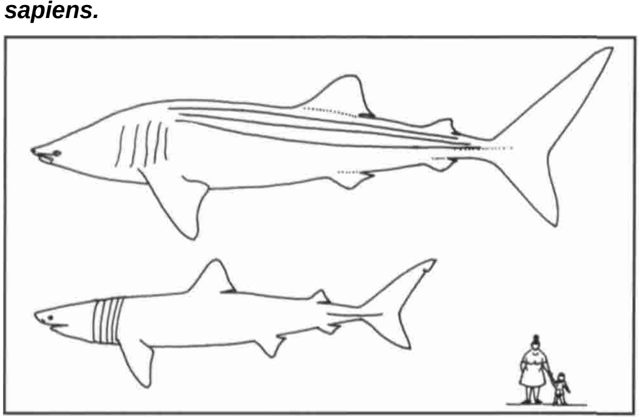
New methods were used to reanalyse previously published length-frequency data on basking shark *Cetorhinus maximus* and thereby resolve an earlier controversy about the growth rate of this fish. These methods confirm earlier suggestions of a slow growth (von Bertalanffy K >0.06/year, for an asymptotic length of 10m), and correspondingly low natural mortality (M >0.07/year), as appropriate for a fish with a record length of 9.7m.

Given what is known of the inverse relationship between asymptotic length and K in hundreds of fish species (including sharks), the above results imply that whale sharks *Rhincodon typus* should exhibit, for an asymptotic length of 14m, K and M values of about 0.03 and 0.05/year, respectively. Such slow growth and the high longevity this implies should make whale sharks even more sensitive than basking sharks to human-induced mortality, thus arguing against exploitation by fisheries. Also, ecotourism schemes will have to be careful to avoid becoming a source of indirect mortality.

Introduction

The basking shark *Cetorhinus maximus* (Gunnerus, 1765), Family Cetorhinidae, and the whale shark *Rhincodon typus (Smith* 1829), Family Rhincodontidae, are the largest fish in the world, with documented maximum lengths of 9.7m and 13.7m, respectively (Compagno 1984; Figure 1). Both species feed mainly on zooplankton, though the diet of the basking shark, a passive filter feeder, appears to be less varied than that of the whale shark, whose ability to 'suck in' its food leads to a wider diversity of prey, including nekton (Compagno 1984). The distribution of the basking shark is temperate (both North and South), while that of the whale shark is circumtropical (Compagno 1984, Last and Stevens 1994, Wolfson 1986). These distributions, with only limited overlap, and the roughly similar trophic niches and anatomy of these two sharks (notably the modifications of the head required to accommodate immense gills) suggest they can be treated as functional analogues, though inferences derived from such comparison must be viewed as tentative. Downing (1991) and Pauly (1994) discuss technical and epistemological issues involved in comparisons of various sorts, which must always compare *dissimilar* items if they are to lead to any new insights.

Figure 1. Relative sizes of whale shark *Rhincodon typus*, basking shark *Cetorhinus maximus* and humans, *Homo sapiens.*



This contribution attempts to resolve an earlier controversy concerning the growth of basking sharks, and, based thereon, to infer a likely growth pattern for whale sharks. Herein, the fact will be explicitly taken into account that growth is likely to occur throughout the year in the whale shark, a tropical species, but only seasonally in the basking shark, a temperate species.

For basking sharks, a reanalysis is justified by the emergence of new methods that allow a fresh look at the small database available for inferences on its growth, and by the urgent need for information useful for its conservation. For whale shark, indirect inferences are inherently justified, as it is unlikely that extensive data allowing direct inferences on its growth and related processes will become available soon (Colman 1997).

The estimates presented below for both basking and whale sharks represent, moreover, easy targets, and their existence may encourage the publication and analysis of data presently not available.

This contribution thus starts with a brief review of work so far published on the growth and mortality of basking sharks, provides an update, then uses the resulting estimates of growth parameters to infer likely growth and related vital statistics in whale sharks.

Previous analyses of growth in basking shark

Matthews (1950) was the first to attempt the construction of a growth curve for the basking shark. He subjectively arranged 13 length records into four clusters, presumed to represent age groups, and inferred an extremely rapid growth. Parker and Boeseman (1954) also used this subjective approach to length frequency analysis and, after adding 47 further observations from the literature on stranded and freshly caught sharks, drew a curve similar to that of Matthews (1950). They also noted that winter-caught sharks (November to February) had in many cases shed their gill-rakers. Thus, they suggested that basking sharks should neither feed nor grow in winter. Their overall growth curve therefore oscillates seasonally (Figure 2a).

Length-frequency analysis is a method fraught with danger when applied to such large and long-lived fish as the basking shark (see contributions in Pauly and Morgan 1987). Indeed, figure 2a, illustrates what, to this author, is an erroneous approach to such analysis (see below for an alternative approach).

Parker and Stott (1965) used another length-based approach to draw inferences on the growth of basking sharks. Separately plotting the length-frequency distributions offish caught in spring (May-June) and fall/ winter (October-February) allowed them to detect, among the smaller fish (<4m), a shift in mean length from 3.09m (n = 15, s.e. = 0.020) in June to a mean length of 3.52m (n = 18, s.e. = 0.018) in December. This shift of 43cm in about 6 months was assumed by Parker and Stott (1965) to represent half of the annual growth of basking sharks with length around 3.3m, and they built a growth curve around this assumption (Figure 2b). This approach thus ignores the seasonal oscillations of growth previously considered by Parker and Boeseman (1954).

Parker and Stott (1965) further reported a match between their growth curve (growth curve b, Figure 2) and another, based on the assumption that the calcified circular structures they had observed on the vertebrae of basking sharks are laid twice per year. However, Parker and Stott (1965) presented no evidence which would justify their extraordinary two-rings-per year assumption, citing instead (Ridewood 1921) who, however, had argued that vertebral rings may be formed in response to structural stress. Moreover, Parker and Stott (1964) interpreted the time to origin of their growth curve (-3.5 years) as an estimate of the gestation period of whale sharks (again without independent evidence), and thus had to accept the bizarre notion that young basking sharks should have seven rings at birth.

Pauly (1978a) attempted to identify the basis of this confusing series of claims. First, he noted that the growth increment recorded by Parker and Stott (1965) occurred precisely during that period of the year (from late spring to early fall) when most of the annual growth of temperate fish occurs. He proposed therefore that the observed 43cm growth increment represented a year's worth of growth (with no further growth in length from late fall to early spring, when most basking sharks lack their gill rakers). Note also that other temperate fishes do not grow during this period (Pauly *et al.* 1992). This led to the von Bertalanffy growth curve in Figure 2c). Further, he followed Jagerskold

Figure 2. Some previous growth curves for *Cetorhinus maximus;* a): hand-drawn curve of Parker and Boeseman (1954), with clusters of points representing length groups, subjectively arranged; b): curve of Parker and Stott (1965); c): curve of Pauly (1978a).

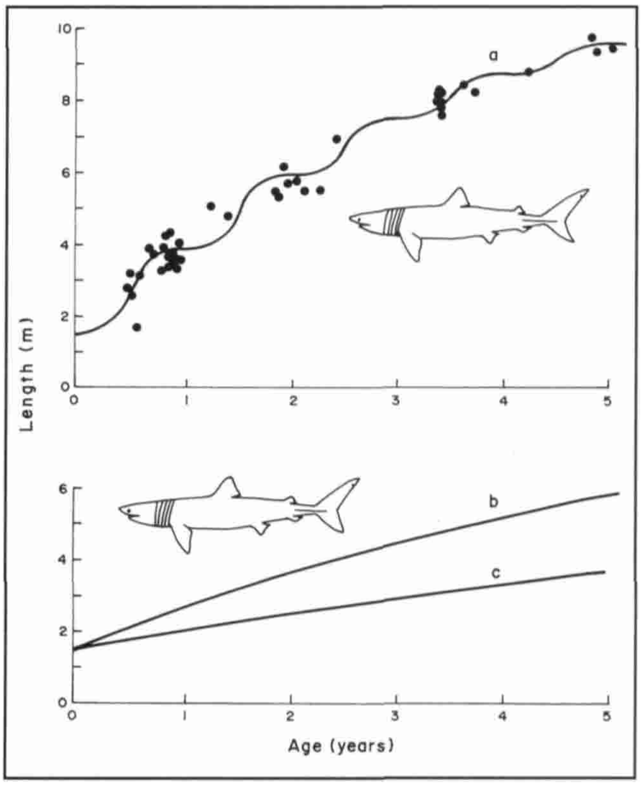


Table 1. Number of vertebral rings in eight specimens of basking sharks reported in Ehrenbaum (1922, 1925, 1926, 1928), and Parker and Stott (1965).

Length (m)	Sex	Number of rings
3.40	-	9
4.75	male	16
5.44	-	12
7.63	female	27
7.93	female	26
8.55	female	26
8.60[a]	-	32
8.77	female	27

a. Ehrenbaum (1926) gave for this specimen a live weight of 4,500-5,000kg.

(1915), Ehrcnbaum (1926) and Kyle (1927) in assuming that vertebral rings, in basking sharks, are laid annually, as is the case in other sharks (see e.g., Brown and Gruber 1988, Caillet *et al*. 1990, Holden and Vince 1973). Applied to the data in Table 1, this led to a von Bertalanffy growth curve almost equal to that in Figure 2c.

Thisclose match oftwo different approaches to estimate growth with what is widely known of temperate fish phenology did not worry Stott (1984), who simply reasserted the inferences of Parker and Stott (1965). The result was confusion, and frequent references to 'controversial results', e.g., in Compagno (1984). The re-analysis below of length and age data in basking sharks suggests that there is no reason to consider any further the two rings-per year hypothesis.

Re-analysis of basking shark growth

The equation used here to model growth is the von Bertalanffy growth formula (VBGF). When seasonal oscillations are neglected, this has the form

$$L_t = L¥ \{l\text{-}exp\text{-}[K(t\text{-}t_0)]\} \qquad ...1)$$

where L_t is the length at age t, K is a constant, t_0 the theoretical age the fish would have at length zero and L¥ is the average length the fish would reach if they were to grow indefinitely. [The parameter t_0, it must be emphasised, does not correspond to the gestation period, although it is frequently misinterpreted that way; see below].

Equation (1) is equivalent to the equation used by Parker and Stott (1965) of the form

$$L_t = L¥[l\text{-}exp\text{-}(a + bt)] \qquad ...2)$$

with b = K, and t_0 = a/b (Stott 1984). Thus, their results can easily be re-expressed in terms of the parameters of the VBGF.

To allow direct comparisons of his results with those of Parker and Stott (1965), Pauly (1978a) used their estimate of 12.26m for the asymptotic size of the basking shark. This now appears too high, as there are no credible records of basking sharks reaching a length in excess of 9.7m (Compagno 1984). Thus, Last and Stevens (1994) simply stated that basking sharks "attain 1,000cm". Also, extreme value theory (Formacion *et al.* 1991), applied to the 14 largest north Atlantic records of basking sharks (from p. 191 in Parker and Stott 1965), suggests that basking sharks in excess of 10m are very unlikely to exist (Figure 3). Thus, 10m will be used throughout as the estimate of asymptotic size in basking shark.

Given the observation of a basking shark of 8.6m weighing 4.5-5.0 tonnes (Table 1), and assuming an isometric length-weight relationship ($W = a \cdot L^3$), leads to an estimate of 'a' = 0.0075; thus L¥ =10m implies W¥ >7.5t.

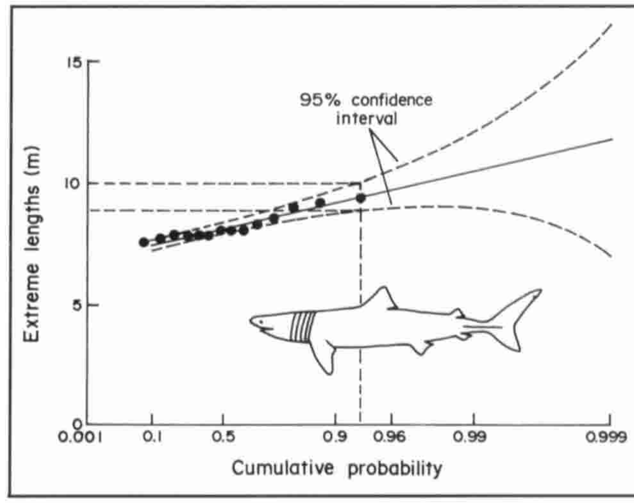


Figure 3. Plot of the largest north Atlantic records of basking sharks, based on data on p. 191 in Parker and Boeseman (1954), and extreme value theory plot of Formacion *et al.* (1991), as implemented in the FiSAT software of Gayanilo *et al.* (1996). The 95% confidence interval suggests 10m to be a likely upper size limit for basking sharks.

First estimates of K in equation (1) can be obtained from the growth increment of 43cm mentioned above and a value of L¥ = 10m. The form of equation (1) used for this purpose is

$$K = [\ln(L¥ - L_1) - \ln(L¥ - L_2)] / (t_2 - t_1) \qquad ...3)$$

where L_1 and L_2 are the length at the beginning and end, respectively, of a growth increment (here 3.09m and 3.52m; see above) and $t_2 - t_1$ is the time pertaining to the growth increment. Using equation (3), K was estimated twice, once under the assumption that growth is seasonal (i.e., that the increment of 43cm, which occurred during the warmest half of the year, represents all of the annual growth of basking sharks of about 3.3m, and thus $t_2 - t_1$ = 1 year). The second use of equation (3) was under the assumption that the annual growth increment of basking sharks of 3.3m is two times 43cm = 86cm (i.e., under the assumption that growth does not oscillate seasonally).

This leads to K = 0.064 $year^{-1}$ under the assumption that seasonal growth occurs, and K = 0.128 $year^{-1}$ if, as assumed by Parker and Stott (1965), seasonal growth does not occur.

For direct inferences on seasonal growth in basking sharks, a seasonally oscillating version of the VBGF must be used. Here, the curve of Somers (1988) is employed, of the form

$$L_t = L¥\{l\text{-}exp\text{-}[K(t\text{-}t_0) + S_{ts}\text{-}S_{t0}]\} \qquad ...4)$$

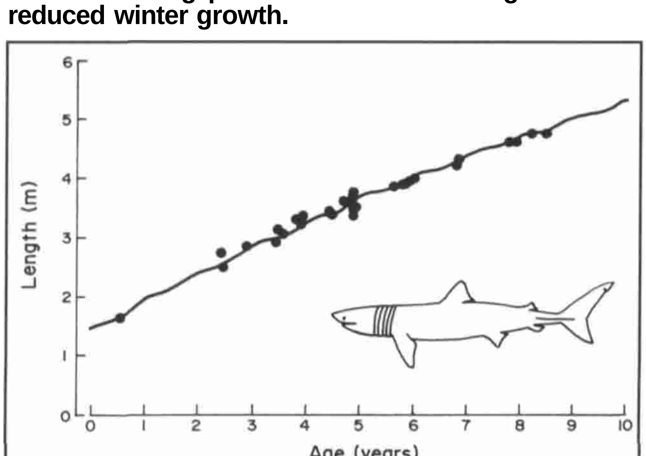
where $S_{ts} = (CK/2p) \cdot \sin [2p (t\text{-}t_s)]$, $S_{t0} = (CK/2p) \sin [2p (t\text{-}t_0)]$, C expresses the amplitude of the seasonal growth oscillations, t their onset with regards to t = 0, and all other parameters are defined as in Equation (1). In our analyses, which used the FiSAT software of Gayanilo *el al.* (1996), t_s is replaced by the Winter Point (WP), using WP = 0.5 + t_s, with WP expressing, as a fraction, that period of the year when growth is slowest (this usually occurs in winter, hence the name).

Table 2. Records of north Atlantic basking sharks of less than 5m, by date of capture or stranding, arranged sequentially such as to allow inferences on growth (see Figure 4 and text). Records marked with a* are from Table 2 in Parker and Stott (1965); all others are from p. 191 in Parker and Boeseman 1954).

Length (m)	Age (years)	Dates[a]	Length (m)	Age (years)	Dates
1.64	0.54	July (15)	3.55	4.90	Nov 25
2.54	2.48[b]	June 21	3.60	4.80	Oct 19
2.76	2.45	June 11	3.64	4.68	Sept 5
2.85	2.88	Nov 15	3.70	4.88	Nov 15*
2.90	3.46	June 15*	3.75	4.88	Nov 17
3.07	3.55	July (15)	3.84	5.63	Aug (15)
3.15	3.47	June 17	3.86	5.78	Oct 11
3.24	3.90	Nov 26	3.90	5.88	Nov 15*
3.30	3.78	Oct 8	4.00	6.00	Jan 1
3.37	3.82	Oct 23	4.21	6.79	Oct 14
3.39	4.46	June 15*	4.32	6.83	Oct 31
3.40	3.96	Nov 15*	4.60	7.79	Oct 15*
3.40	4.88	Dec 15*	4.60	7.96	Dec 15*
3.44	4.43	June 2	4.75	8.22	May 18
3.47	4.88	Nov 18	4.75	8.54	July 15*
3.55	4.93	Dec 7	-	-	-

a. Bracketed values (15) refer to month originally without dates;
b. Assuming this fish to be one instead of two years older than that of 1.64m leads to breaks in the subsequent part of the growth curve (see Figure 4).

Figure 4. Seasonally oscillating growth curve of basking sharks in the North Atlantic, based on lengths plotted sequentially against the corresponding months of capture or stranding. Based on data in Table 2. Note that plotting the second smallest point one year earlier would lead to an extremely 'fast' growth curve, not supported by the rest of the sequence, and inconsistent with alternating periods of fast summer growth and reduced winter growth.



The length at age data to be fitted by equation (4) were generated by attributing increasingly higher ages to 46 successively larger records of small (mostly stranded) basking sharks (<5m), reported in p. 191 of Parker and Boeseman (1954) and on Table 2 of Parker and Stott (1965). Note, in Table 2, how the records, each consisting of a length and a date, were arranged such that the lengths in a given month were higher than (or at least equal to) those of the preceding months. While seemingly resembling the approach used by Matthews (1950) and Parker and Boeseman (1954) to generate their growth curves, the method used here is superior because:

1. no prior assumption is made concerning the number of age groups represented by the length records (Matthews 1950 and Parker and Boeseman 1954 assumed *a priori* the existence of 4 and 3 age groups, respectively, see Figure 2a);
2. the smallest fish used (1.64m) is considered to be younger than the next larger one, of 2.5m (this was not the case with Parker and Boeseman's analysis (see dots for youngest fish in Figure 2a);
3. no fish larger than 5m was used, thus reducing the effects of increasing variance of length about age, known to occur in many fish (Sainsbury 1980); Parker and Boeseman (1954) included fish up to 10m in their analysis;
4. only records originating from 'North-west European waters' were used, i.e., records from 'South-west European waters' and 'Mediterranean' were not considered, as they may have reflected the different growth patterns of warm water populations.

Using non-linear regression to fit the sequence of 31 length records plotted in Figure 4 yielded, with a set value of L¥ = 10m, the following estimates of growth parameters (and standard errors) for equation (4): K = 0.060 (+/- 0.007), t_0 = -2.46 (+/- 0.084), C = 0.57 (+/- 0.28) and WP = 0.28 (+/- 0.33). The growth curve in Figure 4 is based on these estimates.

The estimated values of C, expressing the amplitude of seasonal growth oscillations appears to be, as in other fish, proportional to the difference between summer and winter temperature (Figure 5). Similarly, the estimate of WP is as might have been expected, given the seasonal cycle of feeding and of gill-raker shedding suggested above.

With L¥ = 10m, the two methods used here to estimate the growth parameter K of basking sharks give similar estimates if the assumption is made that their growth oscillates seasonally. Combining these two independent estimates of K leads to a mean of (0.064 + 0.060)/2 = 0.062 year^{-1}, used for all further analyses.

Note that the VBGF, when fitted to the data in Table 1, using non-linear regression and a set value of L¥ = 10m, leads to K= 0.069 (+/- 0.066) year^{-1} under the one-ring-per-year, and to K= 0.137 (+/- 0.134) year^{-1} under the two-rings-per-year hypothesis. The match of the former value with

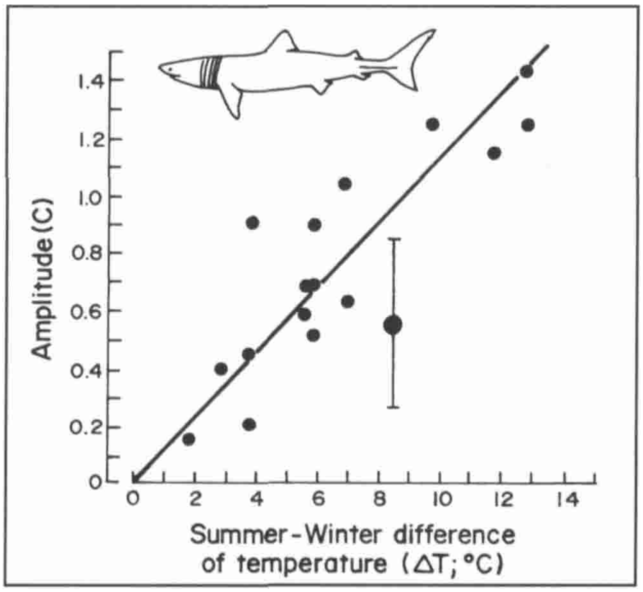


Figure 5. Relationship between the amplitude of seasonal growth oscillations in various fishes from tropical and temperate waters (as expressed by the parameter C) and the difference between maximum and minimum mean water temperature of their habitat (Dt). Adapted from Pauly (1990), with added record for the basking shark (with Dt set at 8 C, an approximate value). This plot suggests that the value of C derived from the data in Figure 4 may be an underestimate.

the estimate of K= 0.062 $year^{-1}$ just obtained, and with that in Pauly (1978a), is a corroboration of the one-ring-per-year hypothesis, notwithstanding the low sample size of the crude ring counts in Table 1.

Reproduction of the basking shark

Accepting a length at birth of 1.5m (Parker and Stott 1965, based on Sund 1943) allows for a test of the method proposed by Holden (1974) to estimate K by solving equation (1) for this parameter. Herein, the equation is solved for K with length at birth used as an estimate of the predicted length at t = 0, a set value of asymptotic length and a gestation period set equal to t_0. Assuming a gestation period of one year gives a value of K = 0.163 $year^{-1}$, while assuming a gestation period of two years gives a value of K = 0.081, both of which differ substantially from the mean value of K = 0.062 $year^{-1}$, estimated above. Indeed, it is only if one assumes a gestation period of about 2.6 years that a value of K is obtained which matches those obtained here, i.e.,

$$0.062 = -(l/2.6)\cdot \ln[l-(1.5/10)] \quad ...5)$$

However, Holden (1974, Table 4) assumed a gestation period of 1 year for *Cetorhimis naximus.* This confirms an earlier finding of Pauly (1978b, p. 118) that Holden's method is misleading, as it always generates values of 'K' between 0.1 and 0.2 $year^{-1}$ (here: 0.163 $year^{-1}$). This is due to the relative constancy, in sharks, of the ratio between length at birth and maximum observed size (see for example Table 13 in Garrick 1982, or Table 4 in Holden 1974). Note that whale sharks may represent an exception to this, as they have relatively small young (see below).

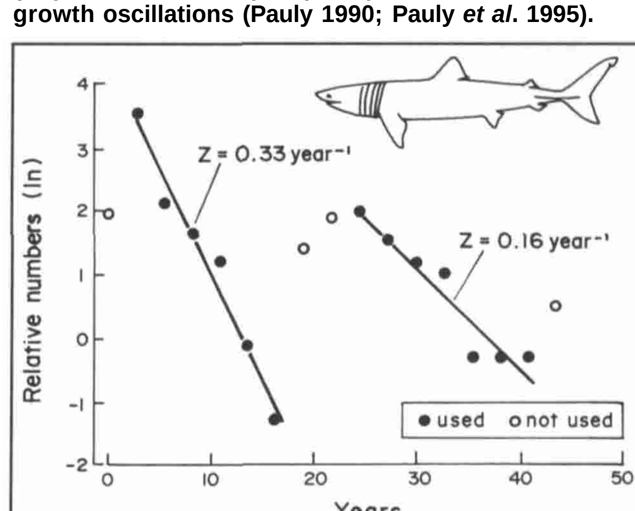
The length at first maturity (L_m) of basking sharks is not well established. Bigelow and Schroeder (1948), who studied the relative size of claspers, suggested that, in males, L_m = 4.6-6.lm. Last and Stevens (1994) proposed that for males, L = 4-5m; thus L /L¥>0.5, as suggested by Beverton and Holt (1959) for large fishes.

Mortality of the basking shark

Assuming the samples used here represent the population. Figure 6 gives length-converted catch curves for juvenile and adult basking sharks which account for seasonal growth (Pauly 1990, Pauly *et al.* 1995). These allow for the estimation of an instantaneous rate of total mortality (Z) equal to 0.33 $year^{-1}$ in the juveniles, and 0.16 $year^{-1}$ in the adults. The value of Z in the juveniles appears too high to represent an estimate of natural mortality (see values of M for temperate fish >lm in Pauly 1980), notwithstanding that the samples analysed here consists mainly of strandings (Parker and Stott 1965).

The value of Z for the adults, on the other hand presumably includes the effects of a fishery for these during the period where most fish were obtained (Parker and Stott 1965). The growth parameters L¥ = 10m and K

Figure 6. Length-converted catch curves based on 93 length records of *Cetorhinus maximus* (from p. 191 in Parker and Boeseman, 1954, and Table 2 in Parker and Stott, 1965). The growth parameter used were L¥ = 10m; K= 0.062 $year^{-1}$; C = 0.57 and t_0 = -2.26 years. The method for catch curve construction, incorporated in FiSAT (Gayanilo *et al.* 1996), explicitly accounts for seasonal growth oscillations (Pauly 1990; Pauly *et al*. 1995).



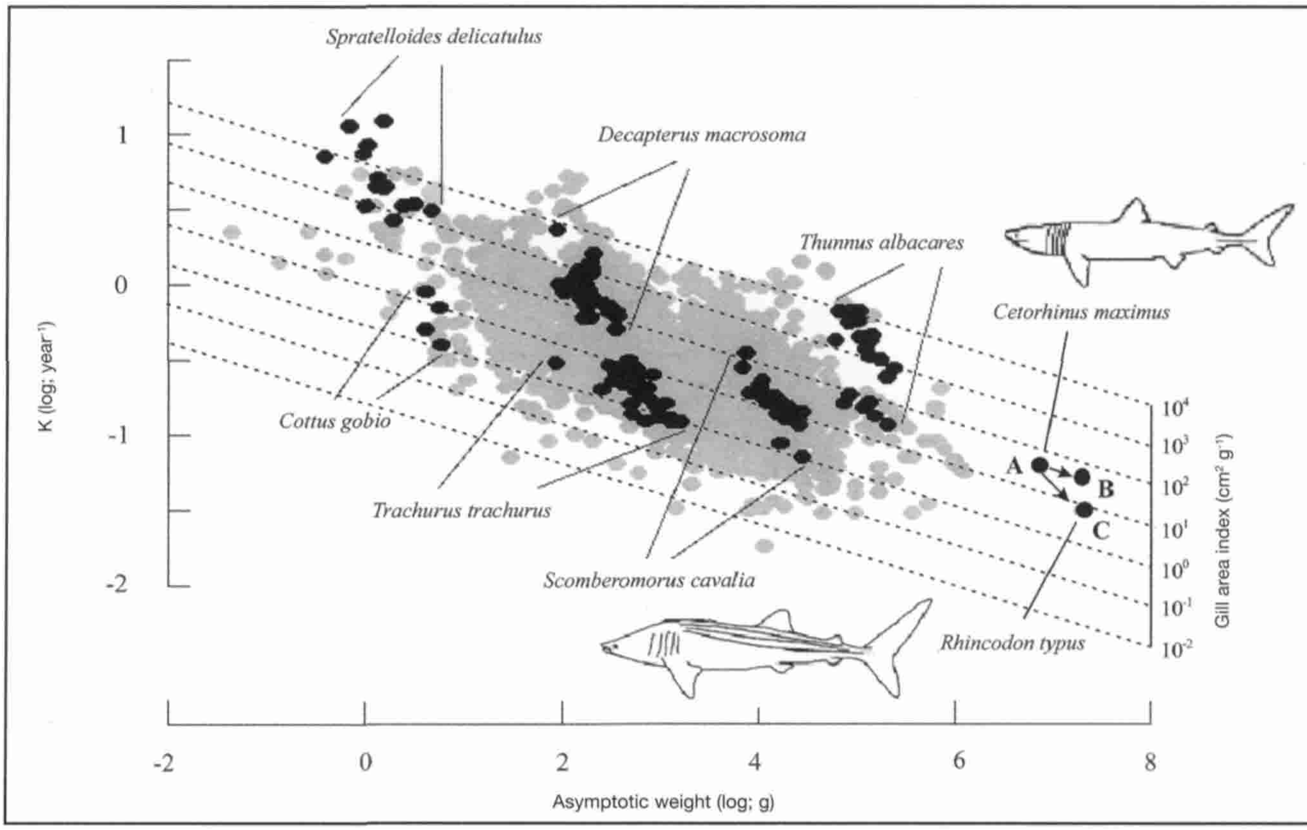


Figure 7. Plot of log$_{10}$ (K) vs. log$_{10}$(W¥) for 2948 populations (608 species) of fish, with superimposed isolines predicting K, given w¥and gill surface area (from Pauly 1998, based on data in FishBase 98; Froese and Pauly 1998). The isolines have a slope of -0.2, allowing extrapolation from the point defined by K and W¥ in basking sharks (point A) to a tentative estimate of K = 0.051 year^{-1} in whale sharks, given its estimated asymptotic weight of 20 t (point B). Other species are identified to illustrate the tendency of different populations of the same species to form ellipsoid clusters, whose major axis has a, on the average, a slope of -0.33 (Pauly 1994,1998). Using this within-species relationship for an inference from basking to whale sharks leads to an estimate of K = 0.031 year^{-1} (point C; see also text).

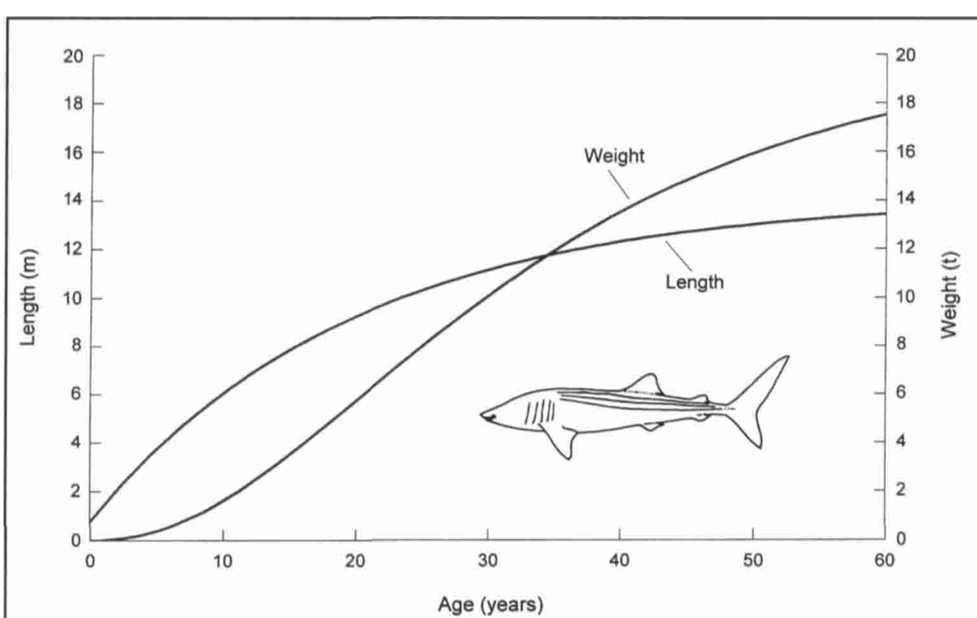


Figure 8. Tentative length and weight growth curves of the whale shark *Rhincodon typus,* for L¥ = 14m; W¥ = 20 t; K= 0.051 year^{-1} and t_0 = 1.1 years (see text for caveats concerning these parameters estimates).

= 0.062 $year^{-1}$ and a mean annual temperature of 10°C, appropriate for the north Atlantic, provide, when entered into the empirical equation of Pauly (1980), an estimate of M = 0.068 $year^{-1}$.

Our estimates of Z and M jointly suggest that fishing mortality in adult basking sharks was F = 0.162 - 0.068 = 0.094 $year^{-1}$, during the period covered by the samples included in Figure 6. This corresponds to F/Z = 0.6, an exploitation rate that no fish - especially not a long-lived, low-fecundity fish such as the basking shark - can withstand for long (Beddington and Cooke 1983).

That the basking shark is long-lived can be inferred from the approximate rule of thumb stating that in fishes, longevity (t_{max}, in years) is about equal to 3/K (Pauly 1984, based on Taylor 1958, and Beverton 1963). This implies t_{max} >50 years in the basking shark.

Inferring the growth and natural mortality of whale shark

There are many exaggerated reports of the size that whale sharks can reach, e.g., 20m (Nikolskii 1961). Given the maximum measurement rated as credible by Compagno (1984), of 13.7m, we shall assume L¥ = 14m (see also Colman 1997). This implies W¥ >20 t, if we assume a length-weight relationship similar to that of basking shark (see above).

Two comparative approaches are available to estimate the parameter K of the VBGF in whale sharks, based on the growth parameters of basking sharks. The first is based on the use of the growth performance index f, based on Pauly (1979), used for comparative purposes by e.g., Munro (1983), further documented in Moreau *et al.* (1986), and defined by

f = $\log_{10}$K + 2/3 $\log_{10}$W¥ ...5)

These authors, and a number of others have shown that in different populations of the same species, f is remarkably constant, thus implying a rather tight, inverse relationship between W¥ and K.

The analog relationship corresponding to Equation (5), linking L¥ and K is f = $\log_{10}$K + 2 $\log_{10}$L¥ and it has also been shown to be applicable, in the context of fish stock assessment, for within- and among-species comparisons and for estimation of growth parameters (see e.g., contributions in Venema *et al.* 1988). Applied to 10 and 14m, the asymptotic lengths assumed here, and to the value of K = 0.062 $year^{-1}$ for the basking shark leads, via f= 0.792, to K= 0.031 $year^{-1}$ in the whale shark. This is the same value that is obtained if the asymptotic weights of 7.5t and 20t respectively, are used. This would imply, if t_{max} >3/K, a longevity of about 100 years, which strikes one as rather high, though perhaps not impossibly so. The problem however, is that, even though they may be ecological analogs, basking and whale sharks are probably not close enough for this 'within-species' approach to be appropriate. The second approach relies on the overall pattern formed by plotting $\log_{10}$K in a wide range of fishes against the corresponding value of $\log_{10}$W¥. As might be seen, this generates a pattern whose overall shape and slope (-0.2) are determined by the gill area of these fishes (Figure 7). Assuming that basking sharks and whale sharks of similar sizes have similar gill areas allows computation, from the growth parameters of basking sharks and the slope of -0.2, of K= 0.051 $year^{-1}$ in whale sharks with W¥ = 20t (see translation from point A to point C in Figure 7). This estimate of K is more credible than the previous one, based on f', as it does not rely on a within-species relationship; moreover it implies, via t_{max} >3/K, a longevity of about 60 years, which also appears more sensible than the previous, higher estimate.

Compagno (1984) suggested that whale sharks hatch at about 55cm. However, it has been established that whale sharks bear live young, ranging from 42 to 63cm (Colman 1997). Thus, 55cm can be taken to indicate mean length at birth. Assuming that growth follows the VBGF from this size on (which is not the same as assuming, with M. Holden, that intrauterine growth follows the VBGF; see above), then t_0 can be estimated by solving

t_0 = t- {(1/K) · ln[l- (L_t/L¥)]}

With L_t = 0.55, L¥= 10, and K = 0.051 $year^{-1}$, this gives t_0 = - 1.1 years.

The whale shark growth curves for length and weight that result from these parameter estimates are shown in Figure 8. Their tentative nature cannot be overemphasised.

This also applies to the estimate of M = 0.088 $year^{-1}$ that is obtained from these parameters, a mean environmental temperature of 23°C (Compagno 1984, Colman 1997) and the empirical equation of Pauly (1980). This rate would imply that about 9% of the adults in a whale shark population die every year. However, this is probably biased upward, as various authors have found that the empirical equation used here tends to overestimate natural mortality in long-lived fishes with low values of K (see e.g. Russ *et al.* 1998).

Conclusions

From these results, the following conclusions may be derived:

1. the two-rings-per year hypothesis assumed by Parker and Stott (1965) for the vertebral structures of basking sharks generates patterns of growth and mortality that are incompatible with what little is known of the biology of this large shark. This applies even more to the fanciful growth curves of earlier authors. Standard interpretations (one ring per year and seasonally oscillating

growth) lead on the other hand, to growth parameters that are located along the main axis of a plot of growth parameters in over 1,000 species of fish (Figure 7).

2. The slow growth and low natural mortality of the basking shark, magnified by the behaviour that gave it its other name of'sunfish'(i.e., basking in the sun) make this fish extremely vulnerable to overfishing, especially in an age when populations of large fish species are severely reduced in many areas (Pauly *et al.* 1998, Casey and Myers 1998);
3. The growth parameters and other vital statistics estimated here for the whale shark are very tentative, though well in line with what may be expected, given their huge body size, and large gill area (Figure 7). Future work will undoubtedly revise these estimates, but will probably fail to turn whale sharks into a short lived, high turnover species;
4. Based on past experience (Ludwig *et al.* 1993) and present fisheries trends (Pauly *et al.* 1998), it can be assumed that direct exploitation of whale sharks as fishery resources, as occurs in the Philippines (Trono 1996), will lead to a collapse of the population(s) in the affected area(s), unless the recently proclaimed ban on this fishery (Anon 1998) is enforced. Indeed, the precautionary principle would suggest that bans on fishing of whale sharks, as introduced in the Maldives in 1993, and strictly enforced, may be the only viable approach for long term maintenance of whale shark populations;
5. Benign schemes, such as SCUBA-diving ecotourism in the feeding or mating grounds of whale sharks (Anon. 1998, Colman 1997) must ensure minimum interference to prevent the possibility of indirect mortality. This is common sense, since such industry depends on shark sightings, but must be stressed here, given that even the low value of natural mortality derived above may be an overestimate.

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International Elasmobranch Management and Conservation Initiatives

Sarah L. Fowler
Co-chair, IUCN Shark Specialist Group, c/o Naturebureau International, 36 Kingfisher Court, Hambridge Road, Newbury, Berkshire, RG14 5SJ, UK.

A reported steady increase in the international trade in shark products (particularly fins, but also cartilage, meat, teeth, skins, jaws and oil) in the early 1990s led to concern that species were being heavily and potentially unsustainably exploited by fisheries. This issue was debated at the 9th Conference of the Parties to the Convention on International Trade in Endangered Species (CITES) in 1994, and a Resolution agreed. The Resolution noted the lack of specific management or conservation measures for sharks at a multilateral or regional level. It directed the CITES Animals Committee to compile and review existing data on the biological and trade status of shark species subject to international trade, and to prepare a discussion paper on these data prior to the 10th CITES Conference in 1997. Parties to CITES, FAO and other international fisheries management organisations were also asked to establish programmes to provide biological and trade data. This paper describes the work undertaken as a result of this Resolution, which resulted in several important new international initiatives on the monitoring and management of elasmobranchs. Some other selected regional and international natural resource management instruments and organisations which are or may be used for the collection of data on shark fisheries and/or to promote shark fisheries management are also outlined (these have been updated following the presentation of the original paper in Sabah in 1997). The potential use of and synergy between fisheries and wildlife legislation for shark fisheries management and species conservation at international and regional level is noted.

Introduction

Although sharks and rays have traditionally provided an important source of food in some regions, with a few exceptions they had not often been of sufficiently high market value to be targeted by many fishers prior to the late 1980s. Where catch data are available for these few exceptions (e.g. Anderson 1990, Camhi *et al.* 1998), these demonstrate a short period of high yields followed by a rapid decline (a 'boom and bust' pattern).

In contrast to the generally low demand for elasmobranch meat, shark fins have long been among the highest value fisheries products in the world. An ancient tradition of serving shark fin soup at banquets in China developed during the Qing Dynasty (mid 17th to early 20th century) from an exclusively imperial practice to wide usage in wealthy society and became well-established in Cantonese cuisine and in Hong Kong (Rose 1996). As a high cost luxury item, the consumption of shark fin soup became politically incorrect in China in the mid 20th Century (Cook 1990). Subsequent relaxation of state market controls in China and increased disposable income in East Asia during the late 1980s and early 1990s resulted in a dramatic increase in demand for and prices of unprocessed shark fin and shark fin soup. For example, average values of imported dry fins in Hong Kong rose from US$11.20 per kg in 1980, to US$41.00 in 1992 (Rose 1996), with dried fins from highly desirable species commonly retailing for over US$400 per kg (Parry-Jones 1996), and ex-vessel prices rising to US$60/kg (Visser, this volume). During the same period China reported to the UN Food and Agricultural Organisation (FAO) imports of 48t of dried fins in 1982, rising to 1,335t in 1990, and 3,375 in 1994 (many of these fins were processed for re-export). This rising demand and value appeared not only to stimulate increased shark fishing effort in some regions, but also to encourage landings of sharks taken as bycatch (for example in pelagic fisheries, which Bonfil (1994) estimated to contribute nearly a third of world elasmobranch catches). Declines in yields in some traditional fisheries may also have resulted in a shift to increased targeting of 'under-utilised' shark and ray stocks to meet demand not only for shark fins, but also for meat, cartilage and other products.

Awareness of the increased quantities of shark products entering international trade, combined with a widespread lack of shark fisheries management and lack of accurate data on shark fishing effort, landings and trade, caused considerable concern over the long-term sustainability of shark fisheries in some regions. Rather than initially being debated in an international fisheries management forum, this issue first received detailed international attention from a wildlife convention: the Convention on International Trade in Endangered Species (CITES), resulting in significant new international shark data collection, management and conservation activity. The following paragraphs describe some of the initiatives stimulated by CITES and other international instruments of relevance to shark conservation and management (those activities initiated by FAO as a result of CITES described by Visser elsewhere in this volume are not covered here).

Convention on International Trade in Endangered Species

The Convention on International Trade in Endangered Species (CITES) came into force in 1975 to protect species of wild fauna and flora from over-exploitation through international trade. It establishes the international legal framework for the prevention of trade in endangered species of wild fauna and flora, and for the effective regulation of international trade in other species which may become threatened in the absence of such regulation. One hundred and fifty-five countries were Party to CITES in December 2001. CITES is, through its Secretariat, one of the most influential and effective of international instruments regulating natural resource use. Appendix I of CITES lists about 820 species that are threatened with extinction and for which no international trade is allowed (except under exceptional circumstances). Trade in Appendix II species (there are about 29,000 of these) is subject to strict regulation and monitoring to ensure that it is not detrimental to the status of the listed species. Appendix III lists about 230 species identified by Parties as subject to regulation within their jurisdiction in order to prevent or restrict exploitation and as needing the cooperation of other Parties in the control of trade.

CITES is now widely accepted by a large number of States as the world convention covering international trade in wild species. As a result, several other conventions (e.g. the ASEAN Agreement on the Conservation of Nature and Natural Resources) no longer have this role. CITES' leading role in the promotion of international shark conservation and management measures is notable in that it commenced long before any species of shark was listed on the Convention. As outlined above, concern over increasing levels of international trade in shark products and unmanaged exploitation of shark populations led to the subject being raised at the 9th Conference of the Parties (CoP) to CITES in November 1994. A CITES Resolution proposed by the USA was reviewed by a working group, reintroduced and passed without opposition (Fordham 1995). This Resolution (Conf. 9.17), entitled The Status of International Trade in Shark Species', noted the lack of specific management or conservation measures for sharks at a multilateral or regional level. It directed the CITES Animals Committee to compile and review existing data on the biological and trade status of shark species subject to international trade, and to prepare a discussion paper on these data prior to the 10th CITES Conference in 1997. In addition, Parties to CITES, FAO and other international fisheries management organisations were also asked to establish programmes to provide biological and trade data in time for the 1 lth Conference three years later.

With contributions from many sources (a US National Marine Fisheries Service discussion paper on shark status and fisheries worldwide, a Shark Specialist Group report on the biology and conservation status of sharks (Camhi *et al.* 1998), a TRAFFIC network report on their global overview of the utilisation of and trade in sharks and related species (Rose 1996), a report from Japan on the status of pelagic sharks in the Pacific Ocean, and information on activities from FAO, ICCAT and OLDEPESCA),theCITES Animals Committee compiled and reviewed existing data on the biological and trade status of shark species subject to international trade. The Animals Committee report based on these data was presented to the 10th CITES CoP in 1997 (see Box 1). It recognised the vulnerable nature of chondrichthyans (sharks, rays and chimaeras), the danger of rapid population collapse, lack of accurate fisheries data, and paucity of information on international trade. It recommended that FAO undertake an enquiry into the availability of biological and trade data on chondrichthyans and undertake a consultation of experts to develop a programme to implement shark fishery data

Box 1. CITES Animals Committee discussion paper recommendations.

The CITES Animals Committee discussion paper on the Biological and Trade Status of Sharks (defined as all chondrichthyan fishes) made the following recommendations for activities directed towards the full implementation of the Shark Resolution (Conf. 9.17), accepted by the 10th Conference of Parties to CITES:

- improvement of identification, recording and reporting, at species level, of landings, bycatch and trade;
- discrimination between different shark products in international trade;
- initiation of a more intensive FAO work programme on sharks and rays;
- initiation of research and management efforts by Parties to CITES which operate shark fisheries, including data collection, compilation of life history information, biological parameters, distribution, and reduction of bycatch mortality;
- improved subscription to and implementation of the principles and practices in
  - the FAO Code of Conduct for Responsible Fisheries;
  - the FAO Precautionary Approach to Fisheries (Part I: Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions); and
  - the FAO Code of Practice for Full Utilisation of Sharks;
- FAO to convene a consultative meeting of FAO representatives, fisheries biologists/managers, intergovernmental fisheries organisations and non-governmental organisations with expertise on shark management; and
- the CITES Secretariat to communicate relevant recommendations to FAO and other intergovernmental fisheries management and/or research organisations and to establish liaison with them to monitor implementation.

and collection (see Visser, this volume). The report was adopted by the 10th Conference of Parties, which agreed that the CITES Secretariat should communicate the relevant recommendations to FAO and other management and/or research organisations and establish liaison with these bodies to monitor implementation. The Animals Committee has continued to actively monitor and report on progress in shark fisheries management. Conference Resolution 9.17 has resulted in the collection of large quantities of data on landings and trade which will aid in the future management of these species.

Other proposals debated but rejected by the 10th CoP included a proposal to list all species of sawfishes, Pristiformes, on Appendix I, and a proposal for the establishment of a Marine Fish Species Working Group. If accepted, the latter would have been charged with preparing an analysis of implementation concerns associated with inclusion in Appendix II of marine fish species subject to large-scale harvesting and international trade and to develop recommendations for the 11th Conference.

Three shark listing proposals were debated at the 11th Conference in 2000. All three (Appendix II listings for the basking shark *Cetorhinus maximus*, great white shark *Carcharodon carcharias* and whale shark *Rhincodon typus)* were rejected, the basking shark proposal narrowly missing the necessary two-thirds majority for acceptance. The basking shark was listed on Appendix III by the European Union later in 2000, and the great white shark listed on Appendix III by Australia in 2001 (Appendix III listings do not require the approval of a two-thirds majority of the Conference of Parties).

The 1 lth Conference repealed Conference Resolution 9.17. which had largely been implemented by 2000, but recorded two Decisions concerning outstanding Conf. 9.17 instructions regarding monitoring of the implementation of the FAO International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) and improving international records of trade in shark products. The full text of these Decisions is provided in Box 2.

There was considerable debate during CoP 11 on the respective roles of the FAO IPOA-Sharks (as a voluntary fisheries management agreement) and the role of CITES (asan international wildlife trade monitoring convention). The FAO IPOA-Sharks notes that the national Shark Plans to be developed by shark fishing nations should aim to facilitate and pay special attention to vulnerable or threatened stocks, but does not specify how this should be done (see Appendix 2). As pointed out by Weber and Fordham (1997), CITES can contribute towards elasmobranch management by using its established trade monitoring role to assemble information on catch and trade that is not now collected, but that is crucial to the proper management of fisheries. Indeed, CITES provides the only international legal mechanism to enable these aspects of the IPOA-Sharks to be implemented.

Box 2. Decisions of the 11th Conference of Parties to CITES in 2000.

Decision 11.94: Regarding the biological and trade status of sharks.
Directed to the Animals Committee.

The Chairman of the Animals Committee shall maintain liaison with the Secretary of the Committee on Fisheries of the United Nations Food and Agriculture Organization to monitor the implementation of the International Plan of Action for the Conservation and Management of Sharks, and report at the 12th meeting of the Conference of the Parties on progress made with this.

Decision 11.151: Regarding trade in shark specimens.
Directed to the Secretariat.

The Secretariat shall continue to liaise with the World Customs Organization to promote the establishment and use of specific headings within the standard tariff classifications of the Harmonized System to discriminate between shark meat, fins, leather, cartilage and other products.

Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)

The Convention on the Conservation of Migratory Species (CMS) was signed in 1979, and ratified in 1983. It included 279 Parties in February 2002, within a regional structure (Africa, America and the Caribbean, Asia, Europe and Oceania). CMS recognises the need for countries to cooperate in the conservation of animals that migrate across national boundaries, if an effective response to threats operating throughout a species' range is to be made. It provides a framework within which Parties may adopt strict protection measures for migratory species that have been categorised as endangered (listed under Appendix I). or conclude Agreements for the conservation and management of migratory species that have an unfavourable conservation status (listed in Appendix II). These Agreements are open to accession by all Range States of the species concerned, not just CMS Parties, and may cover any species that would benefit significantly from international cooperation.

While initially directed at the problems of conservation of migratory birds, CMS now covers a much wider range of species, including seals, cetaceans and marine turtles. The whale shark *Rhincodon typus* was the first species of shark to be listed by CMS after being proposed and accepted for Appendix II listing by the Philippines at the 6th Conference of Parties 1999. The 6th Conference also called for cooperative actions during the 2001–2002 biennium for this species.

Convention on Biological Diversity

The Convention on Biological Diversity (CBD) was concluded at the 1992 UN Convention on Environment and Development (UNCED). It had 182 Parties and 168 Signatories in December 2001. CBD aims to conserve biological diversity and to promote the sustainable, fair, and equitable use of its benefits. Although similar to CITES in terms of numbers of Parties, the implementation of this Convention by each member state is the individual responsibility of each Party. Parties are required to develop or adopt national strategies for the conservation and sustainable use of biological diversity in accordance with the CBD, to monitor components of biological diversity that are important for conservation, and to identify and monitor activities with likely adverse impacts on the conservation and sustainable use of biodiversity. The 1995 meeting of the CBD Conference of Parties adopted the Jakarta Mandate on Marine and Coastal Biodiversity that calls upon Parties to take action for the sustainable use of marine and coastal living resources and invites major international bodies to improve their existing activities in this area. At least one state (the United Kingdom) is focusing on the conservation and management of certain species of elasmobranch as part of their response to the CBD.

ASEAN Agreement on the Conservation of Nature and Natural Resources

Parties to the ASEAN Agreement (Brunei, Indonesia, Malaysia, the Philippines, Singapore and Thailand) are required to give special protection to threatened and endemic species and to preserve those areas which constitute the critical habitats of endangered or rare species, of species that are endemic to a small area, and of migratory species. This Treaty has been described as one of the most modern, comprehensive and forward-looking of all conservation treaties (de Klemm and Shine 1993). It could be applied for the conservation of threatened, rare or migratory elasmobranchs in the region. The whale shark *Rhincodon typus* is one of many species that might potentially receive management attention under this Agreement.

Convention for the Protection, Management and Development of the Marine Environment and Coastal Areas of the East African Region

This Regional Seas Convention applies to all areas of the Indian Ocean that come under the jurisdiction of the Parties, including coastal waters, territorial seas and Exclusive Economic Zones (EEZ). Appendix II of the Protocol on Protected Areas and Wild Fauna and Flora lists animal species in need of special protection, many taken from the *IUCN Red List of Threatened Species.* Parties are required to take all appropriate measures to ensure the strictest protection of Appendix II species. Appendix III lists exploitable species for which protection measures are necessary. The exploitation of these species must be regulated in order to 'restore and maintain populations at optimum levels'. Appendix IV lists some migratory species, requiring Parties to coordinate their protection efforts in respect of these species (de Klemm and Shine 1993). Very few marine species are listed and none of these is a shark or ray. Many elasmobranchs clearly do, however, qualify for listing under this Regional Seas Convention. It may, therefore, be used to identify species of elasmobranchs requiring the various levels of management outlined by each Appendix and to encourage appropriate management within state EEZs.

United Nations Convention on the Law of the Sea (UNCLOS)

UNCLOS was adopted in 1982, and came into force in July 1994. It provides a framework for the conservation and management of fisheries and other uses of the seas. Its provisions on the Exclusive Economic Zones of coastal states (Article 56) and high seas provisions require cooperation between states for the conservation and utilisation of highly migratory species, which may be achieved by bilateral agreements or an international organisation. Coastal states are also required to consider the effects of fishing on associated and dependent species (Article 61(4)). The management goal adopted by UNCLOS (Article 61(3)) is that of maximum sustainable yield, qualified by environmental and economic factors.

UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks

This Agreement facilitates implementation of the UN Convention on the Law of the Sea (UNCLOS) provisions relating to the conservation and management of high seas fish stocks. Adopted in 1995, it needed to be ratified by 30 states before coming into force (the 30th ratification occurred in November 2001). The Agreement establishes rules and conservation measures for high seas fishery resources. It calls for Parties to protect marine biodiversity, minimise pollution, monitor fishing levels and stocks, provide accurate reporting of and minimise by-catch and discards, and gather reliable, comprehensive scientific data as the basis for management decisions. It mandates

Box 3. Oceanic sharks defined as highly migratory species under the UNCLOS Agreement on Straddling and Highly Migratory Fish Stocks.

Sixgill shark	*Hexanchus griseus*
Basking shark	*Cetorhinus maximus*
Whale shark	*Rhincodon typus*
Thresher sharks	Alopiidae spp.
Whaler sharks	Carcharinidae spp.
Hammerhead sharks	Sphyrnidae
Mackerel sharks	Lamnidae spp.

a precautionary, risk-averse approach to the management of these species when scientific uncertainty exists. The Agreement also directs States to pursue cooperation in relation to these species through appropriate subregional fishery management organisations or arrangements. It is complemented by the FAO Code of Conduct for Responsible Fisheries, which sets out principles and international standards of behaviour for responsible practices.

Many species of oceanic sharks are already defined as highly migratory species under UNCLOS (see Box 3). Other species and populations may qualify as a 'straddling stock' under Article 63(2) of the Convention, particularly in areas where jurisdiction has not been extended to the 200 mile limit. For these sharks, coordinated management and assessment of shared migratory populations would promote an understanding of the cumulative impacts of fishing effort on the status of shared populations.

Regional Fisheries Management Organisations

A number of regional fishery management organisations (RFMOs) operate in or adjacent to the Indo-Pacific region, including the Indian Ocean Tuna Commission, Indian Ocean Fisheries Commission, Asia-Pacific Fishery Commission, South Pacific Commission, and South Pacific Forum Fisheries Agency. While the terms of reference of some RFMOs are generally not as precautionary in their approach as that mandated by the UN Agreement on Straddling Fish Stocks, we may see increased emphasis in the future on oceanic shark research and management through some of these Commissions. One example of an intergovernmental RFMO is the Indian Ocean Tuna Commission (IOTC).

The IOTC is mandated to manage tuna and tuna-like species in the Indian Ocean and adjacent seas. Its objective is to promote cooperation among its Members with a view to ensuring, through appropriate management, the conservation and optimum utilisation of stocks covered by this Agreement and encouraging the sustainable development of fisheries based on such stocks. In order to achieve these objectives, the IOTC keeps under review conditions and trends in the tuna, scombrids and billfish stocks for which it has responsibility; gathers, analyses and disseminates scientific information, catch and effort statistics and other data relevant to the conservation and management of the stocks and their fisheries; encourages, recommends and coordinates research and development activities in respect of these stocks and fisheries; and adopts, on the basis of scientific evidence, conservation and management measures to ensure the conservation of these stocks and to promote their optimum utilisation. In addition to the species under the management mandate of IOTC, the Commission has instructed the Secretariat to collate data on non-target, associated and dependent species affected by tuna fishing operations. It is also studying the effects of shark predation on fish taken in fisheries under its remit and will report on this study in 2004.

Conclusions

There is a wide range of potential international instruments and agreements available to encourage or deliver improved management of shark populations in the Indo-Pacific region and worldwide, both within state waters and on the high seas. Most national and regional fisheries organisations would prefer to see shark management (particularly for commercially-fished species) remain within their remit and operate under fisheries agreements, such as the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocksand the FAO's International Plan of Action for the Conservation and Management of Sharks (IPOA – Sharks, see Appendix 2). On the other hand, the regional membership of Fishery Management Organisations (FMOs) is generally restricted to a very much smaller number of Parties than is the equivalent regional membership of international wildlife conventions such as CITES and CMS. Additionally, some wildlife conventions already list sharks (e.g. CMS) or provide a much stronger framework within which to deliver shark conservation or trade management than do voluntary fisheries codes or agreements, or regional FMOs with a tightly defined remit for the active management only of certain listed species. For example, CITES is the only truly effective means for monitoring international trade in products from wild species, while the IPOA-Sharks is a wholly voluntary measure. Paragraph 25 of the IPOA-Sharks also notes that 'states, within the framework of their respective competencies and consistent with international law, should strive to cooperate through regional and subregional fisheries organisations or arrangements, and other forms of cooperation, with a view to ensuring the sustainability of shark stocks'.

Ultimately, the case for improved management of threatened and commercially-exploited species of sharks and rays is so urgent that it is arguably important for managers and policy-makers to promote the use of all relevant management tools available to them. Fisheries and wildlife agreements do not cover completely different natural resource management priorities, but overlap significantly within the area of sustainable resource utilisation. They can complement each other and the thoughtful use of both types of instruments may yield an important synergy, equipping fisheries and natural resource managers to reverse current population declines and promote sustainable use more effectively than would be the case if only a single form of management is applied.

Finally, there is no doubt that, as a result of the original CITES Shark Resolution in 1994 and the FAO IPOA-Sharks agreed as a result, there will continue to be significant regional and international activity directed towards data collection and the sustainable management of sharks, rays and chimaeras. As an international centre of biodiversity and fisheries for these species, activities within the Indo-Pacific Region will be of great importance.

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FAO Initiatives for Elasmobranch Fisheries Research and Monitoring

Theo Visser
Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific (FAO-RAPI), Thailand

In November 1994 the Convention on International Trade in Endangered Species (CITES) passed Resolution 9.17, which asks the Food and Agriculture Organization of the United Nations (FAO) and other international organisations to establish programmes to further collect and assemble the necessary biological and trade data on sharks. Current statistics to support the widespread decline of shark catches are scarce, and global statistics show several gaps and inaccuracies. The main problems with existing data are the lack of data for shark bycatch and lack of species detail for catches on a global and national level. Acknowledging the gaps in the information available, and in order to allow FAO to respond to the CITES request, FAO has recently included some shark activities in addition to existing programmes. A special inquiry was undertaken on shark fisheries in the autumn of 1996, and a consultant reviewed all available biological and fishery data on sharks, including those resulting from the inquiry, and prepared a report on the biological status of sharks worldwide. FAO also intends to: (1) review the trade status of sharks and shark parts; (2) commission a study on species identification using DNA analysis; (3) commission the preparation of case studies on shark fishery management; (4) update the shark species catalogue and the technical paper on shark utilisation. In addition, the 1997 Commission on Fisheries meeting at FAO HQ in Rome proposed organising an expert consultation with Japan and US on conservation and management of shark populations. [An Editor's note provides an update on activities since 1997.]

Introduction

In the early 1980s, political and economic changes throughout the world affected fishing markets and operations. In South East Asia the easing of trade restrictions opened vast markets with a tremendous demand for shark fins, with resultant high prices. When the ex-vessel price reached US$60 per kg, this provided enough incentive to harvest sharks, even when the meat was unmarketable. In other areas, declining catches and rising prices of traditional food fishes made under-utilised sharks an inexpensive source of protein.

At the same time the pelagic swordfish *Pristis* and tuna *Thunnus* longline fisheries were also growing dramatically. These fisheries normally catch a large proportion of sharks as bycatch. Although initially sharks were usually released or discarded, the high price of the fins provided incentive for the sharks to be brought on board to be finned. Today, the shark bycatch seems to be a significant portion of the total shark mortality.

Sharks are exploited mainly for their fins and meat, but also for their skin and lately for cartilage. Shark cartilage has gained popularity in the alternative health circuit in recent years as a treatment for a variety of ailments, including cancer, arthritis and skin disorders, and may lead to destructive fishery practices in some areas.

The above-mentioned factors have given rise to numerous and diverse shark fisheries throughout the world. Currently, shark fisheries pursue nearly all large species of coastal and oceanic sharks. The history of shark fisheries indicates that intensive fisheries are not sustainable, and that initial exploitation is followed by, at best, a rapid decline in catch rates or, at worst, by a complete collapse of the fishery (Holden 1974). Once a shark fishery has collapsed, it takes many decades for the stocks to recover, if at all.

In November 1994, in response to growing concern that some shark species are being over-exploited due to demand in international trade for sharks and shark products, CITES (Convention on International Trade in Endangered Species) passed Resolution 9.17 which asks the Food and Agriculture Organization of the United Nations (FAO) and other international organisations to establish programmes to further collect and assemble the necessary biological and trade data on sharks. The CITES Resolution reflects the concern that sharks are being depleted rapidly and it is an attempt to understand and quantify the effects of the world trade on shark populations (see Fowler, this volume).

Status of statistics and information on sharks

Global shark catches reported at the time of writing are slightly over 750,000t (FAO 1997a) and have shown a gradual increase from the early 1950s. In recent years the majority of reported shark catches have been from Indonesia, followed closely by India, and with smaller catches reported by Pakistan, Taiwan, USA, Mexico and Japan.

The actual amount of sharks caught is unknown. Shark statistics suffer from the same problems as fisheries statistics in general: limited coverage, a high level of 'guess-timates' and a varying (but mostly low) degree of species detail. The situation for sharks is even worse than for general fishery statistics, in that a large proportion of the catch originates from bycatch, and species differentiation for sharks has an even lower priority than for teleosts.

The status of trade data available to FAO is even less favourable. Currently, yearly trade records are available for only about 50,000t of fresh or frozen shark and shark products (FAO 1997b). In addition, FAO does not collect statistics on products such as cartilage, skins and teeth etc, which belong to product groups that FAO traditionally does not monitor. Furthermore, national trade classifications seldom make reference to the species traded. It is clear that the trade statistics currently available do not match CITES expectations.

It seems obvious that a species approach is the only meaningful and practical approach to shark conservation and management. However, from the above it is clear that current information and statistics on sharks is scarce. Data currently available to FAO are almost useless for management purposes, due to the large percentage of aggregated species groups and limited coverage of the fisheries. There are three main problems in determining the impact of trade upon species of sharks (Castro and Woodley 1996):

A general lack of biological knowledge about sharks
This is largely the result of there hitherto being little economic incentive to study sharks, in contrast to the teleosts which have been much more important and lucrative. Furthermore, prior to the emergence of commercial shark fisheries in the mid-1980s, most students were discouraged from studying sharks by the logistical problems encountered in trying to obtain specimens. As a result, most fisheries scientists ignored sharks. This situation has been changing in the last decade, with the increase in value of shark products and ecological concerns about sharks. However, due to limited research money and logistical problems, progress in shark biology continues to be slow.

Evaluation of available data is difficult, because there is a lack of suitable models for stock assessment and a lack of the necessary data for demographic models
There is a lack of suitable population models to assess the impact of fishing and trade on sharks, and the sizes of shark populations or stocks are unknown. Most of the theoretical stock assessment models are based on bony fishes, with life histories that are quite different from sharks. Only a handful of shark species have been analysed so far and, in most cases, not all parameters necessary for analysis, such as age at maturity, mortality etc., are known. In addition, the growth rate of a species and its estimated age at sexual maturity are essential for stock assessment and demographic models and in general there is a serious lack of validated age estimates for sharks.

A general lack of species-specific catch and effort statistics in the shark fisheries and in the shark bycatch
Most nations simply do not record shark landings by species and usually lump all shark species and even all elasmobranchs together. The reasons for this practice are a lack of trained personnel capable of discriminating species, and a lack of incentive to produce shark statistics. The interpretation of the aggregated data is difficult, since the present and past species composition is not known. Even when present catch composition is known, and good time series are available, extrapolation is impossible since the catch composition will have changed over time.

Reliable effort data are usually missing in fishery statistics in general, not just for sharks, making the interpretation of landings statistics very difficult. Even those countries that have good fishery statistics available are often reluctant to publish such data, because they fear that restrictions will be placed on their fishing activities.

The migratory patterns of sharks complicate the analysis of fisheries data. Many of the commercially important species are migratory and travel great distances and cross many national boundaries. Many of these species are caught by various fisheries in two or more countries, making it difficult to determine the total catch or the age structure of the total catch.

A quick glance at the data on sharks available from the FAO database F1SHSTAT is sufficient to demonstrate that sharks are currently not very well-covered and global statistics show several gaps and inaccuracies.

The main problems with the existing data are:

- lack of data for shark bycatch (particularly when they are finned and the remainder of the shark discarded)
- lack of species detail for catches on a global and national level.

Although lack of data is hard to quantify, it is widely assumed that there is a large amount of under-reporting, especially where sharks are caught as bycatch. The lack of species detail in the available data is quite clear, and it is well recognised within FAO that the lack of species detail for catch and trade data is a major problem. Catches are typically recorded as "unspecified sharks" and trade as "shark fins". In 1995 more than 65% of the reported catches were assigned to the very broad groups of Elasmobranchii and Rajiformes. Moreover, fewer than 10% of the catches were assigned to individual species or narrow species groups. A recent FAO inquiry revealed that there is little more species detail information available nationally than reported to FAO. Action is required at the national level to improve the identification of sharks and shark parts and the collection of more detailed statistics.

FAO initiatives

It is unlikely that the present lack of fishery data will change in the near future, because many countries simply lack the resources and infrastructure to monitor their fisheries (including shark fisheries) adequately. It will take a concerted effort by interested countries and international agencies to improve the training of fishery workers in shark identification before meaningful statistics on shark catches or landings can be expected.

One tool to increase the species detail in the catches and landings statistics is the family of software programs called ARTFISH, produced by the FAO Fisheries Department. FAO has put a major effort into the production of software packages for the statistical monitoring of fisheries.

The current ARTFISH/ARTSER program (MS DOS version 2.0), developed in 1994, is a general purpose system designed to handle sample-based surveys operating with varying sampling scenarios and estimation approaches. This set of programs was originally designed to facilitate the analysis of artisanal fisheries. It now includes socio-economic, aquaculture and industrial fisheries components. The underlying methodology of the program is a generalised approach taken from the analysis of many fishery statistical surveys around the world. It is based on collection of data from three sample-based surveys (for CPUE, effort and active fishing days) and one census (frame survey). Its data management component (ARTFISH) caters for stratification in space and time, organisation of collected primary data into databases, and the estimation for total catch, fishing effort, prices and values with a wide range of indicators for various sources of variation. It can be customised to a very large extent to adapt to local fishing practices. It can also be adapted for use with logbook data, although a separate component to handle industrial fisheries data is under consideration. Its reporting component (ARTSER) operates with estimated data supplied by ARTFISH and provides users with tables, graphical presentations and interfaces with commonly used applications software.

A fully integrated ARTFISH/ARTSER Windows version is now available. It comes with three languages as standard and a fourth optional user defined language. Carefully designed survey forms can be printed out which conform to the input screens of ARTFISH for inputting of the primary data. The Windows version offers users a complete suite of statistical services, including:

1. **ARTPLAN:** A survey planner that assists in the design of sample surveys as well as assisting in estimating the total fish production for sectors not covered by a statistical system, this software component operates on parameters supplied by users and generates a simulated fishery which will then be used for testing and evaluating alternative sampling scenarios.
2. **ARTFISH/ARTSER** for Windows. Functionally this component follows the same methodological approach used by its MS DOS equivalent. However, it provides enhanced system functions, more transparent handling of data inter-relations, and much improved reporting features and integration with international computer standards, including reporting national statistics in standard form to FAO or other international bodies.
3. **ARTHELP:** Help and on-line tutorial. The above two components are fully described and supported by a comprehensive set of interactive documents, slides and graphics which provides users with tutorial and help.
4. **ARTBIEC:** Bio-economic component. This consists of a number of supplementary modules, each focusing on a specific applications sector. Special procedures link the ARTFISH estimates with samples of length-frequency and other important biological data, whereas other modules provide linkages to socio-economic information.

The importance of ARTFISH in the elasmobranch context is that it removes one limitation of most statistical systems: the difficulty of recording more than a handful of species. This does not mean, though, that statistical enumerators will be able to recognise or weigh independently all sharks in a landing. Hence the development of ARTBIO, currently under way, which will serve to disaggregate species groupings based on biological sub-sampling, the results of which can be integrated with the ARTFISH estimates. This may well be a tool used by scientific institutions, rather than directly by enumerators and may use observers on board fishing vessels to obtain information.

Acknowledging the existing information gaps and to allow FAO to respond to the CITES request, FAO included some shark activities in the Kyoto follow-up project (International Conference on the Sustainable Contribution of Fisheries to Food Security, 4-9 December 1995, Kyoto, Japan) which is being funded by Japan. One of them was to undertake a special inquiry to countries on shark fisheries, which was carried out in autumn 1996. Another follow-up was to employ a consultant to review all available biological and fishery data on sharks, including those resulting from the inquiry, and prepare a report on the biological status of sharks worldwide (Castro and Woodley 1996). It is comprehensive in terms of species coverage but identifies numerous gaps in knowledge and data.

To facilitate countries to collect better statistics on sharks, FAO, in addition to the already mentioned activities, also intends to:

- review the trade status of sharks and shark parts
- revise the shark species catalogue (Compagno 1984)
- commission the preparation of case studies on shark fishery management
- commission a study on species identification by using DNA analysis of sharks and shark parts
- update the technical paper on shark utilisation.

The 22nd meeting of the FAO Commission on Fisheries in 1997 led to the convening of a Consultation on Shark Fisheries in 1998. This led to an International Plan of Action on Shark Fisheries (IPOA-Sharks). At the time of writing this was due for discussion in early 1999. (See Appendix 2, this volume.)

Some further detail on the revision of the shark species catalogue and plans for the study on species identification by using DNA analysis of sharks and shark parts is given below, based on a brief prepared by David Ardill, Chief FIDI, FAO.

The FAO species catalogue (Compagno 1984) has proved to be an indispensable source for general knowledge on sharks and their importance for fisheries, especially in the field. Additionally, judged on the Science Citation Index over the past decade, the FAO shark catalogue has been cited in more than 200 publications and thus had a major impact on the primary scientific literature. It can be expected that the revised shark catalogue will receive the same attention. It should be mentioned that the revised shark catalogue will cover around 480 species, while the catalogue published in 1984 (which is out of print) included only 350 species.

The work on the shark catalogue revision has progressed well. The framework for most of the first volume (non-carcharhinoid sharks) and a good part of the second volume (carcharhinoid sharks) has been partially revised and research on the distribution of elasmobranchs for the revision of the shark distribution sections has been continued. The final manuscript of the first volume was available by mid-1998, and of the second volume in the last quarter of 1998. The revised catalogue will be published in the near future.

At the same time, a CD-ROM version based on the material of the revised shark catalogue is being developed by the Expert Center for Taxonomic Identification of the University of Amsterdam, in collaboration with FAO and Dr L.J.V. Compagno.

FAO, in collaboration with the Laboratory of Ichthyology of the University of Girona in Spain, is also undertaking work to discover if molecular techniques such as Polymerase Chain Reaction (PCR) to amplify and sequence portions of DNA are useful to characterise species of sharks. A number of previous studies have demonstrated the utility of molecular genetics techniques for defining patterns of inter-specific variation. In this study molecular techniques (such as PCR) will be used to amplify and sequence portions of DNA to characterise the level of genetic variation among species. This technique has already been used with success for the identification of species of Hake *Merluccius* and to characterise them for phylogenetic analysis. Currently the major interest lies in assessing if it is possible to identify species of sharks by using samples of dried fins.

If this exercise has success, and funds are allocated a case study will be carried out on a fishery (e.g. the surface long-line European fishery on swordfish in the Atlantic Ocean) to try to quantify the bycatch of sharks by species and fishing area.

CITES prepared a follow-on report to Resolution 9.17 on the biological and trade status of sharks which recommended that FAO should proceed with the planned work in close consultation with CITES. Other recommendations were to:

- consult with the World Customs Organisation to establish more specific categorisation of shark products in the harmonised system commodity classification
- encourage FAO member states to subscribe to and implement the FAO Code of Conduct for Responsible Fisheries, the FAO Guidelines on the Precautionary Approach to Fisheries and the FAO Code of Practice for the Full Utilisation of Sharks (see Fowler, this volume).

The 17th session of the Coordinating Working Party on Fishery Statistics (March 1997, Hobart, Australia) noted that some progress has been made in improving the collection of catch, bycatch and discard data by various organisations and several observer programmes have been implemented. However, only a few regional fisheries management organisations have actually implemented specific measures for sharks beyond basic catch reporting requirements.

Conclusion

The recent survey commissioned by FAO attempted to describe the status of all shark species. The work was incomplete, due to the fragmentary knowledge of sharks and the paucity of fisheries data available. Many species are simply listed as being data deficient, reflecting that no relevant biological or fishery data could be localised in the time available to the consultants. It is clear that better data are needed to assess the current situation and to design proper management plans. However, from what is known today, and from the papers published in these proceedings, it is clear that unless efforts are undertaken promptly to reduce present catch rates and bycatch, the future of shark resources is very bleak indeed.

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Editor's note: Recent FAO activity related to elasmobranch research, monitoring and management

Considerable advances have been made since this paper was written. These are summarised below:

- The FAO Technical Working Party on Conservation and Management of Elasmobranchs (April 1998 Tokyo, Japan) recommended that a series of elasmobranch-related publications be produced, most importantly guidelines on management of shark fisheries.
- In 1999 a voluntary International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) was adopted by the FAO Committee on Fisheries (COFI). The IPOA-Sharks highlights the action required for sharks within the context of the Code of Conduct for Responsible Fisheries. Technical guidelines have been published to support the implementation of the IPOA-Sharks (see below: FAO Rome 2000 and Appendix 2, this volume).
- FAO is currently expanding the information on its Web Site (www.fao.org/fi/ipa/manage.asp) to include a list of elasmobranch experts, publications, and news about IPOA-Sharks raised at meetings of the FAO Committee on Fisheries (COFI).

Publications by the Fisheries Department of the FAO relating to Elasmobranch Fisheries

Bonfil, R. 1994. *Overview of world elasmobranch fisheries.* FAO Fisheries Technical Paper, No. 341. Food and Agriculture Organization of the United Nation, Rome. 119pp.

Castro, J.I., Woodley, C.M. and Brudek, R.L. 1999. *A preliminary evaluation of the status of shark species.* FAO Fisheries Technical Paper, No. 380. Food and Agriculture Organization of the United Nation, Rome. 72pp.

Shotton, R. (ed.) 1999. *Case studies on the management of elasmobranch fisheries.* FAO Fisheries Technical Paper, No. 378. Food and Agriculture Organization of the United Nation, Rome. Vols 1 & 2. 920pp.

Vannuccini, S. 1999. *Shark utilization, marketing and trade.* FAO Fisheries Technical Paper, No. 389. Food and Agriculture Organization of the United Nation, Rome. 470pp.

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A revised and expanded version of the catalogue *"Sharks of the World'* is being published in three volumes as part of FAO-SIDP's Species Catalogues for Fishery Purposes. Volume II will be published in 2002, Volume I in late 2002 or early 2003, and Volume III later in 2003.

Planning is underway for the preparation of a new catalogue of *"Batoids of the World",* in three volumes.

A *Field Guide to Elasmobranchs of the Red Sea* is in preparation and due for distribution in late 2002.

A *Field Guide of Elasmobranchs of the Mediterranean* (in English) is in preparation, based on the *"Guide d'identification des ressources vivantes du Maroc",* the Field identification guide to *Sharks and Rays of the Red Sea and the Gulf of Aden* and the catalogue *of Sharks of the World.*

Review of Fisheries and Processes Impacting Shark Populations of the World

Terence I. Walker
Marine and Freshwater Resources Institute, PO Box 114, Queenscliff, Victoria, Australia 3225

Populations of many species of shark around the world are being affected by harvesting and habitat change. Widespread stock reductions have occurred for targeted and bycatch species of shark in certain industrial fisheries. More localised reductions have occurred closer to shore from the effects of industrial, artisanal, recreational and, possibly, traditional fisheries. Beach protection programmes, designed to reduce the risk of shark attack on humans at bathing beaches, have also reduced numbers. Several countries are beginning to manage usage of their shark resources rationally, but most are not. Whilst stocks of some species are being harvested sustainably, stocks of other species have been reduced to levels where they now require total protection. Other factors impacting shark populations are more difficult to quantify. Industrial, domestic and agricultural development in coastal and catchment areas are affecting inshore nursery areas. Aquaculture, ecotourism, spread of exotic organisms, pollution and environmental disturbance by fishing gear, and, in the long-term, global warming and ozone thinning are probably having more subtle impacts. These anthropogenic non-harvesting influences together are likely to be impacting first on those species of shark reliant on inshore areas for their nurseries; certain migratory species are likely to be impacted in the long-term.

Introduction

A total of 468 extant species of shark have been described from various habitats, from near shore to the abyss in all oceans of the world (Compagno, this volume, a). They are most numerous above 2,000m in tropical and warm temperate continental marine habitats. A few occur in freshwater and hypersaline habitats (Last and Stevens 1994).

Sharks are often characterised as long-lived, slow growing and producing few offspring. These characteristics, and the declining catch rates in shark fisheries, have raised doubts about whether sharks can be harvested sustainably. Despite the concerns expressed about the impacts of fishing and habitat change, little attempt has been made to quantify these impacts.

One difficulty in assessing the impacts of fishing is that most of the shark catch is taken by fishers targeting teleost species. As a result, most of the catch reported is as unidentified elasmobranchs or unidentified fish, or not reported at all (Bonfil 1994 and Visser, this volume). In addition, there is unreported discarded shark bycatch, and dead sharks dropping out of fishing gear or being eaten by invertebrates, other fish or mammals while in the fishing gear before being landed (Walker 1998). This lack of information on catch, as well as on fishing effort, has prevented adequate fishery stock assessment (Visser, this volume).

Impacts of habitat change on fish populations are generally more difficult to study, and historically have been less intensively examined than the impacts of harvesting. In the case of sharks, other than identifying pupping, nursery and mating grounds for several species (Ripley 1946, Olsen 1954, Williams and Schaap 1992, Branstetter and Musick 1993, Castro 1993, Freer and Griffiths 1993, Holland *et al.* 1993), there is little information available for evaluating the potential or actual effects of habitat change. Hence, this review is necessarily speculative, and draws on anecdotal information and impressions from personal observations.

Shark fishing

Shark populations around the world are harvested in several fisheries targeting shark, most are taken as bycatch in fisheries deploying many types of fishing gear. These fisheries, along with shark beach protection programs designed to reduce the risk of shark attack on humans and with habitat modification, have contributed to a significant decline in shark abundance (Bonfil 1994). Reported landings of cartilaginous fishes currently exceed 700,000t. A small amount of this is of chimaeras, most is fairly evenly divided between sharks in one category and batoids (skates and rays) in another (Anonymous 1996b). While sharks provide below half of one percent of the world's fisheries products, shark landings continue to rise with the growing demand for shark meat, fins, cartilage, liver oil and other body parts as food, medicine and artefacts.

Fisheries are often referred to as either industrial or non-industrial fisheries. Non-industrial fisheries cover traditional, recreational (including game fishers and divers) and artisanal fisheries and beach protection programs. There is no clear distinction between artisanal and industrial fisheries; the terms refer to a vessel's size, which relates to its capacity to remain at sea. Some countries use the distinction as a basis for setting fishery access rights to designated waters. Industrial vessels are usually required to operate outside prescribed distances from shore. Some countries, such as Argentina, require artisanal vessels to operate inside these distances. In Trinidad and Tobago, the artisanal fishery is characterised by the vessels smaller than 10m, operating within 1 day of port. The industrial longline vessels are larger vessels up to 30m that can remain at sea for periods of several weeks (Anonymous 1990). Bonfil (1997), on the other hand, describes the Mexican artisanal vessels operating in the Gulf of Mexico with outboard-motor powered vessels of 7.5-12m with hulls constructed of fibreglass. With the exception of a few old vessels constructed of wood, the boats are capable of 1-3 day trips within the waters of the continental shelf. In this fishery there are 10-20m inboard diesel-powered vessels with hulls constructed of fibreglass, wood, steel or ferro-cement that operate in several states and stay at sea for periods up to 15 days. This mix of vessels is consistent with a common trend of gradual upgrading of vessels to enable more distant fishing.

Around the world, most sharks, along with other chondrichthyans, are taken as bycatch in industrial fisheries targeting teleosts. These use trawl nets on continental shelves and slopes and target tunas and tuna-like fishes Scombridae, marlins Istiophoridae and swordfish Xiphiidae with surface-set longlines and drift-nets further offshore and on the high seas. They are also taken by artisanal fisheries targeting a mix of teleost and shark species with gillnets and longlines in coastal waters. The relatively few target fisheries for sharks exhibit the pattern of artisanal fisheries developing into industrial fisheries (Walker 1998).

Non-industrial fisheries

Traditional fisheries are confined to inshore and coastal waters, and have a minor impact on shark resources. For example, in New Zealand parties of Maori periodically venture into coastal waters in fleets of canoes to catch sharks on baited hooks (Francis 1998). Subsistence shark fishing occurs in the Polynesian, Micronesian and Melanesian countries (Sant and Hayes 1996), South Africa (Smale 1996) and many other parts of the world.

Beach protection programmes occur in Dunedin of New Zealand (Cox and Francis 1997), KwaZulu-Natal (Dudley and Cliff 1993a,b), Queensland (Simpfendorfer 1993) and New South Wales (Reid and Krogh 1992 and Stevens, this volume a). Some of the authors describing these programmes found an initial trend of decline in catch per unit of fishing effort (CPUE) followed by stability for most species of shark caught. Designed to cull species such as great white shark *Carcharodon carcharias,* tiger shark *Galeocerdo cuvier* and bull shark *Carcharhinus leucas,* they also catch many of the species taken in recreational fisheries.

Game fishing for sharks, usually with rod and reel, also tends to be in coastal waters. High-speed-planing hull vessels also enable many of these recreational fishers to reach deep water. These fishers mainly target pelagic sharks such as mako *Isurus oxyrinchus,* thresher *Alopias* spp., hammerhead *Sphyrna* spp., blue *Prionacea glauca* and requiem sharks *Carcharhinus* spp. The fisheries occurring in Argentina, Brazil and Mexico are not so well described as in the USA (Hoff and Musick 1990), Australia (Pepperell 1992), New Zealand (Francis 1998) and South Africa (Smale 1996). Available gamefish records indicate catch rates have declined (Pepperell 1992). The largest recreational fisheries are in the USA. Annual harvests along the Atlantic and Gulf of Mexico coasts are estimated at 183,000 sharks weighing 780t (Anonymous 1997). Other recreational fishers operating from beaches or rocks at the edge of the sea have less impact.

Artisanal fisheries generally involve large numbers of fishers. Most of the shark catch is taken by baited hooks on longlines or by gillnets (constructed with monofilament or multifilament webbing), which are set either on the seabed or on the surface (Weber and Fordham 1997). These fisheries also use seine-nets, fish-traps, scoop-nets, hand-lines, and, in tropical and subtropical countries of Central and South America, small prawn trawl nets.

Artisanal fisheries have probably caused declines in the abundance of many species of sharks in inshore and coastal waters, but their impact must vary considerably between species. Because the boats are restricted to a range of only a few kilometres from shore, and because many of the species harvested are distributed widely inshore and offshore, the ranges of these fisheries are often small compared with the distributions of the species. If nursery grounds, or major aggregations of breeding sharks, do not fall within the ranges of these fisheries and developed offshore industrial fisheries harvesting the same species, are absent, declining catches probably reflect localised stock depletion of sharks, rather than major decline of the overall population.

Industrial fisheries

Industrial shark fisheries, growing steadily since the 1920s, appear to be having the greatest impact on shark populations. Underlying the overall trend of rising catch is the increased fishing of previously unutilised stocks, while catches from established shark fisheries decline (Compagno 1990, Bonfil 1994). The histories of the few fisheries targeting sharks exhibit the trend of rising catch followed by substantial decline. A harpoon fishery for basking shark *Cetorhinus maximus* off the western coast of Ireland began in 1770 and lasted until the 1830s when the species became scarce. With subsequent rebuilding of the stock, the fishery was re-established during the 1940s. The catch quickly peaked, and then declined again to a low level by the end of the 1950s (Fowler 1996). The demand for shark liver oil during the 1930s and 1940s stimulated rapid growth of longline, driftnet and bottom-set gillnet fisheries for *Galeorhinus galeus* on the continental shelves of various parts of the world. Catches from all these fisheries subsequently declined or, as in the case of California, collapsed. In the Norwegian fishery for porbeagle sharks *Lamna nasus,* catches peaked during the 1940s and 1960s, but declined to a low level by the mid-1980s. The pattern of rise and fall in catch occurred very rapidly in the Californian driftnet fishery for the common thresher shark *Alopias vulpinus.* This fishery began in 1977, peaked in 1982 and fell to below 20% of the peak catch by 1987 (Bedford 1987).

Sharks are taken in large quantities as bycatch in longline, purse seine and driftnet fisheries targeting tunas and tuna-like species, both on the high seas and in Exclusive Economic Zones (EEZ) through bilateral access agreements (Sant and Hayes 1996). Research cruises in the Pacific Ocean (Nakano *et al.* 1996), and observer programmes on-board Japanese longline vessels in the Atlantic Ocean (Matsunago and Nakano 1997) indicate blue shark *Prionace glauca* is the main species caught. Other species caught in lower quantities are shortfin mako *Isurus oxyrhinchus,* bigeye thresher *Alopias supercilious,* oceanic whitetip shark *Carcharhinus longimanus,* and, in the central Atlantic, the porbeagle *Lamna nasus.*

Logbook shark CPUE data available from the Japanese longline fishery in the Atlantic Ocean, when standardised, show an initial decline during the early 1980s followed by stability (Nakano 1997). This suggests the abundance of blue shark is stable but provides no information about the less prevalent and possibly less productive species in the catch. Analyses, combining logbook and observer data for the longline fishery in the USA EEZ of the western Atlantic, show an earlier initial decline in blue shark during the entire 1970s followed by a levelling but more variable trend. Similar analyses provide no evidence of decline for shortfin mako (Hoey and Scott 1997). The low value of blue shark meat, due to its soft muscle tissue and strong ammonia odour, combined with the relatively high value of its fins, has led to the widespread practice of finning and discarding of carcasses at sea. Hence, while blue shark and mako populations appear stable, at least in some regions, the effects of the fisheries on the less abundant, and possibly less productive, species remain unknown.

Other, less widely distributed, species, particularly those occurring mainly in coastal regions, appear to have undergone greater depletion. Annual catches taken from the coastal region of eastern USA increased rapidly during the late 1980s and early 1990s, whilst catch rates of many of the species declined by 50-75%. The popular, and predominant, species in the catch are blacktip shark *Carcharhinus limbatus* and sandbar shark *Carcharhinus plumbeus* (Anonymous 1996a, 1997). Longline CPUE for the latter declined to 10-15% of earlier levels within less than a decade (Musick 1995). Catch rates of dusky shark *Carcharhinus obscurus* also exhibit a marked decline in catch rates. Trends in stock abundance of some of the smaller shark species such as the Atlantic sharpnose shark *Rhizoprionodon terraenovae,* the bonnethead shark *Sphyrna tiburo,* the blacknose shark *Carcharhinus acronotus* and the finetooth shark *Carcharhinus isodon* are less clear.

It is likely that some of the most heavily impacted stocks are angel sharks Squatinidae, batoids, chimaeras and dogfishes Squalidae taken as bycatch in demersal trawl fisheries. As in the high seas fisheries, much of the catch is discarded dead and not reported. Marked declines in abundance of angel shark *Squatina guggenheim* and guitarfish *Rhinobatos horkelii* are evident from commercial pair trawling CPUE data for vessels operating out of Rio Grand, Brazil (Vooren 1990). In New South Wales, Australia, a fishery-independent survey of the upper region of the continental-slope trawl-fishing grounds (180-630m) indicates major declines in the abundance of several species of dogfish, angel shark, skate and chimaera between the periods 1976-77 and 1996-97 (Andrew *et al.* 1997). Dogfishes inhabiting the continental shelves and continental slopes are taken as bycatch in large demersal trawl fisheries such as those off western Europe, Canada, South Africa, New Zealand and south-eastern Australia. Like many of the teleost species studied from the deeper and colder waters of the continental slopes, the deepwater dogfishes are likely to have particularly low productivity. Dogfishes appear to be longer lived, producing fewer young per pregnancy than many other groups of shark. The slopes are usually steep, and their total area of seabed is small compared with the areas on top of the continental shelves and on the abyssal plains of the oceans. Given that some species of dogfish are confined to a limited depth-range on these slopes, the total area occupied by these species is remarkably small. The high fishing intensity on the slopes in some regions of the world containing large highly valued stocks of teleosts must be placing several species of dogfish are at high risk of major depletion.

Need for improved fishery management and species conservation

The status of shark stocks around the world is poorly known and little attempt has been made to manage them. Of 26 countries reporting annual catches greater than 10,000 tonnes (Bonfil 1994), only Australia (Walker *et al.* 1997), New Zealand (Francis 1998) and USA (Musick 1995) have shark fishery management plans and ongoing research programs; a few other countries have implemented fishery controls.

How well certain species can withstand the uncontrolled fishing mortality will depend on their productivity. A higher proportion of the biomass can be taken sustainably each year from a species with high productivity than from a species with low productivity. Long-lived species with low natural mortality and low reproductive rates have low productivity, whereas short-lived species with high natural mortality and high reproductive rates have high productivity. Productivity varies widely between shark species. The productivity of sharks as a group is less than invertebrate groups and teleosts, but probably higher than that of marine mammals (Walker 1998). Harvested species such as gummy shark *Mustelus antarcticus* (Walker 1992, 1994a, b) and the Atlantic sharpnose shark *Rhizoprionodon terraenovae* are more productive than *Galeorhinus galeus* (Punt and Walker 1998). Two species with low productivity, considered to have experienced unsustainably high levels of fishing mortality are *C. carcharias* and the spotted ragged-tooth shark *Carcharias taurus.*

C. carcharias are taken in beach protection programs, targeted by trophy seekers using heavy tackle to catch large animals for their jaws or teeth, caught by recreational fishers, and discarded bycatch in various industrial fisheries. The species is widely distributed in coastal temperate waters. It has suffered severe population reductions in several regions of the world over the last three or four decades. As a top-level predator its abundance is naturally low, compared with many other species of shark, and its productivity also appears to be low. It produces about 7-10 young per pregnancy (Francis 1996, Uchida *et al.* 1996), suggestive of low reproductive rates, and lives at least 22 years (Francis 1996). Great white sharks, often occurring close to shore, are readily captured, particularly large, maturing or mature animals when feeding around seal-breeding colonies. Younger animals tangle in fishing gear. The decline in abundance of great white sharks indicated by game fishing records (Pepperell 1992) and beach protection programmes (Dudley 1995) led to their protection in South Africa, Australia and several states of the US. Similarly, *C. taurus* off New South Wales has been protected following marked reductions in its population, due to the combined effects of commercial longline fishing, the beach protection programme and recreational spear fishing (Pollard 1996).

Habitat change

Habitat changes can be natural or human induced and can potentially change a species' abundance and distribution. Storms can damage reef and inshore habitats. Large swells can cause structural change to shorelines. Storm tides can flood inshore areas and upset the balance in areas not accustomed to heavy wave action of high-salinity waters. Large, sudden, influxes of abnormally warm or cold, or fresh or saline water into an area is known to cause fish kills (Kailola *et al.* 1993). They might affect the survival of sharks, particularly if the area is a shark nursery. Sharks have been living with these natural cycles of habitat change for millions of years and are adapted to cope with them. Sharks, however, are not so well adapted to cope with rapid, permanent, habitat changes induced by human activity.

Freshwater and inshore habitat modification

Habitat modification is most conspicuous in freshwater habitats, with the construction of physical barriers such as dam walls and the abstraction of large volumes of water for agricultural irrigation and heavy industry. Land clearing and poor land-use practices, in a river catchment can affect shark habitat within the river, the estuary and offshore. Plumes of suspended sediment flowing down rivers increase turbidity and can smother reefs and seagrass. Such changes provide the conditions for few species of plants and animals, which may lead to the alteration of a shark species' habitat.

Dredging harbours and shipping channels and the translocation of dredge spoil cause long-term increases in turbidity and can cause a build-up of silt deposits in some of the sensitive coastal ecosystems. Renourishing beaches with sand for recreational use can have similar localised effects.

Some of the most threatened shark species occur in freshwater habitats (see Compagno, this volume, b). The amount of freshwater in rivers and lakes is relatively small compared with the amount of seawater on Earth. The tropical rivers and lake habitats of freshwater species are mostly in developing countries with large, expanding human populations (Compagno and Cook 1995). These areas are much more accessible than marine waters for harvesting sharks. Water temperature, dissolved oxygen, clarity and water flow are less stable in freshwater habitats, and are gradually changing due to deforestation. Contamination of the water with toxicants from oil extraction, mining and agriculture, physical modifications to the waterways through dam construction and irrigation, and inevitable changes to the flora and fauna in freshwater habitats are likely to alter them beyond the tolerance of indigenous sharks. Some species of "river shark" are now likely to be extremely rare. These include the Ganges shark *Glyphis gangeticus* known only from the Ganges-Hooghly River system of the Indian subcontinent (Compagno 1984) and possibly more species of the genus *Glyphis* occurring in the region of Borneo, northern Australia and New Guinea (Last and Stevens 1994, Compagno, this volume b, Manjaji, this volume).

Effects of fishing on habitat

Fishing activities also affect fish habitat. The impact of commercial fishing on the marine environment has long been a matter of concern, particularly for fishers competing for fish resources (de Groot 1984). Apart from topographic changes, depending on weight of gear and softness of the sediments (Jones 1992), demersal trawls and dredges dislodge and uproot epiflora and epifauna in sponge, bryozoan, mollusc and seagrass communities (Currie and Parry 1996, Hutchings 1990, Sainsbury 1988). While, occasionally, a change might be beneficial to a species, the change is more likely to reduce the availability of suitable habitat for an indigenous species.

Fishing can have indirect impacts on shark populations. Sharks, like other fish and wildlife, can tangle in fish netting and plastic bait wrappings. White, tiger and blue sharks are known to bite at floating debris. New laws and codes of practice in various parts of the world are beginning to be implemented to discourage discarding unwanted equipment, fishing gear and plastics at sea. Lost gillnets can continue 'ghostfishing'. This is not such problem in areas of strong tidal flow, where they usually roll into a ball, but it can be a problem in areas of weak tidal flow. Loss of gillnets can be avoided; they are rarely lost by experienced fishers when equipped with modern navigational position fixing instruments and reliable equipment for retrieving gillnets.

Fishers in the industrial shark fishery off southern Australia targeting *G. galeus* believe that the presence of sharks captured in bottom-set gillnets repels free-swimming sharks from an area. Many express the view that habitat disturbance and noise from trawl fishing also have the effect of repelling sharks from an area. To maintain their catch rates the fishers tend to shift position after hauling the gear and for several weeks will avoid grounds known to have been previously fished (personal observation).

Aquaculture industries

Aquaculture industries are expanding in marine coastal waters, in response to growing demand for fish, while food production from wild fisheries declines and aquaculture production from inland waters levels out. Based on high valued species such as prawns Penaeidae, scallops Pectinidae, abalone Haliotidae, oysters Ostreidae, pearl oysters Pinctadae, salmon Salmonidae and tuna Scombridae, aquaculture depends on the collection of juvenile stages or spawning stock from the wild. Also, various species are being reared to enhance the wild fishery stocks of freshwater fish and marine scallops. Whilst aquaculture can help sustain world fisheries production, it seems unlikely that there will be large-scale aquaculture industries for sharks. There might be potential for rearing full-term embryos retained from pregnant sharks captured in wild shark fisheries, but holding sharks captive for breeding purposes is unlikely to be economically viable. Species that can remain inactive, because they are not required to swim to maintain ram-jet gill ventilation, would have the highest potential aquaculture.

Aquaculture requires pollution-free waters, but their development alters marshlands, mangroves and other inshore habitats (Landesman 1994) where nursery areas for marine species such as sharks occur. In parts of Asia and South America, prawn fanning has resulted in the mass destruction of mangroves and alteration of the hydrological characteristics of adjacent areas (Phillips *et al.* 1993, Primavera 1993). Escape of both cultured exotic species and genetically altered strains, and fouling of cages by drift algae and food wastes (Liao 1997) must also affect shark habitat. In addition, sharks die as a result of devices designed to protect underwater cages from being raided by sharks.

Marine ecotourism

Ecotourism is a growing industry based on viewing and filming sharks, particularly *C. carcharias*, from boats on the surface and from underwater cages. Development of eco-tourism based on sharks is providing an incentive for improved protection of some species (Anderson, this volume, Newman *et al.*, this volume). However,in some cases the industry depends on attracting sharks to an area by berleying with mammal or fish blood and oil; these areas are often near seal breeding colonies. This raises such questions as impact on seals and other marine life either directly by fouling an area or indirectly by concentrating sharks in an area (Bruce 1995; Presser and Allen 1995).

Exotic marine organisms

Introductions of non-indigenous organisms to an area threaten the integrity of natural communities of flora and fauna, and could impact on shark nursery and other sensitive inshore areas inhabited by sharks. Carlton and Geller (1993), noted that any mechanism for rapidly transporting water or suspended sediments containing plankton from shallow, coastal waters across natural oceanic barriers, such as ship ballast water, has the potential for invasions by entire assemblages of marine organisms. Ships have been drawing ambient water into ballast tanks and floodable holds for stability since the 1880s. This water is discharged while under way, or at ports-of-call as cargo is unloaded. Marine organisms are also transported attached to the hulls of ships and to oilrigs.

Surveys indicate that most major taxonomic groups are being transported this way. The water includes plankton that occurs during either part or all of their life cycle in the water column or the sediments; such organisms include phytoplankton, ctenophores, cnidarians, turbellarian flatworms, polychaete worms and crustaceans. The plankton also includes the larvae of molluscs and fish. These organisms occur at many different trophic levels in the food chains (i.e. phytoplankton, herbivores, carnivores and scavengers). Many inshore and coastal waters receiving ballast water have already been disturbed by the effects of urbanisation, making them particularly susceptible to invasions, further altering community structure and function. The ecological impacts of exotic species can be only partially predicted from knowledge of their biology and ecology in their original areas.

Pollution

Pollutants, can affect whole ecosystems. Some of the more notable pollutants are sewage effluent, plastics, petrochemicals, tin-based antifoulants, heavy metals and persistent organochlorine compounds. Increases in the naturally limited nutrients phosphorus, nitrogen and silicon cause eutrophication which can lead to clogging of channels and bays, or the overgrowth of coral and rocky reefs. It can also stimulate toxic algal 'blooms'.

Persistent pollutants such as heavy metals and slowly degraded organic chemicals like polychlorinated biphenyls (PCBs) can adversely affect aquatic organisms and ecosystems. Individual organisms can differentially accumulate some of these pollutants to concentrations much higher than background levels (bioaccumulation), whilst pollutants can be increased as they are passed up the food chain (bioamplification). Mercury is one pollutant known to reach particularly high levels in sharks, depending on their species, sex, size and locality (Walker 1976). Mercury accumulates in these animals from natural background sources, but the concentrations can be further elevated by human activities (Walker 1988).

More than 2,000,000t of oil enter the marine environment each year. Fifteen percent comes from natural oil seeps, the rest from discharges from tankers and other shipping along major routes, discharges from storage facilities and refineries, and accidental events such as oil spills and rupture of pipelines. Recent wars resulted in major inputs to the Persian Gulf and Arabian Sea (Anonymous 1993). Although not identified as a major problem in open waters, hydrocarbons and other toxicants in oil can contaminate the flesh of shark and other fish either through direct contact or via the food chain. Oil spills affect sharks through impacts on the vulnerable and sensitive coastal seagrass, mangrove, salt marsh, coral reef, rocky reef and polar habitats.

Ozone thinning and climate change

At the global level, ozone thinning has the potential to alter shark habitat and shark abundance through its effects on whole ecosystems. An increase in ultraviolet radiation penetrating surface waters may potentially alter the abundance and species mix of phytoplankton (Woods 1988). Any changes at this primary level will have effects further up the food chain.

According to the Intergovernmental Panel on Climate Change (Everett 1997), the composition and geographic distribution of many ecosystems will shift as individual species respond to changes in climate, with reductions in biological diversity. Some ecological systems may not reach a new equilibrium for several centuries, once the climate achieves a new balance. In the shorter-term, some coastal ecosystems are particularly at risk, including saltwater marshes, mangrove ecosystems, coastal wetlands, coral reefs, coral atolls and river deltas (Everett 1997). Long-term effects of climate change include changes in sea level, water temperatures, tidal and current patterns, coastal erosion, precipitation and storm patterns, with changes felt more in non-tropical regions. Abundance and distribution of species are affected by many factors such as climate, food supply and ability to compete with other species. In turn, all these factors affect each other in a complex web of interactions. A species that is successful in today's climate might be ousted by competitors better suited to the new combination of factors resulting from climatic change. Such effects could quickly affect migratory species where migration is timed to fit in with food supplies along the route or conditions suitable for high survival of the offspring. If events get out of phase, effects on the migrants could be catastrophic (Pain 1988).

Sharks as a group, and certain extant species (or closely related species), flourished during the warmer climates of the Mesozoic and survived the recent periodic ice ages. It therefore seems likely, depending on the magnitude, speed and patterns of climate change, most species of shark will survive. It is less likely that the species' levels of abundance and patterns of distribution will remain as they are today.

Vulnerability of shark nursery areas

In the short-term, species of shark with inshore nursery areas appear to be most likely affected by habitat change. Many of these, mostly small, areas must already be at high risk through loss or change of habitat from coastal developments, pollution, aquaculture industries and exotic organisms. Whilst threats to these areas might be recognised locally in various parts of the world, the information is not readily accessible through the literature.

One species whose nursery areas are being affected is *G. galeus* off south-eastern Australia (Stevens, this volume b). Changes in abundance of neonatal and juvenile tope sharks are evident in inshore and coastal waters of Victoria and southern Tasmania (Stevens and West 1997). In Port Phillip Bay, Victoria, intensive fishing of juvenile tope sharks from 1942 to 1944 caused the catch to increase threefold, but then fall rapidly until the early 1950s (Olsen 1954 and 1959). At the time, the western region of the Bay—the Geelong Arm—was identified as an important nursery area for this species. During 1947-51, more than 200 small sharks a day were caught by handline (A. M.

Olsen, personal communication). Since then, inshore fishers have caught only small numbers of *G. galeus* of any size from anywhere in the Bay. Recently, professional fishers working with scientists in the same area over a 3-year period, caught fewer than 10 small sharks a day. Adoption of a legal minimum length for the species and fishers giving up targeting *G. galeus* during the early 1950s, and the subsequent lack of recovery, can be partly explained by a decline in the number of breeding animals. However, given the high movement rates of adult sharks, it appears more likely that the reduced use of this formerly important nursery is a result of habitat modification in the now highly industrialised area of the Geelong Arm (Walker 1996).

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Whale Shark Tagging and Ecotourism

H.E. Newman and A.J. Medcraft
Newman Biomarine Pte Ltd, 14 Hyde Park Gate, Singapore
J.G. Colman
Marine Conservation Branch, Department of Conservation and Land Management, 47 Henry Street, Fremantle, WA6160, Australia

Whale sharks are becoming increasingly important to the growing dive tourism industry in South East Asia and Western Australia. Seasonal aggregations of whale sharks in specific areas in Asian countries have been recorded by dive operators, who actively promote diving and snorkel trips with these sharks. Whale sharks are also being harvested, apparently on an increasing scale, in the Philippines, Taiwan and Indonesia for their meat, fins, oil and cartilage. At present little is known about their population numbers, migratory habits and behaviour. This paper describes a proposal to use ecotourism operations as a basis for a South East Asia regional effort to assess whale shark populations and exploitation, in conjunction with other studies in South Africa, Mozambique, the Seychelles and Western Australia.

Introduction

The great size and gentle nature of whale sharks *Rhincodon typus*, has made them one of the most desirable fish that recreational divers wish to see. Even seasoned diver operators and instructors are awed by these animals on the usually rare occasions that they can be observed. Encounters are unpredictable, as whale sharks are generally solitary and difficult to spot from a boat, even if they are feeding on the surface. Dive operators that can offer a greater chance of seeing whale sharks have a distinct marketing advantage over other competitors. In the May 1997 Asian Dive Exhibition and Conference (ADEC), 17 dive operators or locations featured whale sharks in their marketing materials. Those operators, who have been in the area for a number of years, have built up local knowledge of where, and when, whale sharks are likely to be seen. Some, such as those operating live-aboard trips out of Phuket in Thailand, will almost guarantee their clients a whale shark sighting during the February to May season.

The commercial interest in, and general enthusiasm about, whale sharks, by dive operators and recreational divers, provides an opportunity to capitalise on their skills to undertake non-technical survey work, given the proper training and support. In this region, due to the number, and distribution, of dive operations, data can be collected relatively rapidly over a much greater geographical area than would be possible for a normal scientifically-based project to undertake, due to the limitations of funding and personnel.

The use of trained non-scientists to accurately record and report scientifically valid data has been established in a number of projects such as Coral Cay Conservation (Mumby *et al.* 1994) and Operation Wallacea (Stanzel and Newman 1997). Recreational divers are becoming more actively involved in survey work, with examples including Reefcheck, associated with the International Year of the Reef, and monitoring of crown-of-thorns starfish *Acanthaster planci* organised by the Great Barrier Marine Park Authority. A study of this type on whale sharks could contribute the essential information required to properly conserve and manage whale shark populations.

General biology and conservation status

The published literature on whale sharks is extensive, consisting mainly of sightings records, anecdotal reports, speculative reviews of distribution and movement patterns, and limited observations of general biology, feeding and behaviour. The information available on biology and ecology of the species has been reviewed by Compagno (1984), Silas (1986), Last and Stevens (1994) and Colman (1997). See also Pauly (this volume).

The international conservation status of the species is unclear – it was listed as having an "Indeterminate" status on the *1994 IUCN Red List of Threatened Animals* (Groombridge 1993). This category is given to animals known to be Endangered, Vulnerable or Rare, but for which there is not enough information available to say which of these three categories is appropriate. In the 1996 IUCN Red List, the whale shark's status was considered to be 'Data Deficient' and in the 2000 Red List it was assessed as Vulnerable (www.redlist.org). In the past, the animal has been of little interest to man, as it poses no threat nor had it been widely exploited for human consumption or for other products. Consequently, there has been virtually no sustained scientific research of this species.

Fisheries

The whale shark is considered to be at potential risk from pelagic fisheries (Casey *et al.* 1992). There are indications that even small traditional fisheries may be unsustainable. Globally, commercial fisheries for whale sharks are limited at present, but may expand due to an increased demand for food products. There may be an increasing market for whale shark meat, fins, oil and cartilage.

In South East Asia, whale sharks are specifically targeted in the Philippines and Taiwan. These fisheries have apparently been declining (Chen *et al.* this volume, Barut and Zartiga, this volume and Alava *et al.* this volume). Whale sharks also form a significant part of the bycatch of the tiger trap fishery for tuna *Thunnus* spp. in Indonesia. Eighteen whale sharks were reported captured in one location off Bitung, Sulawesi, during an 11 month period from May 96 to April 97 (R. Marinos, pers. comm.). These are also exported to Taiwan. In the Maldives, the limited fishery for liver oil has ceased in recent years, and in 1995 the Ministry of Fisheries and Agriculture introduced legislation banning all fishing for whale sharks (R.C. Anderson, pers. comm. and 1999). This protection was introduced because of the low monetary value of the fishery, the possible serious impact that the fishery may have been having on whale shark stocks, and the possible benefits to the tuna fishery and tourist industry from restricting the whale shark fishery.

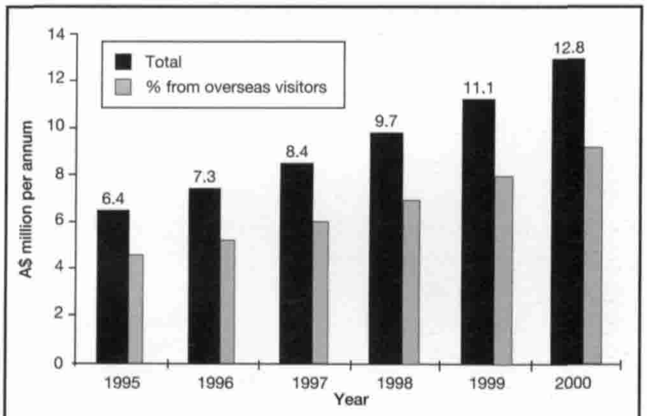
Ecotourism value of whale sharks

The whale shark based tourism industry in the Ningaloo Marine Park in Western Australia, while still relatively small, has one of the highest profiles of all of the state's ecotourism activities. The seasonal nature of the industry, relative isolation of the location and high cost of whale shark tours have all served to keep participant numbers low. Those visitors, however, are willing to pay for a high quality experience, and the benefits from the industry are spread through many parts of the local economy.

It has been estimated that mean expenditure by participants in whale shark tours was of the order of A$3.198 per person in 1995 (including travel costs within Australia) and. based on 2,000 participants, this translated to a primary injection of funds to the economy of approximately AS6.4 million (D. Davis, pers. comm.). During the 1997 season there were an estimated 2,640 whale shark tour participants, which translates to an industry 'value' of A$8.4 million. If the annual 15% rate of growth seen from 1995 to 1997 is repeated over the next three years, it is estimated that there will be approximately 4,000 participants by the year 2000. Taking the 1995 mean expenditure figure of A$3.189 per participant, the industry's value to the local and regional economy will be in the order of A$ 12.8 million by the turn of the century (Figure 1). Currently, it is estimated that expenditure on whale shark tours comprises only 16% of the total expenditure by visitors who come to Western Australia to participate in ecotourism (Figure 2). Undoubtedly, the financial benefits from this industry flow on to other regions in the state and throughout Australia. Overseas visitors made up 65% of the total number of whale shark tour participants in 1995, and 76% in 1996 (D. Davis, pers. comm.). The national and international profile of the activity is apparent from many articles about the whale sharks of Ningaloo in newspapers and magazines worldwide. The industry is actively promoting itself through national and international marketing efforts.

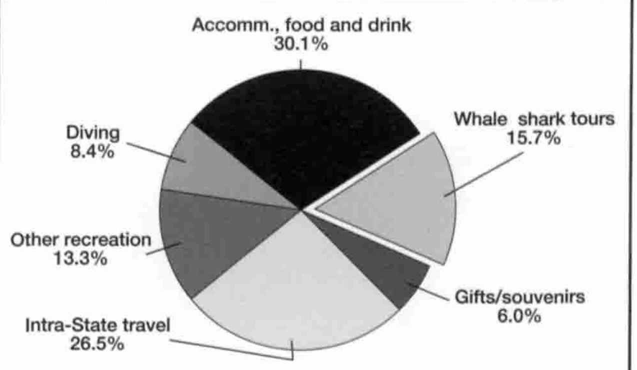
The Seychelles whale shark ecotourism pilot project took place in November 1996 with a weekly total of 162 members of the public having in-water encounters with whale sharks. This project used only one dive operator with two boats. Bearing in mind that the Seychelles already

Figure 1. Estimated value of whale shark ecotourism to the Western Australian economy, 1995-2000.



(These estimates are based on a 15% annual rate of growth, a mean expenditure per participant of A$3,189 and an overseas visitor figure of 70% – D. Davis, pers comm.)

Figure 2. Estimated breakdown of expenditure by participants in whale shark ecotourism, 1997.



(These figures are based on a 1995 mean expenditure per participant of A$3,189 – D. Davis, pers comm.)

has a well developed tourism industry which encourages eco-sensitive tourists (currently 130,000 per annum), the revenue return from these activities could be substantial. The average length of vacation stay in the Seychelles is 10 days; the costs of such a vacation including flights and accommodation plus whale shark excursions ranges from US$1,880 to $2,375 dependent on season and hotel chosen. The whale shark season can be reasonably calculated as eight weeks in July and August and six weeks in November and December, thus giving a total of 14 weeks of operation.

If the project is expanded to include another two operators, averaging seven trips per week with 10 passengers per trip, this would result in a weekly average of about 300 passengers. If each passenger is doing two trips then the overall income would be around US$282,000 to $356,250 per week of operation, giving US$3.95 to $4.99 million per annum.

There is a substantial tourism industry in Thailand based on whale sharks, with at least five live-aboard boats offering regular trips to see whale sharks in the Phuket area alone. The whale shark season runs from January to May. A dive package from Europe would cost an average of US$2,500. With 12 divers per boat per week for 20 weeks, this would give a minimum value of US$3 million for this small sector alone. Whale sharks are also an attraction on the east coast of Thailand in areas such as Koh Tao.

Figures for the area south of Bohol in the Philippines are not currently available, but there are a number of dive operators in Panglao offering whale shark trips. Other locations where divers can see whale sharks include the east coast of Peninsular Malaysia, Sabah, several parts of eastern Indonesia and Christmas Island.

The value of the whale shark tourism industry in the region will certainly grow if more information on whale shark distribution becomes available, allowing more predictable encounters. The dive industry as a whole is growing dramatically with Professional Association of Diving Instructors (PADI) Asia Pacific predicting they will certify more than 70,000 new divers in this region in future years, up from 38,500 in 1994.

Rationale for whale shark tagging and monitoring programmes

Like many other shark species, the whale shark may have K-selected biological characteristics, such as large size, slow growth, late maturation and extended longevity, that limit recruitment and mean that populations are slow to recover from any over-exploitation (Pauly, this volume).

Throughout South East Asia, whale shark populations are being exposed to increasing pressure from fisheries. Whether this increased pressure is having any detrimental impacts on whale shark numbers is not known. Currently, there is no information upon which to judge sustainability of the present level of use. A key factor in sustainable management of whale shark fisheries is a clear understanding of the population dynamics of whale sharks. Until both intra- and inter-annual variability in abundance and distribution are known, it will be impossible to identify any long-term impacts. Therefore, monitoring studies have to establish an independent, and repeatable, series of population counts. At present it is impossible to fix the spatial boundaries of whale shark populations, as there is no indication where the sharks may migrate.

Passive tagging, in conjunction with sustained aerial monitoring, will provide vital information about population size, distribution and whether the same individuals revisit specific locations on a seasonal basis. It will also yield information about migratory patterns and may indicate whether certain populations, which are becoming an important ecotourism resource in locations such as Ningaloo Reef, are potentially being affected by fisheries in other areas. If individuals undertake large-scale migrations they may potentially be at risk from fishery activities in neighbouring areas.

Existing whale shark tagging and monitoring programmes

South Africa and Mozambique

A whale shark tagging programme was started by the Shark Research Institute (SRI) in South Africa in 1993, using a passive tagging system developed by Rob Allen (pers. comm.). The whale sharks are first located using a microlight aircraft, which directs a fast boat carrying the tagging team to the shark. A snorkeller then applies the stainless steel tag to a ridge below the dorsal fin. The whale sharks generally do not react to the implanting of the tag (R. Allen, pers. comm.).

From 1993 to May 1996, 55 sharks were tagged. Three re-sightings have been reported. Since then the programme has been extended up the coast of Mozambique where greater numbers have been sighted and tagged (R. Allen, pers. comm.). In the latter project, selected dive operators are used to provide the boats and expertise to tag the sharks, with the costs underwritten by tourists, who follow the teams and are subsequently allowed to swim with the whale sharks, once they have been tagged.

Seychelles

In November 1996, a pilot study of the number of whale sharks in the area around Mahe was undertaken with the assistance of SRI (SA) and their equipment. During an eight-day period, 21 whale sharks were tagged. The tagging operations were again underwritten by tourists and the Underwater Centre, the main dive operator in the Seychelles.

The reaction of the whale sharks to being tagged varied, from none in the case of large specimens over 7m in length to that of smaller specimens 4-5m long, which occasionally gave a slight twitch and briefly increased their swimming speed. They were not apparently concerned when recreational snorkellers were subsequently allowed to swim with them. The snorkellers were given strict instructions not to touch the whale sharks, or obstruct them in any way. The behaviour of individual whale sharks varied from those that were actively feeding and ignored the presence of snorkellers (and on one occasion a video team using scuba), to those that were actively curious and swam up to the boat and investigated the snorkellers (pers. obs.).

The 1996 pilot project has been followed up with an on-going tagging programme organised by the newly formed SRI in the Seychelles. In June 1997 a microlight was purchased, and whale shark tagging commenced in July 1997, with tourist revenue paying for much of the operating costs. All data collected will be sent to SRI in the United States for collation and publication

The option to undertake satellite and other forms of active tagging is being investigated, as are methods of taking tissue samples for collaboration with researchers doing DNA analysis of whale sharks in the USA (D. Rowat, pers. comm.).

Western Australia

A preliminary aerial survey of whale sharks at Ningaloo Reef was carried out during the 1997 season by the Western Australian Department of Conservation and Land Management (CALM) - the state government agency that manages the Ningaloo Marine Park and the whale shark interaction. During the survey a total of 75 sharks were recorded, 67 in the strip transect areas and eight outside the transects. The primary objective was to obtain a series of independent and repeatable counts of whale shark numbers in order to monitor the variability in abundance and distribution of sharks throughout the season. Secondary objectives were to establish appropriate spatial and temporal scales and examine the suitability of field methods and data handling techniques for a long-term aerial survey of the whale shark population in the Ningaloo Marine Park, commencing in 1998. Some initial passive tagging has been undertaken (G. Taylor pers. comm.). CSIRO is currently trialling satellite tracking at Ningaloo.

In conjunction with the aerial monitoring programme it is hoped that a passive tagging project can be initiated at Ningaloo. It is proposed that this tagging will be carried out by the whale shark tour operators at Ningaloo, with appropriate training and support from CALM. The project would utilise the techniques of the SRI tagging system currently used in South Africa, Mozambique and the Seychelles, and would form part of the proposed South East Asia regional tagging and monitoring initiative discussed below.

Proposed tagging and monitoring programme for South East Asia

The proposed project aims to combine the academic and conservation requirements of a whale shark monitoring programme, with established dive operators who have a known interest in a sustainable whale shark tourism industry. The project would use the methods and system developed in South Africa and currently in use in South Africa, Mozambique and the Seychelles, and would work closely with these existing tagging projects and the monitoring programme in Western Australia.

It is proposed that in each Asian country, where whale shark sightings are frequent, the closest appropriate academic institute should be approached to locally oversee the tagging programme, and to monitor and report on the results. The selected local dive operator(s) would provide the equipment and personnel to be trained, to tag the whale sharks and record size and sex information. Global Positioning System (GPS) fixes would be taken to provide location information, as well as time and date of each sighting. All local dive operators would be provided with information on the project for the purpose of recording information on tagged sharks.

A training and education programme, to introduce the project at each location, would provide information and guidelines on responsible interaction with whale sharks, as well as reporting procedures.

It is anticipated that the projects would be well supported in each country by the Ministry of Tourism, Fisheries and Marine Parks Authorities, who would be able to provide assistance in arranging permits for use of the microlight aircraft and tagging operations. The publicity generated would be beneficial, both to the local diving industry, and in raising awareness of the existence and vulnerability of whale shark populations. It may even lead to local protective legislation for whale sharks, independent of any international laws, as has happened in the Maldives where they are fully protected.

It is proposed that a regional headquarters for the project be established in Singapore as a registered society. The society would initiate the projects in each country and establish the relationship between the local institute and dive operators. The society would provide the training and technical support including provision of the microlight aircraft where appropriate and possible. In conjunction with the local SRI, the society would coordinate with the relevant Government departments to ensure the project's approval. The society would also liaise with other interested parties, regarding the collection of tissues for DNA analysis and be active in the development and deployment of active tagging systems.

Progress to date

Thailand

One of the oldest and best established dive operators in Phuket has enthusiastically received the proposal. They already have an established working relationship with the Phuket Marine Laboratory and would be happy to coordinate directly with them, and other appropriately located and established dive operators in Phuket to undertake the project.

Malaysia

Initial discussions with the Head of the Marine Parks Authority and the University of Sabah are supportive. A number of dive operators have expressed interest both in Peninsular Malaysia (Pulau Kapas, where whale sharks are sighted during the 'Blachan' shrimp season), and in Sabah where whale sharks are seasonally sighted off the north coast.

Brunei

The Department of Fisheries has expressed interest as they are also interested in promoting marine tourism. Whale sharks have been sighted close inshore during the 'Blachan' shrimp season. The local dive club is very supportive, and can provide a fast boat with radio communications and experienced divers.

Philippines

Dive operators from Panglao, south of Bohol, have expressed some interest, but have reservations about the distances and costs to reach the whale shark feeding grounds.

Indonesia

Dive operators in the Manado and Bitung area of north Sulawesi are very supportive, and can provide boats and experienced divers. Positive responses are expected from operators in Ujung Pandang and the Marine Park Authority in Komodo where whale shark sightings have been regularly reported.

Western Australia

The whale shark tourism industry at Ningaloo Reef already has a working relationship with the managers of the marine park (CALM), and has been supporting whale shark research for the past three years. The Whale Shark Research Foundation (WSRF), a non-profit organisation recently established by a dive operator at Ningaloo, provides funding for research, monitoring projects, and for travel and conference costs. WSRF funding will come from membership fees and from part proceeds of the sale of a Ningaloo Reef souvenir booklet. The operators at Ningaloo can provide considerable operational expertise to dive operators throughout South East Asia, both on the establishment of an ecotourism industry centred on whale shark interactions and in the development of appropriate protocols and in-water codes of conduct for the activity.

Funding

A major commercial sponsor who would benefit from the potential publicity associated with this project is being sought. Funding from alternative sources, including governments and grants, will be considered if a major sponsor cannot be found. Sponsorship costs would cover the use of the microlight, tagging equipment, travel, training and administration costs. The ecotourism element would pay for the bulk of the costs including boats, fuel, dive master (tagger), accommodation and food for the training team, dissemination and collection of data.

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Reproductive Strategy of the Japanese Common Skate (Spiny Rasp Skate) *Okamejei kenojei*

H. Ishihara[1] *T. Mochizuki, K. Homma and T. Taniuchi*
[1]Taiyo Engineering Co. Ltd. TAF Kyobashi Building, 1-19-4 Kyobashi, Chuoh-ku, Tokyo 104-0031 Japan

The reproductive biology of *Okamejei kenojei* is described, based on the examination of 134 female specimens collected from waters off Choshi, Japan. Female skates started to mature at a size of 390mm (total length), when the shell gland formed, and the gonad index (100 x gonad weight/total weight) began to exceed 1.0. The female skate possesses egg-capsules in its oviduct throughout the year except in January, when the maximum ovum diameter exceeds 12mm. Observations of three live skates in the Oh-arai aquarium were recorded. One female skate began to lay egg-capsules soon after it was introduced to the aquarium. This skate has produced a total of 291 egg-capsules in seven years. The other two aquarium skates produced 510 egg-capsules in five years and 612 egg-capsules in four years, respectively. The offspring of these skate began to lay egg-capsules between three years and two months and three years and six months after hatching. Female individuals of the species may live at least seven years after sexual maturity without any further growth. This species of skate's reproductive strategy is characterised by rapid sexual maturity, a high rate of fecundity and, once sexual maturity has been reached, direction of energy resources towards reproduction rather than additional growth.

Introduction

The Japanese common skate (spiny rasp skate) *Okamejei kenojei* Müller and Henle is distributed from the East China Sea to the southern part of Hokkaido, Japan, at depths less than 100m. The first specimens of the skate were collected by German scientist Dr Franz von Sieboldt in the 19th century from Nagasaki, southern Japan, and taken back to Netherlands. There, the species was described by Muller and Henle in 1841, the first of 34 Japanese species of skate to be described.

In 1958, Ishiyama erected a new subgenus *Okamejei* in the genus *Raja*, distinct from the subgenus *Dipturus*. The subgenus *Okamejei* has a blunt snout and a total length of 55cm or less. He recognised *Raja jusca* (= *O. kenojei)* as the type species of the subgenus. The species of subgenus *Okamejei* also inhabit shallower waters than species of the subgenus *Dipturus*. In 1999, Compagno elevated the subgenus *Okamejei* to generic rank when he revised the checklist of the living elasmobranchs (Compagno 1999 and Appendix 1). *O. kenojei* has a variety of morphotypes, which led to some taxonomic confusion before Ishihara (1987,1990)synonymised *Rajaporosa*, *R. fusca*, *R. japonica*, *R. tobae*, *R. katsukii* and *R. atriventralis* with *R. kenojei*.

Although the reproductive biology of European and American skates has received some attention, until now that of Japanese skates has been little studied. The research presented here was based on 232 specimens of *O. kenojei* (98 males and 134 females), collected from waters off Choshi from 1988 to 1989. Additional data were provided by observing three live specimens in an aquarium, along with two female offspring of the first and second introduced females. These data form the basis for the description of the species.

Materials and methods

A total of 232 skates were collected with a beam trawl off Choshi between October 1988 and May 1989, and forwarded for examination to the laboratory of the

Figure 1. Map of the Japan showing the survey areas.

Table 1. Number of specimens of *Okamejei kenojei* examined by month.

Months	Male	Female	Total
October	7	7	14
December	8	5	13
January	35	30	65
February	10	14	24
March	10	23	33
April	18	24	42
May	10	31	41
Total	98	134	232

Museum, Tokyo University of Fisheries (Table 1 and Figure 1). The total length, body weight, gonad weight, shell gland weight and width, and the maximum diameter of the ova were measured. The presence of egg-capsules in the oviduct was also recorded.

Three live female skate were collected using a gill-net off Oh-arai Aquarium between July 1990 and April 1993. They were kept at the aquarium and began to lay egg-capsules soon after introduction. From these egg-capsules two female skates were reared in captivity; these skates began to lay egg-capsules about three years after hatching. The number and frequency of egg-laying, times when egg-laying occurred and times of hatching were recorded.

Results

Field survey

Judging from the presence of the shell gland, it is likely that females begin to mature when their total length reaches 390mm and gonad index (100 x gonad weight/total weight) exceeds 1.0 (Figures 2 and 3). Among the 134 females examined, 87 specimens possessed a shell gland. The width of the shell gland increased as the total length increased (see Figure 2). Females with egg-capsules in their oviducts had a maximum ovum diameter exceeding 12mm and a gonad index exceeding 1.8 (Figure 4). Since females possess egg-capsules in every month except January, it is suspected that egg-laying occurs throughout the year, excluding January, under natural conditions (Table 2).

Table 2. Presence of egg capsules in mature female *Okamejei kenojei*.

Months	No. of skates (Total length >450mm)	No. of skates with egg capsules	Proportion (%)
October	2	1	50.0
December	1	1	100.0
January	12	0	0.0
February	9	2	20.2
March	21	4	19.0
April	17	2	11.8
May	25	6	24.0

Figure 2. Relationship between the total length (TL) and shell gland width (SGW) in female *Okamejei kenojei*. N = 87.

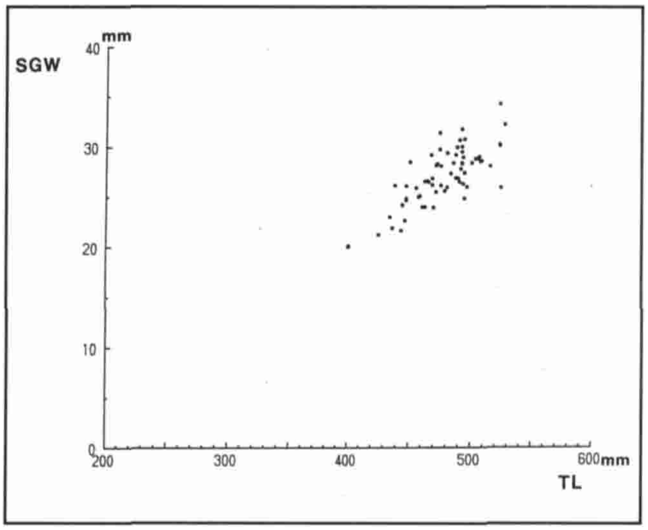


Figure 3. Relationship between the total length (TL) and Gonad Index (GI) in female *Okamejei kenojei*. N = 108.

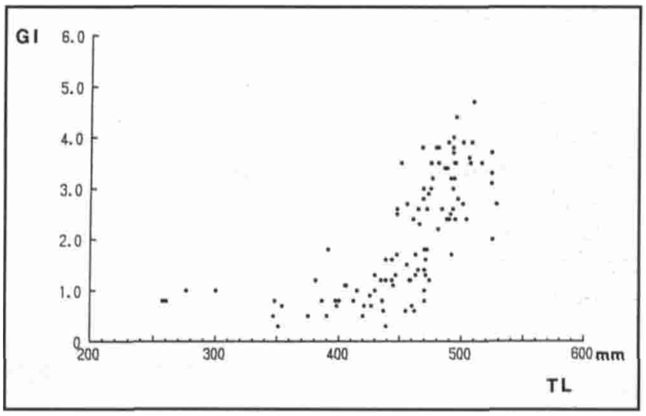
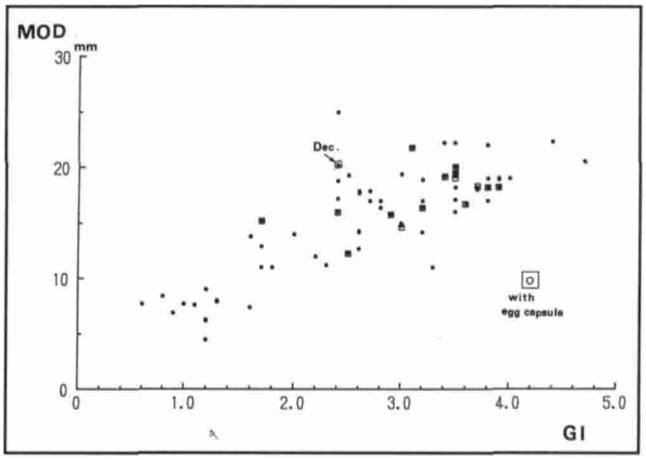


Figure 4. Relationship between Gonad Index (GI) and Maximum Ovum Diameter (MOD) in female *Okamejei kenojei*. N = 68.



Aquarium survey

Data for the egg-laying of three females and their female offspring are shown in Table 3. Female no. 1 began to lay egg-capsules soon after introduction to the aquarium in June 1990, and had produced a total of 291 egg-capsules by June 1997 (Table 3). Female no. 2 also began to lay egg-capsules soon after introduction in May 1992 and had produced a total of 400 egg-capsules by June 1997 (Table 4). Female no. 3 began to lay egg-capsules soon after introduction in April 1993 and had produced a total of 540 egg-capsules by June 1997 (Table 5).

A daughter of female no.l, hatched in October 1990, began to lay egg-capsules in April 1994, at an age of about three years and six months. A daughter of female no. 2, hatched in September 1992, began to lay egg-capsules in November 1995, at an age of about three years and two months.

Egg-capsules were produced alternately from left and right oviducts. Egg-laying occurred mainly at night, but sometimes during the day. Intervals between egg-laying were usually three to six days. The time between egg-laying and hatching was from 128 to 146 days (four to five months). The total (accumulated day-degrees) temperature was 1,954.2-2,119.9°C (average daily temperature 14.6°C). Egg-capsules were laid on sand at the bottom of the aquarium, with the capsules' horns protruding above the sand for respiration.

Table 3. Egg-laying by female no. 1 and its daughter.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Female no. 1													
1990						0	2	1	4	0	0	0	7
1991	0	0	0	0	4	8	6	0	2	0	0	0	20
1992	0	0	12	12	12	12	8	6	0	0	0	0	62
1993	0	0	0	7	5	2	0	0	0	0	0	4	18
1994	6	6	8	9	7	8	0	0	0	0	0	8	52
1995	9	9	12	10	10	12	10	6	6	0	0	0	84
1996	0	6	14	10	6	0	0	0	0	0	0	0	36
1997	0	0	1	7	4	0							12+
Daughter of female no. 1, born in October 1990													
1994				18	16	8	4	0	0	0	0	0	46
1995	0	10	12	10	8	4	4	0	4	6	14	16	88
1996	12	12	17	17	12	6	8	10	10	10	12	12	138
1997	12	12	14	12	8	8							66+

Table 4. Egg-laying by female nO. 2 and its daughter.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Female no. 2													
1992					2	8	0	0	0	0	0	0	10
1993	0	0	13	15	11	1	0	0	0	0	0	4	40
1994	0	4	10	21	18	13	2	0	0	0	0	0	68
1995	14	12	18	12	12	6	4	6	10	10	16	14	134
1996	18	12	16	20	18	14	10	12	10	10	10	12	162
1997	14	12	18	14	14	14							86+
Daughter of female no. 2, bom in September 1992													
1995	0	0	0	0	0	0	0	0	0	0	2	9	11
1996	7	6	0	0	0	0	0	0	0	0	0	0	13
1997	0	4	13	11	4	0							32+

Table 5. Egg-laying by female no. 3.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1993				4	4	0	0	0	0	0	0	0	8
1994	0	0	0	0	16	18	20	23	16	14	8	8	123
1995	14	12	16	16	16	18	19	18	17	14	10	8	178
1996	8	12	14	19	20	11	11	12	12	12	11	11	153
1997	14	14	14	14	12	10							78+

Compared with females no. 2 and no. 3, female no. 1 produced fewer egg-capsules and the number of eggs laid was more variable.

Discussion

Ishiyama (1951) was successful in determining the age of *Okamejei kenojei.* According to his results, the length range at hatching was 114-192mm, at age one it was 232-369mm and at ages two and three was 469-515mm. Judging from the field and aquarium data, *O. kenojei* begins to mature at about 400mm total length, and starts to lay egg-capsules at about three years old. Ishiyama (1951) did not suspect that the life span of the species was more than four years of age.

Female no. 3 was estimated to be about three years of age when introduced in the aquarium. This individual, therefore, has lived for more than nine years. It is recognised that fishes in captivity are able to live longer than those under natural conditions. However, the life span of the captive skates may reflect the true life span of the species in the natural environment.

So far we have not observed any individual of *O. kenojei* whose total length exceeds 55cm. It is therefore suspected that this skate stops growth after attaining a maximum length of 55cm, when it is four or five years old.

In conclusion, the reproductive strategy of the species is summarised as follows.

1. *O. kenojei* attains sexual maturity at around three years of age, a very rapid sexual maturation in comparison to other elasmobranchs.
2. *O. kenojei* produces at least 300 egg-capsules during seven years (40 per year, female no. 1) and as many as 500 (100 per year, female no. 2) and 600 (150 per year, female no. 3) egg-capsules during four years. It is therefore suggested that the fecundity of the species is high (compared with the fecundity of *Raja brachvura, R. montagui*and *R. clavata*(Holden *et al.* 1971)and of *R. naevus* (Du Buit 1976)). Fecundity is still lower than bony fishes.
3. After the species reaches a total length of 55cm, growth ceases and energy is switched to reproduction, aiding high fecundity.

Advice to fisheries

The catch of skates and rays in Japan from 1947 to 1986 is shown in Table 6 and that of all elasmobranchs in the period 1986-1995 is shown in Table 7.

Forty years ago, the catch of skates and rays reached about 18,000 metric tonnes (t) per year, decreasing to about 4,000t per year at present. This is mainly due to a decrease in the catch in the East China Sea. This catch consists of small-sized *Okamejei* species. This may be due to overfishing of these skates in the East China Sea. As discussed above, the fecundity of the species of the subgenus *Okamejei* is not low (compare also the fecundity for *Okamejei acutispina*, estimated at 88 per year (Misaki 1989)). Based on the results above, the following advice is suggested for fisheries.

Table 6. Annual catch of skates and rays in the period 1947-1986. Data from the Fukuoka Office of the Fisheries Agency, Japan (1947-1966) and the Statistics Information Center of the Fisheries Agency, Japan (1963-1987).

Year	Total	East China Sea	Sea of Japan	Hokkaido	Other regions
1947	1,683	1,683	-	-	-
1948	1,731	1,731	-	-	-
1949	1,136	1,136	-	-	-
1950	701	701	-	-	-
1951	_	2,381	-	-	-
1952	-	10,519	-	-	-
1953	17,168	11,254	-	-	-
1954	18,469	12,814	-	_	-
1955	18,782	12,855	_	-	_
1956	18,070	11,618	_	-	-
1957	17,676	10,609	-	-	-
1958	16,783	10,404	-	-	-
1959	15,490	8,703	-	-	-
1960	14,202	8,772	-	-	-
1961	13,048	8,087	-	-	-
1962	12,403	7,291	-	-	-
1963	13,707	7,981	3,277	2,938	-
1964	12,148	7,287	2,900	2,100	_
1965	10,323	5,704	2,731	2,114	-
1966	10,732	5,682	2,707	2,588	
1967	10,589	5,258	2,970	2,857	_
1968	–	4,974	-	-	-
1969	8,456	4,522	2,580	1,978	-
1970	10,161	5,948	2,518	2,495	-
1971	7,681	5,049	1,286	1,553	_
1972	6,963	4,827	1,342	1,129	_
1973	7,539	5,213	1,410	1,381	-
1974	6,425	4,406	929	1,029	60
1975	7,684	4,311	1,161	2,095	117
1976	7,819	4,154	1,140	2,336	189
1977	9,409	4,379	1,148	3,789	93
1978	8,264	4,893	875	2,096	400
1979	7,496	4,995	781	3,135	-
1980	11,884	5,338	696	5,181	669
1981	9,400	4,856	670	3,135	745
1982	9,990	4,717	514	3,798	961
1983	8,083	3,859	513	2,640	1,071
1984	9,065	4,166	335	3,268	1,296
1985	6,577	3,207	349	1,729	1,292
1986	6,610	3,010	407	2,053	1,140

Notes: - = Data unavailable; Since the data was obtained from different offices, here is an apparent contradiction between total catch and catch from each region in this table. After World War II, fisheries data was collected again but from 1947 to 1950 catches of skates and rays were only recorded from the East China Sea. Data for skates and rays in other regions was collected from 1951, although total catch was not recorded in 1951 and 1952. From 1953 to 1962 catch of skates and rays in the Sea of Japan Hokkaido and other regions was unavailable.

Table 7. Annual catch of all elasmobranchs in the period 1986-1995.

Year	Sharks	Rays	Total
1986	35,139	6,610	41,749
1987	33,809	6,799	40,608
1988	32,128	6,637	38,765
1989	24,659	5,350	30,009
1990	21,979	5,492	27,471
1991	25,167	4,778	29,945
1992	27,589	4,585	32,174
1993	25,673	4,247	29,920
1994	23,537	4,040	27,577
1995	18,286	3,985	22,271

1. Female skates should not be caught before sexual maturity (i.e. at less than 45cm length in the case of *O. kenojei).*
2. Catch of adult females should be regulated
3. Sandy sea-bed spawning and nursery grounds should be protected.

Future research

Skates should be maintained in aquarium conditions in order to ascertain the full life span. The use of the shell gland to store sperm should be investigated, and the length of time over which sperm can be kept alive should be examined

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The Role of Protected Areas in Elasmobranch Fisheries Management and Conservation

John Stevens
CSIRO, Division of Marine Research, G.P.O. Box 1538, Hobart, Tasmania 7001, Australia

Elasmobranchs characteristically show sex and size segregation and as most are active, mobile animals which often have extensive distributions, closed areas will seldom protect all parts of a population. However, closed areas can be used to protect particular segments of the population which are particularly vulnerable, for example closure of inshore pupping and nursery areas as part of fishery management plans, and seasonal closures of shallow mating areas to boat traffic as part of conservation plans. Closure of areas, or protection of species within certain areas, have been used in various ecotourist ventures based on elasmobranchs. Fishery management measures have also used large-scale closures of inshore areas to provide a general refuge for stocks of commercial species and rolling closures have been used to protect pregnant females moving along migratory routes to pupping grounds.

Introduction

While Marine Parks have come into prominence in the last 10 years, the concept of marine protected areas has been around for ages. For the purposes of this paper marine protected areas include marine parks, reserves, sanctuaries, fishery area closures or whatever term is used to afford some kind of protection to a component of the biota within a given area. Marine reserves are best suited to protecting species with restricted geographical movements, such as coral or temperate reef systems where the eggs and larvae produced can be spread by ocean currents to enhance both exploited and protected areas. The main purpose of these reserves is usually to ensure the continued existence of fisheries by protecting a portion of the spawning stock, as well as protecting the reef itself. Protected areas may vary in size from isolated reefs to whole ecosystems such as the Florida Keys or Great Barrier Reef. Protected areas span the range from small highly protected reserves to large multiple-use areas and from single species protection to whole ecosystems.

Discussion

Closed areas (areas without interchange) may be able to protect a proportion of the breeding stock for benthic, site-attached elasmobranchs; this would be particularly important for rare endemic species. Closed areas could potentially be used to protect freshwater elasmobranchs which, because of their restricted habitat, are very susceptible to overfishing (see Compagno, this volume b). During the dry season when water levels are low, species such as sawfish *Pristis* spp. may become isolated in restricted water holes where they are very vulnerable to capture. Seasonal closures could be used at such times.

Protected areas are less useful for highly migratory species. Since elasmobranchs are mostly active, mobile animals which often have extensive distributions over which there is often sex and size segregation of the population, closed areas will seldom protect all parts of the population. However, closed areas still have a useful role to play in the management and conservation of elasmobranchs and there are a number of examples, although the scientific literature contains almost nothing on this topic.

Closed areas have been used to protect particular segments of elasmobranch populations which are especially vulnerable to fishing or human disturbance; probably the oldest example relates to tope shark (school shark) *Galeorhinus galeus* in Australia (see also Walker, this volume). This is an important commercial species in southern Australia, which has been fished since the 1920s. Research in the 1940s and 1950s (Olsen 1954) showed that tope sharks pupped during December and January in inshore bays and estuarine areas of Tasmania and Victoria. In 1954, the Tasmanian government introduced measures prohibiting the taking of tope sharks in a number of inshore Tasmanian nursery areas. Currently, gillnetting is totally banned in some of these areas while in others both recreational and commercial netting is allowed but the taking of tope sharks and gummy sharks *Mustelus antarcticus* is prohibited. In Victoria, coastal waters out to three miles are almost entirely closed to commercial shark fishing. Pupping of many other shark species occurs in coastal embayments; these are often close to centres of human settlement and are consequently subjected to high recreational and commercial fishing pressure. Protection of juveniles can be an important tool in the management of shark fisheries. Because of the close stock-recruitment relationship in sharks, reduced fishing mortality on new-born and juvenile sharks will translate more directly into increases in adult stock size than in scale-fish fisheries.

Shark fishers are able to target pregnant school sharks as they move towards the shallow pupping areas; the known movement routes and narrow entrances of some of these embayments make the sharks particularly vulnerable at this time. As early as 1953, a one month closure of State waters was introduced in South Australia to protect pregnant females. More recently, time-area closures were tried; areas were closed and re-opened sequentially along the migratory route of the pregnant females as they travelled from South Australia to Victoria and Tasmania. The Western Australian shark fishery uses closure controls in the form of time/gear units; one unit allows a fisher to use one net for one month. Closures can be used to zone different fisheries by gear type. The Southern Shark Fishery in Australia, which uses gillnets and longlines, overlaps in fishing area with trawlers. Shark fishers believe that trawling destroys the bottom habitat which is important for the sharks and want areas closed from trawling to provide a refuge for shark stocks.

A group mating area for nurse sharks *Ginglymostoma cirratum* has recently been protected from human disturbance in the Dry Tortuga Island group in the Florida Keys (Carrier *et al.* 1994). These sharks mate in shallow waters within the Florida Keys National Marine Sanctuary (designated in 1990), which is one of the most heavily used coral reef areas in the world. Because of the risk of disturbance to the mating sharks a seasonal closure to boat traffic was implemented recently. Some form of time-area closures would provide a useful management tool for any events which may aggregate elasmobranch populations at particular times, whether they be related to reproduction or feeding.

Area closures or protection of species within certain areas both have, and could, be used in various ecotourist ventures based on elasmobranchs. An industry based on snorkelling with whale sharks *Rhincodon typus* has developed over the last five years at Ningaloo Reef, Western Australia (Thomson and Stevens 1995). Whale sharks within the Ningaloo Marine Park are fully protected by the Wildlife Conservation Act and a set of guidelines are in place which are designed to keep interaction between people and the sharks to an acceptable level (Newman *et al.* this volume). Great white sharks *Carcharodon carcharias* are another popular ecotourist species and one where management of the resource could benefit from differently zoned areas to take account of the various 'user groups' or groups impacted by these sharks. Cage-diving ecotourist operators, gamefishers, abalone divers, swimmers and surfers have an interest in great white sharks for different reasons. Managers may be faced with having to accommodate the interests of all these parties and zoning areas may be one way of addressing this problem. Gamefishing areas could be separated from cage-viewing areas while chumming could be banned from areas used by abalone divers, swimmers and surfers. In Victoria, the immediate area around a number of seal colonies is closed to chumming, which gives some added protection to great white sharks which frequent these areas.

Following decimation of sand tiger shark (gray nurse shark) *Carcharias taurus* populations in New South Wales, Australia, in the post-"JAWS" era, this species was protected in that State in 1984. However, there are still concerns over the population levels of this shark, which is a popular attraction for SCUBA divers (Pollard *et al.* 1996). Dive guides know the locations where social groups of often the same individual sand tiger sharks can be seen regularly, suggesting a degree of site-attachment by this species. Pollard *et al.* (1996) suggest the use of spatial or seasonal closures as a means of further management of this shark. In a number of Pacific Island countries, shark and ray feeding is a popular tourist attraction in shallow lagoonal areas. While these areas are not covered by any legislative closures there is presumably agreement with the local fishers not to operate in these places.

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Kinabatangan River Conservation Area

Junaidi Payne
WWF Malaysia, W.D.T. 40, 89400 Likas, Sabah, Malaysia
Patrick Andau
Wildlife Department, Tingkat 5, Blok B, Wisma MUIS, Sembulan, Kota Kinabalu, Sabah, Malaysia

Historical background

The Kinabatangan is Sabah's largest river, with a total catchment of about 23% of the State's land area. (Refer to Manjaji, this volume for a map.) Excluding brackish water swamps, the lower reaches include about 65,000 hectares of flood-prone freshwater swamp forest land. Until the 1950s, the majority of the catchment was covered in natural forest, only lightly utilised by a sparse human population. Commercial extraction of timber for export commenced in the 1950s. In the 1970s, based on a Statewide Land Capability Classification, most of the lower Kinabatangan catchment, including extensive freshwater wetland areas, was made available for conversion to permanent agriculture.

Establishment of conservation areas

Studies conducted during the 1980s showed that the lower Kinabatangan supported large populations of several rare vertebrate species, including orang-utan *Pongo pygmaeus*, proboscis monkey *Nasalis lavatus*, waterbirds such as oriental darters *Anhinga rufa*, and estuarine crocodiles *Crocodilus porosus*. Although commitments for agricultural development had been made, the Government of Sabah recognised the importance of lower Kinabatangan for conservation of natural heritage and agreement in principle was given for the establishment of a conservation area. A 1989 feasibility study predicted good prospects for tourism development in the lower Kinabatangan and supported the need for the establishment of a wildlife sanctuary. Criteria for selection of the sanctuary boundary included continuity of natural habitats along the main river, and inclusion of seasonal and oxbow lakes and forest surrounding the lakes. Fortunately, seven small Forest Reserves (totalling about 11,660ha.) had already been established in the lower Kinabatangan and a government-owned rattan plantation in natural forest (about 8,200ha.) had been established in the early 1980s. The Kinabatangan wildlife sanctuary (about 27,000ha.) essentially joins these forest areas into a larger conservation area, which incorporates a variety of natural habitats including freshwater swamp forests, dry land forests, limestone outcrops, streams, oxbow lakes and seasonal open wetlands. Since 1989, the majority of the land outside these areas has been converted to oil palm plantations.

Elasmobranchs

During the process of establishment of the conservation areas, the importance of the lower Kinabatangan in sustaining populations of freshwater elasmobranchs was not yet known and, in fact, had not even been considered. In January 1996, field work to seek elasmobranchs in the Kinabatangan River started under the "Elasmobranch Biodiversity, Conservation and Management Project" funded by the UK Government's "Darwin Initiative for the Survival of Species", and was carried out jointly by the IUCN Species Survival Commission's Shark Specialist Group and the Department of Fisheries, Sabah (Fowler, this volume). As a result, it is now confirmed that this river does support several elasmobranch species, including a species of river shark *Glyphis* sp., the giant freshwater stingray *Himantura chaophraya* and greattooth sawfish *Pristis microdon* (Manjaji, this volume).

Issues and challenges

The existence of the protected forest areas now provides a key foundation for conservation of the freshwater elasmobranchs. A number of issues and challenges relevant to elasmobranch conservation now merit attention. It is suggested that the following four areas may be of special importance.

1. Consideration of the development of a multisectoral, regional or District level environmental management plan.
2. Further study and management of fishing activities both within and outside the sanctuary.
3. Promotion of practices which result in minimal adverse environmental impacts for land uses outside the conservation areas but within the Kinabatangan catchment.
4. Encouraging cooperation and instilling a sense of pride in supporting nature conservation among the various stakeholders in the lower Kinabatangan.

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Appendix 1

Checklist of Living Chondrichthyes Cited in This Volume

Based on the World Checklist of Living Chondrichthyes (Compagno and Didier, in press)

* = Species found outside the Indo-Pacific region.
Notes: Numbers refer to papers in this volume where species are listed or mentioned.

1. An Overview of Sharks in World and Regional Trade. Page 25.
2. Elasmobranchs as a Recreational Resource. Page 46.
3. Review of the Biodiversity of Sharks and Chimaeras in the South China Sea and Adjacent Areas. Page 52.
4. Review of the Biodiversity of Rays in the South China Sea and Adjacent Areas. Page 64.
5. New Records of Elasmobranch Species from Sabah. Page 70.
6. Taiwan's Shark Fishery - An Overview. Page 95.
7. Elasmobranch Diversity and Status in Thailand. Page 104.
8. Elasmobranch Fisheries in the Maldives. Page 114.
9. Shark Fisheries in the Philippines. Page 127.
10. The Status of Shark Fisheries in Zanzibar. Page 158.
11. Freshwater and Estuarine Elasmobranch Surveys in the Indo-Pacific Region: Threats, Distribution and Speciation. Page 168.
12. Outline of Field Surveys for Freshwater Elasmobranchs Conducted by a Japanese Research Team. Page 181.
13. Freshwater and Estuarine Elasmobranchs of Australia. Page 185.
14. Elasmobranchs Recorded from Rivers and Estuaries in Sabah. Page 194.

COW AND FRILLED SHARKS		
CHLAMYDOSELACHIDAE - FRILLED SHARKS		
Chlamydoselachus anguineus Garman, 1884	Frilled shark	3,8
HEXANCHIDAE - SIXGILL AND SEVENGILL SHARKS		
Heptranchias perlo (Bonnaterre, 1788)	Sharpnose sevengill shark	3,7,8
Hexanchus griseus (Bonnaterre, 1788)	Bluntnose sixgill shark	1,3,7,8.13
Hexanchus nakamurai Teng, 1962	Bigeye sixgill shark	3
Notorynchus cepedianus (Peron, 1807)	Broadnose sevengill shark	1,3,11,13
DOGFISH SHARKS		
ECHINORHINIDAE - BRAMBLE SHARKS		
Echinorhinus brucus (Bonnaterre, 1788)	Bramble shark	1,8
Echinorhinus cookei Pietschmann, 1928	Prickly shark	3
SQUALIDAE - DOGFISH SHARKS		
Cirrhigaleus barbifer Tanaka, 1912	Mandarin dogfish	1,3
Squalus acanthias Linnaeus, 1758	Piked dogfish	1,9,13
Squalus blainvillei? (Risso, 1826)	Longnose spurdog	3,7
Squalus brevirostris? Tanaka, 1912	Japanese shortnose spurdog	3
Squalus cubensis Howell-Rivero, 1936	Cuban dogfish	1
Squalus japonicus Ishikawa, 1908	Japanese spurdog	3
Squalus megalops (Macleay, 1881)	Shortnose spurdog	1,3,7,13
Squalus mitsukurii Jordan & Snyder, *in* Jordan & Fowler, 1903	Shortspine spurdog	1,3,7
CENTROPHORIDAE - GULPER SHARKS		
Centrophorus acus Garman, 1906	Needle dogfish	1,3
Centrophorus atromarginatus Garman, 1913	Dwarf gulper shark	3
Centrophorus granulosus (Bloch & Schneider, 1801)	Gulper shark	1,3
Centrophorus isodon (Chu, Meng, & Liu, 1981)	Blackfin gulper shark	3
Centrophorus lusitanicus Bocage & Capello, 1864	Lowfin gulper shark	1,3
Centrophorus moluccensis Bleeker, 1860	Smallfin gulper shark	3,5,10
Centrophorus niaukang Teng, 1959	Taiwan gulper shark	1,3,8
Centrophorus squamosus (Bonnaterre, 1788)	Leafscale gulper shark	1.3,8
Centrophorus tessellatus Garman, 1906	Mosaic gulper shark	8

Deania calcea (Lowe, 1839)	Birdbeak dogfish	1
Deania profundorum (Smith & Radcliffe, 1912)	Arrowhead dogfish	3
ETMOPTERIDAE - LANTERN SHARKS *Etmopterus brachyurus* Smith & Radcliffe, 1912	Shorttail lanternshark	3
Etmopterus decacuspidatus Chan, 1966	Combtooth lanternshark	3
Etmopterus granulosus (Gunther, 1880)	Southern lanternshark	3
Etmopterus lucifer Jordan & Snyder, 1902	Blackbelly lanternshark	3
Etmopterus molleri (Whitley, 1939)	Slendertail lanternshark	3
Etmopterus pusillus (Lowe, 1839)	Smooth lanternshark	3
Etmopterus spinax (Linnaeus, 1758)	Velvet belly	7
Etmopterus splendidus Yano, 1988	Splendid lanternshark	3
SOMNIOSIDAE - SLEEPER SHARKS *Centroscymnus coelolepis* Bocage & Capello, 1864	Portugese dogfish	3
Centroscymnus owstoni Garman, 1906	Roughskin dogfish	1
Centroselachus crepidater (Bocage & Capello, 1864)	Longnose velvet dogfish	1
Proscymnodon plunketi (Waite, 1909)	Plunket shark	1
Zameus squamulosus (Gunther, 1877)	Velvet dogfish	3,7
DALATIIDAE - KITEFIN SHARKS *Dalatias licha* (Bonnaterre, 1788)	Kitefin shark	1,3,8,10
Isistius brasiliensis (Quoy & Gaimard, 1824)	Cookiecutter or cigar shark	3,8
Isistius labialis? Meng, Chu, & Li, 1985	South China cookiecutter shark	3
Squaliolus aliae Teng, 1959	Smalleye pigmy shark	3
Squaliolus laticaudus Smith & Radcliffe, 1912	Spined pygmy shark	3
SAWSHARKS PRISTIOPHORIDAE - SAWSHARKS *Pristiophorus cirratus* (Latham, 1794)	Longnose sawshark	1,13
Pristiophorus japonicus Gunther, 1870	Japanese sawshark	3
Pristiophorus nudipinnis Gunther, 1870	Shortnose sawshark	1,13
Pristiophorus sp. [Compagno]	Philippine sawshark	3
ANGEL SHARKS SQUATINIDAE - ANGEL SHARKS *Squatina aculeata* Dumeril, *in* Cuvier, 1817	Sawback angelshark	1
Squatina africana Regan, 1908	African angelshark	10
Squatina australis Regan, 1906	Australian angelshark	13
Squatina formosa Shen & Ting, 1972	Taiwan angelshark	3
Squatina japonica Bleeker, 1858	Japanese angelshark	3
Squatina nebulosa Regan, 1906	Clouded angelshark	3,7
Squatina oculata Bonaparte, 1840	Smoothback angelshark	1
Squatina tergocellatoides Chen, 1963	Ocellated angelshark	3
BULLHEAD SHARKS HETERODONTIDAE - BULLHEAD SHARKS *Heterodontus japonicus* (Maclay & Macleay, 1884)	Japanese bullhead shark	3,11
Heterodontus portusjacksoni (Meyer, 1793)	Port Jackson shark	13
Heterodontus zebra (Gray, 1831)	Zebra bullhead shark	3,5,7,11
Heterodontus sp. [Mee]	Oman bullhead shark	11
CARPET SHARKS PARASCYLLIIDAE - COLLARED CARPETSHARKS *Cirrhoscyllium expolitum* Smith & Radcliffe, 1913	Barbelthroat carpetshark	3,7
Cirrhoscyllium formosanum Teng, 1959	Taiwan saddled carpetshark	3
Parascyllium ferrugineum McCulloch, 1911	Rusty carpetshark	13
Parascyllium variolatum (Dumeril, 1853)	Necklace carpetshark	13

BRACHAELURIDAE - BLIND SHARKS *Brachaelurus waddi* (Bloch & Schneider, 1801)	Blind shark	13
Heteroscyllium colcloughi (Ogilby, 1908)	Bluegray carpetshark	11,13
ORECTOLOBIDAE - WOBBEGONGS *Eucrossorhinus dasypogon* (Bleeker, 1867)	Tasselled wobbegong	1,11,13
Orectolobus japonicus Regan, 1906	Japanese wobbegong	3,11
Orectolobus maculatus (Bonnaterre, 1788)	Spotted wobbegong	1,3,7,11,13
Orectolobus ornatus (de Vis, 1883)	Ornate wobbegong	1,11,13
Orectolobus wardi Whitley, 1939	Northern wobbegong	11,13
Orectolobus sp. A [Last & Stevens, 1994]	Western wobbegong	11
Sutorectus tentaculatus (Peters, 1864)	Cobbler wobbegong	11,13
HEMISCYLLIIDAE - LONGTAILED CARPETSHARKS *Chiloscyllium arablcum* Gubanov, *in* Gubanov & Schleib, 1980	Arabian carpetshark	11
Chiloscyllium burmensis Dingerkus & DeFino, 1983	Burmese bambooshark	11
Chiloscyllium griseum Müller & Henle, 1838	Gray bambooshark	3,7,11
Chiloscyllium hasselti Bleeker, 1852	Indonesian bambooshark	3,5,11
Chiloscyllium indicum (Gmelin, 1789)	Slender bambooshark	3,7,9,11,12
Chiloscyllium plagiosum (Bennett, 1830)	Whitespotted bambooshark	3,5,7,11
Chiloscyllium punctatum Müller & Henle, 1838	Brownbanded bambooshark	3,5,7,11,13
Hemiscyllium freycineti (Quoy & Gaimard, 1824)	Indonesian speckled carpetshark	11
Hemiscyllium hallstromi Whitley, 1967	Papuan epaulette shark	11
Hemiscyllium ocellatum (Bonnaterre, 1788)	Epaulette shark	11,13
Hemiscyllium strahani Whitley, 1967	Hooded carpetshark	11
Hemiscyllium trispeculare Richardson, 1843	Speckeled carpetshark	11,13
GINGLYMOSTOMATIDAE - NURSE SHARKS *Ginglymostoma cirratum* (Bonnaterre, 1788)	Nurse shark	1
Nebrius ferrugineus (Lesson, 1830)	Tawny nurse shark	1,2,3,7,8,9,11,13
Pseudoginglymostoma brevicaudatum (Gunther, *in* Playfair & Günther, 1866)	Shorttail nurse shark	10,11
STEGOSTOMATIDAE - ZEBRA SHARKS *Stegostoma fasciatum* (Hermann, 1783)	Zebra shark	2,3,5.7,8,10,11,13
RHINCODONTIDAE - WHALE SHARKS *Rhincodon typus* Smith, 1828	Whale shark	1,2,3,5,7,8,9,11
MACKEREL SHARKS ODONTASPIDIDAE - SAND TIGER SHARKS *Carcharias taurus* Rafinesque, 1810	Sand tiger, spotted raggedtooth, or gray nurse shark	1,2,3,7,11,13
Odontaspis ferox (Risso, 1810)	Smalltooth sand tiger or bumpytail raggedtooth	1,8
PSEUDOCARCHARIIDAE - CROCODILE SHARKS *Pseudocarcharias kamoharai* (Matsubara, 1936)	Crocodile shark	3,8
MITSUKURINIDAE - GOBLIN SHARKS *Mitsukurina owstoni* Jordan, 1898	Goblin shark	3
ALOPIIDAE - THRESHER SHARKS *Alopias pelagicus* Nakamura, 1935	Pelagic thresher	1,3,6,7,8,11
Alopias superciliosus (Lowe, 1839)	Bigeye thresher	1,3,6,7,8,9,11
Alopias vulpinus (Bonnaterre, 1788)	Thresher shark	1,3,7,8,9,10,11,13
CETORHINIDAE - BASKING SHARKS *Cetorhinus maximus* (Gunnerus, 1765)	Basking shark	1,3,11
LAMNIDAE - MACKEREL SHARKS		
Carcharodon carcharias (Linnaeus, 1758)	Great white shark	1,2,3,9,11,13
Isurus oxyrinchus Rafinesque, 1810	Shortfin mako	1,3,6,7,8,9,10,11,13

Isurus paucus Guitart Manday, 1966	Longfin mako	1,3,7
Lamna ditropis Hubbs & Follett, 1947	Salmon shark	1
Lamna nasus (Bonnaterre, 1788)	Porbeagle shark	1
GROUND SHARKS SCYLIORHINIDAE - CATSHARKS *Apristurus acanutus* Chu, Meng, & Li, *in* Meng, Chu & Li, 1985	Flatnose catshark	3
Apristurus gibbosus Meng, Chu & Li, 1985	Humpback catshark	3
Apristurus herklotsi (Fowler, 1934)	Longfin catshark	3
Apristurus investigatoris (Misra, 1962)	Broadnose catshark	7
Apristurus macrorhynchus (Tanaka, 1909)	Flathead catshark	3
Apristurus macrostomus Meng, Chu, & Li, 1985	Broadmouth catshark	3
Apristurus micropterygeus Meng, Chu & Li, *in* Chu, Meng, & Li, 1986	Smalldorsal catshark	3
Apristurus sibogae (Weber. 1913)	Pale catshark	5
Apristurus sinensis Chu & Hu, *in* Chu, Meng, Hu, & Li, 1981	South China catshark	3
Apristurus verweyi (Fowler, 1934)	Borneo catshark	5
Asymbolus analis (Ogilby, 1885)	Grey spotted catshark	13
Asymbolus vincenti (Zietz, 1908)	Gulf catshark	13
Atelomycterus macleayi Whitley, 1939	Australian marbled catshark	11
Atelomycterus marmoratus (Bennett, 1830)	Coral catshark	3,5,7,9,11
Aulohalaelurus kanakorum Seret, 1990	New Caledonia catshark	11
Bythaelurus hispidus (Alcock, 1891)	Bristly catshark	7
Bythaelurus immaculatus (Chu & Meng, *in* Chu, Meng, Hu, & Li, 1982)	Spotless catshark	3
Cephaloscyllium fasciatum Chan, 1966	Reticulated swellshark	3,7
Cephaloscyllium laticeps (Dumeril, 1853)	Australian swellshark	13
Cephaloscyllium sufflans (Regan, 1921)	Balloon shark	11
Cephaloscyllium umbratile Jordan & Fowler, 1903	Japanese swellshark	3,11
Cephaloscyllium sp. [Randall]	New Guinea swellshark	11
Cephaloscyllium sp. [Compagno, 1988]	Dwarf oriental swellshark	11
Cephaloscyllium sp. [Stevens]	Philippines swell shark	3
Galeus eastmani (Jordan & Snyder, 1904)	Gecko catshark	3
Galeus sauteri (Jordan & Richardson, 1909)	Blacktip sawtail catshark	3
Galeus schultzi Springer, 1979	Dwarf sawtail catshark	3
Halaelurus boesemani Springer & D'Aubrey, 1972	Speckled catshark	3
Halaelurus buergeri (Müller & Henle, 1838)	Darkspot, blackspotted, or Nagasaki catshark	3,7,11
Halaelurus lineatus Bass, D'Aubrey & Kistnasamy, 1975	Lined catshark	11
Halaelurus natalensis (Regan, 1904)	Tiger catshark	11
Haploblepharus sp. [Compagno]	Natal shyshark	11
Parmaturus melanobranchius (Chan, 1966)	Blackgill catshark	3
Pentanchus profundicolus Smith & Radcliffe, 1912	Onefin catshark	3
Scyliorhinus canicula (Linnaeus, 1758)	Smallspotted catshark	1
Scyliorhinus garmani (Fowler, 1934)	Brownspotted catshark	3
Scyliorhinus torazame (Tanaka, 1908)	Cloudy catshark	3
PROSCYLLIIDAE - FINBACK CATSHARKS *Eridacnis radcliffei* Smith, 1913	Pygmy ribbontail catshark	3
Proscyllium habereri Hilgendorf, 1904	Graceful catshark	3

PSEUDOTRIAKIDAE - FALSE CATSHARKS		
Pseudotriakis microdon Capello, 1868	False catshark	3,8
TRIAKIDAE - HOUNDSHARKS		
Furgaleus macki (Whitley, 1943)	Whiskery shark	13
Galeorhinus galeus (Linnaeus, 1758)	Tope shark	1,13
Hemitriakis japanica (Muller & Henle, 1839)	Japanese topeshark	3,11
Hemitriakis leucopehptera Herre, 1923	Whitefin topeshark	3,7,11
Hemitriakis sp. [Compagno, 1988]	Ocellate topeshark	3,11
Hypogaleus hyugaensis (Miyosi, 1939)	Blacktip topeshark	3,7,10
lago omanensis (Norman, 1939)	Bigeye houndshark	7
lago sp. [Compagno]	Lowfin houndshark	3
Mustelus antarcticus Gunther, 1870	Gummy shark	1,13
Mustelus griseus Pitschmann, 1908	Spotless smoothhound	3,7,11
Mustelus lenticulatus Phillipps, 1932	Spotted estuary smoothhound or rig	1
Mustelus manazo Bleeker, 1854	Starspotted smoothhound	1,3,7,8.11
Mustelus mosis Hemprich & Ehrenberg, 1899	Arabian, hardnose, or Moses smoothhound	7
Triakis scyllium Muller & Henle, 1839	Banded houndshark	3,11
HEMIGALEIDAE - WEASEL SHARKS		
Chaenogaleus macrostoma (Bleeker, 1852)	Hooktooth shark	3,5,7,11
Hemigaleus microstoma Bleeker, 1852	Sicklefin weasel shark	3,5,7,11
Hemigaleus sp.	Australian weasel shark	11
Hemipristis elongatus (Klunzinger, 1871)	Snaggletooth shark	1,3,5,7,8,10,11
Paragaleus leucolomatus Compagno & Smale, 1985	Whitetip weasel shark	11
Paragaleus randalli Compagno, Krupp & Carpenter, 1996	Slender weasel shark	11
Paragaleus tengi (Chen, 1963)	Straighttooth weasel shark	3,7,11
CARCHARHINIDAE - REQUIEM SHARKS		
Carcharhinus albimarginatus (Ruppell, 1837)	Silvertip shark	1,2,3,7,8,10,11
Carcharhinus altimus (Springer, 1950)	Bignose shark	1,3,8
Carcharhinus amblyrhynchoides (Whitley, 1934)	Graceful shark	3,5,7,11.13
Carcharhinus amblyrhynchos (Bleeker, 1856)	Gray reef shark	2,3,5,7,8,9.10,11,13
Carcharhinus amboinensis (Muller & Henle, 1839)	Pigeye or Java shark	3.7.11,13
Carcharhinus borneensis (Bleeker, 1859)	Borneo shark	3,5,7,11
Carcharhinus brachyurus (Gunther, 1870)	Bronze whaler	1,3,7,11,13
Carcharhinus brevipinna (Müller & Henle, 1839)	Spinner shark	1,3,5,6,7,11,13
Carcharhinus cautus (Whitley, 1945)	Nervous shark	11,13
Carcharhinus dussumieri (Valenciennes, *in* Muller & Henle, 1839)	Whitecheek shark	3,5,7,11,13
Carcharhinus falciformis (Bibron, *in* Muller & Henle, 1839)	Silky shark	1,3,5,6,7,8,10
Carcharhinus fitzroyensis (Whitley, 1943)	Creek whaler	11,13
Carcharhinus galapagensis (Snodgrass & Heller, 1905)	Galapagos shark	7
Carcharhinus hemiodon (Valenciennes, *in* Müller & Henle, 1839)	Pondicherry shark	3,7,11
Carcharhinus leiodon Garrick, 1985	Smoothtooth blacktip	11
Carcharhinus leucas (Valenciennes, *in* Muller & Henle, 1839)	Bull shark	1,3,5,7,11,12,13,14
Carcharhinus limbatus (Valenciennes, *in* Muller & Henle, 1839)	Blacktip shark	1,3,5,7,8,9,11,13
Carcharhinus longimanus (Poey, 1861)	Oceanic whitetip shark	1,3,6,7,8
Carcharhinus macloti (Müller & Henle, 1839)	Hardnose shark	3,7,10,11,13

Carcharhinus melanopterus (Quoy & Gaimard, 1824)	Blacktip reef shark	1,3,5,7,8,9,10,11, 12,13
Carcharhinus obscurus (Lesueur, 1818)	Dusky shark	1,3,6,7,11,13
Carcharhinus plumbeus (Nardo, 1827)	Sandbar shark	1,3,5,6,7,10,11,13
Carcharhinus sealei (Pietschmann, 1916)	Blackspot shark	3,5,7,9,10,11
Carcharhinus signatus (Poey, 1868)	Night shark	1
Carcharhinus sorrah (Valenciennes, *in* Müller & Henle, 1839)	Spottail shark	1,3,5,7,8,9,10,11, 13,14
Carcharhinus tilsoni (Whitley, 1950)	Australian blacktip shark	1,11,13
Carcharhinus sp. [Compagno, 1988]	False smalltail shark	3,5,11
Galeocerdo cuvier (Peron & Lesueur, *in* Lesueur, 1822	Tiger shark	1,3,5,6,7,8,9,10,11,13
Glyphis gangeticus (Muller & Henle, 1839)	Ganges shark	7,11
Glyphis glyphis (Müller & Henle, 1839)	Speartooth shark	11
Glyphis sp. A? [Last & Stevens, 1994]	Bizant river shark [? = G. *glyphis]*	11
Glyphis sp. B [Compagno *et al*.]	Borneo river shark	3,5,11,14
Glyphis sp. C [Compagno & Garrick]	New Guinea river shark	11
Lamiopsis temmincki (Müller & Henle, 1839)	Broadfin shark	3,5,7,11
Loxodon macrorhinus Müller & Henle, 1839	Sliteye shark	3,5,7,8,10,11,13
Negaprion acutidens (Ruppell, 1837)	Sharptooth lemon shark	1,3,7,8,10,11,13
Negaprion brevirostris (Poey, 1868)	Lemon shark	1
Prionace glauca (Linnaeus, 1758)	Blue shark	1,3,6,7,8,13
Rhizoprionodon acutus (Ruppell, 1837)	Milk shark	1,3,5,7,10,11,12, 13,14
Rhizoprionodon oligolinx Springer, 1964	Gray sharpnose shark	3,5,7,11,13
Rhizoprionodon taylori (Ogilby, 1915)	Australian sharpnose shark	11,13
Scoliodon laticaudus Müller & Henle, 1838	Spadenose shark	1,3,5,7,10,11,12
Triaenodon obesus (Rüppell, 1837)	Whitetip reef shark	1,2,3,5,7,8,9,10,11,13
SPHYRNIDAE - HAMMERHEAD SHARKS		
Eusphyra blochii (Cuvier, 1817)	Winghead shark	1,3,5,7,11,13
Sphyrna lewini (Griffith & Smith, *in* Cuvier, Griffith & Smith, 1834)	Scalloped hammerhead	1,2,3,5,6,7,8,9,10, 11,13
Sphyrna mokarran (Rüppell, 1837)	Great hammerhead	1,3,5,7,8,9,10,11,13
Sphyrna zygaena (Linnaeus, 1758)	Smooth hammerhead	1,3,6,7,9,11,13
SAWFISHES PRISTIDAE - MODERN SAWFISHES *Anoxypristis cuspidata* (Latham, 1794)	Knifetooth, pointed, or narrow sawfish	1.4,5,7,11,12,13,14
Pristis clavata Garman, 1906	Dwarf or Queensland sawfish	11,12,13
Pristis microdon Latham, 1794	Greattooth or freshwater sawfish	4,5,7,11,12,13,14
Pristis pectinata Latham, 1794	Smalltooth or wide sawfish	1,4,7,11
**Pristis perotteti* Valenciennes, *in* Müller & Henle, 1841	Largetooth sawfish	12
Pristis zijsron Bleeker, 1851	Green sawfish	4,5,7,11,13,14
GUITARFISHES RHINIDAE - SHARKRAYS *Rhina ancylostoma* Bloch & Schneider, 1801	Bowmouth guitarfish or sharkray	4,5,7,8,11,13
RHYNCHOBATIDAE - SHARKFIN GUITARFISHES OR WEDGEFISHES *Rhynchobatus australiae* Whitley, 1939	Whitespotted shovelnose ray	4,5,7,11,13
Rhynchobatus djiddensis (Forsskael, 1775)	Whitespotted wedgefish or giant guitarfish	1,8,11,12
Rhynchobatus laevis (Bloch & Schneider, 1801)	Smoothnose wedgefish	4,11
Rhynchobatus sp. [Compagno]	Broadnose wedgefish	4,5,7,11,13
Rhynchobatus sp. [Compagno]	Roughnose wedgefish	4,7,11

RHINOBATIDAE - GUITARFISHES		
Aptychotrema rostrata (Shaw & Nodder, 1794)	Eastern shovelnose ray	11,13
Aptychotrema vincentiana (Haake, 1885)	Southern shovelnose ray	11,13
Rhinobatos annandalei Norman, 1926	Bengal guitarfish	11
Rhinobatos formosensis Norman, 1926	Taiwan guitarfish	4.11
Rhinobatos granulatus Cuvier, 1829	Sharpnose guitarfish	4,5,7,11
Rhinobatos halavi (Forsskael, 1775)	Halavi guitarfish	4,7,11
Rhinobatos holcorhynchus Norman, 1922	Slender guitarfish	11
Rhinobatos hynnicephalus Richardson, 1846	Ringstraked guitarfish	4,11
Rhinobatos leucospilus Norman, 1926	Greyspot guitarfish	11
Rhinobatos lionotus Norman, 1926	Smoothback guitarfish	11
Rhinobatos microphthalmus Teng, 1959	Smalleyed guitarfish	4,11
Rhinobatos obtusus Müller & Henle, 1841	Widenose guitarfish	11
Rhinobatos petiti Chabanaud, 1929	Madagascar guitarfish	11
Rhinobatos punctifer Compagno & Randall, 1987	Spotted guitarfish	11
Rhinobatos salalah Randall & Compagno, 1995	Salalah guitarfish	11
Rhinobatos schlegelii Muller & Henle, 1841	Brown guitarfish	4,7,11
Rhinobatos thouin (Anonymous, 1798)	Clubnose guitarfish	4,5,7,11
Rhinobatos typus Bennett, 1830	Giant shovelnose ray	4,5,7,11.13,14
Rhinobatos zanzibarensis Norman, 1926	Zanzibar guitarfish	11
Rhinobatos sp. [Compagno]	Tanzanian guitarfish	11
Trygonorrhina fasciata Müller & Henle, 1841	Southern fiddler ray	13
Trygonorrhina sp. A [Last & Stevens, 1994]	Eastern fiddler ray	11,13
PLATYRHINIDAE - THORNBACKS AND FANRAYS		
Platyrhina limboonkengi Tang, 1933	Amoy fanray	4,7,11
Platyrhina sinensis (Bloch & Schneider, 1801)	Fanray	4,11
ELECTRIC RAYS		
NARCINIDAE - NUMBFISH		
Benthobatis sp. [Carvalho, Compagno & Ebert]	Narrow blindray	4
Narcine brevilabiata Bessednov, 1966	Shortlip electric ray	4,11
Narcine brunnea Annandale, 1909	Brown electric ray	4,7,11
Narcine lingula Richardson, 1840	Rough electric ray	4,11
Narcine maculata (Shaw, 1804)	Darkspotted electric ray	4,7,11
Narcine prodorsalis Bessednov, 1966	Tonkin electric ray?	4,7,11
Narcine tasmaniensis Richardson, 1840	Tasmanian numbfish	13
Narcine timlei (Bloch & Schneider, 1801)	Blackspotted electric ray	4,7,11
Narcine westralensis McKay, 1966	Banded numbfish	11,13
Narcine sp. A [Last & Stevens, 1994]	Ornate numbfish	11
Narcine sp. [Carvalho, Compagno & Mee]	Bigeye electric ray	11
Narcine sp. [Carvalho]	Indian electric ray	4,7,11
Narcine sp.? [Randall]	Whitespot electric ray	11
NARKIDAE - SLEEPER RAYS		
Crassinarke dormitor Takagi, 1951	Sleeper torpedo	4
Heteronarce bentuvai (Baranes & Randall, 1989)	Elat electric ray	11
Heteronarce? sp. [Compagno & Smale]	Ornate sleeper ray	11
Narke dipterygia (Bloch & Schneider, 1801)	Spottail electric ray	4,5,7,11
Narke japonica (Temminck & Schlegel, 1850)	Japanese spotted torpedo	4,11
Narke sp.? [Compagno]	Thailand sleeper ray	11
Narke sp.? [Compagno]	Taiwan dwarf sleeper ray	4,11
Temera hardwickii Gray, 1831	Finless electric ray	4,7,11

HYPNIDAE - COFFIN RAYS		
Hypnos monopterygius (Shaw & Nodder, 1795)	Coffin ray or crampfish	11,13
TORPEDINIDAE - TORPEDO RAYS		
Torpedo fuscomaculata Peters, 1855	Blackspotted torpedo	11
Torpedo nobiliana Bonaparte, 1835	Great, Atlantic, or black torpedo	4
Torpedo panthera Olfers, 1831	Leopard torpedo	11
Torpedo polleni? Bleeker, 1866	Reunion torpedo	11
Torpedo sinuspersici Olfers, 1831	Gulf torpedo	11
Torpedo suissi? Steindachner, 1898	Red Sea torpedo	11
Torpedo tokionis (Tanaka, 1908)?	Trapezoid torpedo	4
Torpedo zugmayeri? Engelhardt, 1912	Baluchistan torpedo	11
Torpedo sp. [Compagno & Smale]	Comoro red torpedo	11
Torpedo sp. [Compagno & Smale]	Mauritius torpedo	11
Torpedo sp. [Compagno & Smale]	Seychelles torpedo	11
Torpedo sp. [Compagno & Smale]	Kenyan spotted torpedo	11
SKATES		
ARHYNCHOBATIDAE - SOFTNOSE SKATES		
Notoraja subtilispinosa Stehmann, 1985	Velvet skate	4
Pavoraja nitida (Günther, 1880)	Peacock skate	13
RAJIDAE - SKATES		
Dipturus gigas (Ishiyama, 1958)	Giant skate	4
Dipturus kwangtungensis (Chu, 1960)	Kwangtung skate	4
Dipturus macrocaudus (Ishiyama, 1955)	Bigtail skate	4
Dipturus tengu (Jordan & Fowler, 1903)	Acutenose or tengu skate	4
Dipturus? sp. A [Last & Stevens, 1994]	Longnose skate	13
Dipturus? sp. L [Last & Stevens, 1994]	Maugean skate	13
Okamejei acutispina Ishiyama, 1958	Sharpspine skate	4
Okamejei boesemani Ishihara, 1987	Black sand skate	4.7
Okamejei hollandi Jordan & Richardson, 1909	Yellow-spotted skate	4
Okamejei kenojei Muller & Henle, 1841	Spiny rasp, swarthy, or ocellate spot skate	4
Okamejei lemprieri (Richardson, 1846)	Australian thornback skate	13
Okamejei meerdervoorti Bleeker, 1860	Bigeye skate	4
Raja brachyura Lafont, 1873	Blonde skate or ray	1
Raja clavata Linnaeus, 1758	Thornback skate or ray	1
Raja whitleyi Iredale, 1938	Melbourne skate	13
ANACANTHOBATIDAE - LEGSKATES		
Anacanthobatis borneensis Chan, 1965	Borneo legskate	4,5
Anacanthobatis melanosoma (Chan, 1965)	Blackbodied legskate	4
Anacanthobatis nanhaiensis (Meng & Li, 1981)	South China legskate	7
STINGRAYS		
PLESIOBATIDAE - GIANT STINGAREES		
Plesiobatis daviesi (Wallace, 1967)	Deepwater stingray or giant stingaree	4
UROLOPHIDAE - STINGAREES		
Trygonoptera mucosa (Whitley, 1939)	Western shovelnose stingaree	13
Trygonoptera ovalis Last & Gomon, 1987	Striped stingaree	13
Trygonoptera personalis Last & Gomon, 1987	Masked stingaree	11,13
Trygonoptera testacea Banks, *in* Muller & Henle, 1841	Common stingaree	11,13
Trygonoptera sp. B [Last & Stevens, 1994]	Eastern shovelnose stingaree	13
Urolophus armatus Valencienes, *in* Muller & Henle, 1841	New Ireland stingaree	11
Urolophus aurantiacus Muller & Henle, 1841	Sepia stingray	4,7

Urolophus circularis McKay, 1966	Circular stingaree	13
Urolophus cruciatus (Lacepede, 1804)	Banded or crossback stingaree	13
Urolophus gigas Scott, 1954	Spotted or Sinclair's stingaree	13
Urolophus javanicus (Martens, 1864)	Java stingaree	11
Urolophus lobatus McKay, 1966	Lobed stingaree	13
Urolophus paucimaculatus Dixon, 1969	Sparsely-spotted, Dixons, or white-spotted stingaree	13
Urolophus sp. A [Last & Stevens, 1994]	Kapala stingaree	13
HEXATRYGONIDAE - SIXGILL STINGRAYS		
Hexatrygon bickelli Heemstra & Smith, 1980	Sixgill stingray	4
POTAMOTRYGONIDAE - RIVER AND FANTAIL STINGRAYS		
**Paratrygon aireba* Müller & Henle, 1841	Discusray	12
**Potamotrygon histrix* (Muller & Henle, *In* Orbigny, 1834)	Porcupine river stingray	12
**Potamotrygon motoro* (Natterer, *in* Müller & Henle, 1841)	Ocellate river stingray	12
**Potamotrygon scobina* Garman, 1913	Raspy river stingray	12
**Potamotrygon yepezi* Garman, 1913	Parnaiba river stingray	12
Taeniura lymma (Forsskael, 1775)	Ribbontailed stingray, Bluespotted ribbontail or fantail ray	5,7,8,11,13
Taeniura meyeni Müller & Henle, 1841	Fantail stingray, round ribbontail ray, speckled stingray	2,5,7,8,11,13
DASYATIDAE - WHIPTAIL STINGRAYS		
Dasyatis akajei (Müller & Henle, 1841)	Red stingray	4,11
Dasyatis annotata Last, 1987	Plain maskray	11,13
Dasyatis bennetti (Müller & Henle, 1841)	Bennett's cowtail or frilltailed stingray	4,11,12
Dasyatis brevicaudata (Hutton, 1875)	Shorttail or smooth stingray	7,11,13
Dasyatis fluviorum Ogilby, 1908	Estuary stingray	7,11,13
**Dasyatis garouaensis* (Stauch & Blanc, 1962)	Smooth freshwater stingray, Niger stingay	12
Dasyatis kuhlii (Muller & Henle, 1841)	Bluespotted stingray or maskray	4,5,7,11,13
Dasyatis laevigata Chu, 1960	Yantai stingray	4,11
Dasyatis laosensis Roberts & Karnasuta, 1987	Mekong freshwater stingray	4,7,11
Dasyatis leylandi Last, 1987	Painted maskray	11,13
**Dasyatis margarita* (Günther, 1870)	Daisy stingray	12
Dasyatis microps (Annandale, 1908)	Thickspine giant stingray	4,5,7,8,11
Dasyatis navarrae (Steindachner, 1892)	Blackish stingray	4.11
Dasyatis sinensis (Steindachner, 1892)	Chinese stingray	11
Dasyatis thetidis Ogilby, *in* Waite, 1899	Thorntail or black stingray	11,13
Dasyatis ushiei Jordan & Hubbs, 1925	Cow stingray	7
Dasyatis zugei (Muller & Henle. 1841)	Pale-edged stingray	4,5,7,11
Dasyatis sp. [Compagno & Cook, 1994]	Chinese freshwater stingray	11
Himantura alcocki (Annandale, 1909)	Palespot whipray	11
Himantura bleekeri (Blyth, 1860)	Whiptail stingray	4,7.11
Himantura chaophraya Monkolprasit & Roberts, 1990	Giant freshwater stingray or whipray	4,5,7,11,12,13,14
Himantura draco? Compagno & Heemstra, 1984	Dragon stingray	11
Himantura fai Jordan & Seale, 1906	Pink whipray	4,5,7,8,11,13
Himantura fava (Annandale, 1909)	Ocellate whipray	5
Himantura fluviatilis? (Hamilton-Buchanan, 1822/ Annandale, 1910)	Ganges stingray	11
Himantura gerrardi (Gray, 1851)	Sharpnose stingray, Bluntnose whiptail ray or whipray, banded whiptail ray	4,5,7,11
Himantura granulata (Macleay, 1883)	Mangrove whipray	4,7,8,11,13

Himantura imbricata (Bloch & Schneider, 1801)	Scaly stingray or whipray	4,7,11
Himantura jenkinsii (Annandale, 1909)	Pointed-nose stingray or golden whipray	4,5,7,11
Himantura krempfi (Chabanaud, 1923)	Marbled freshwater whipray	4,7
Himantura marginata (Blyth, 1860)	Blackedge whipray	4,7,11
Himantura microphthalma (Chen, 1948)	Smalleye whipray	4,7,11
Himantura oxyrhyncha (Sauvage, 1878)	Longnose marbled whipray	4,7,11
Himantura pareh (Bleeker, 1852)	Pareh whipray	11
Himantura pastinacoides (Bleeker, 1852)	Round whipray	4,5,11
Himantura signifer Compagno & Roberts, 1982	White-edge freshwater whipray	4,5,7,11
Himantura toshi Whitley, 1939	Blackspotted whipray or coachwhip ray	11,13
Himantura uarnacoides (Bleeker, 1852)	Whitenose whipray	4,5,11,14
Himantura uarnak (Forsskael, 1775)	Honeycomb or leopard stingray or reticulate whipray	4,5,7,11,12,13
Himantura undulata (Bleeker, 1852)	Leopard whipray	4,5,7,11,13
Himantura walga (Müller & Henle, 1841)	Dwarf whipray	4,5,7,11,14
Himantura sp. A [Last & Stevens, 1994]	Brown whipray	7,11,13
Pastinachus sephen (Forsskael, 1775)	Feathertail or cowtail stingray	4,5,7,8,11,12,13,14
?Pastinacus gruveli (Chabanaud, 1923)	Thailand stingray	11
Pastinachus sp. [Last]	Narrowtailed stingray	1
Pteroplatytrygon violacea (Bonaparte, 1832)	Pelagic stingray	4,13
Urogymnus asperrimus (Bloch & Schneider, 1801)	Porcupine ray	4,5,7,8,11,13
GYMNURIDAE - BUTTERFLY RAYS		
Aetoplatea tentaculata Valenciennes, *in* Muller & Henle, 1841	Tentacled butterfly ray	11
Aetoplatea zonura Bleeker, 1852	Zonetail butterfly ray	4,5,7,11
Gymnura australis (Ramsay & Ogilby, 1885)	Australian butterfly ray	11,13
Gymnura bimaculata (Norman, 1925)	Twinspot butterfly ray	4,7,11
Gymnura japonica (Schlegal, 1850)	Japanese butterfly ray	4,11
Gymnura micrura (Bloch & Schneider, 1801)	Smooth butterfly ray	4,7
Gymnura natalensis (Gilchrist & Thompson, 1911)	Diamond ray or backwater butterfly ray	11
Gymnura poecilura (Shaw, 1804)	Longtail butterfly ray	4,5,7,11
MYLIOBATIDAE - EAGLE RAYS		
Aetobatus flagellum (Bloch & Schneider, 1801)	Longheaded eagle ray	4,7,11
Aetobatus narinari (Euphrasen, 1790)	Spotted eagle ray or bonnetray	4,5,7,8,11,13
Aetobatus guttatus7 (Shaw, 1804)	Indian eagle ray	4,7,11
Aetomylaeus maculatus (Gray, 1832)	Mottled eagle ray	4,5,7,11
Aetomylaeus milvus (Valenciennes, *in* Müller & Henle, 1841)	Ocellate eagle ray or vulturine ray	4,7,11
Aetomylaeus nichofii (Bloch & Schneider, 1801)	Banded or Nieuhof's eagle ray	4,5,7,11,13
Aetomylaeus vespertilio (Bleeker, 1852)	Ornate or reticulate eagle ray	4,5,7,8,11
Myliobatis aquila (Linnaeus, 1758)	Common eagle ray or bullray	11
Myliobatis australis Macleay, 1881	Southern eagle ray	11,13
Myliobatis hamlyni Ogilby, 1911	Purple eagle ray	11
Myliobatis tobijei Bleeker, 1854	Kite ray	4,11
Pteromylaeus bovinus (Geoffroy St. Hilaire, 1817)	Bullray or duckbill ray	11
RHINOPTERIDAE - COWNOSE RAYS		
Rhinoptera adspersa? Valenciennes, *in* Muller & Henle, 1841	Rough cownose ray	4,7,11
Rhinoptera hainanensis? Chu, 1960	Hainan cownose ray	11
Rhinoptera javanica Muller & Henle, 1841	Javanese cownose ray or flapnose ray	4,5,7,11

Rhinoptera jayakari? Boulenger, 1895	Oman cownose ray	11
Rhinoptera neglecta Ogilby, 1912	Australian cownose ray	11,13
Rhinoptera sewelli? Misra, 1947	Indian cownose ray	11
MOBULIDAE - DEVIL RAYS *Manta birostris* (Donndorff, 1798)	Manta	2,4,5,7,8,11,13
Mobula eregoodootenkee (Bleeker, 1859)	Pygmy devilray or oxray	4,5,7,11,13
Mobula japanica (Müller & Henle, 1841)	Spinetail devilray	4,5,7,11
Mobula kuhlii (Valenciennes, *in* Müller & Henle, 1841)	Shortfin devilray	4,7,11
Mobula tarapacana (Philippi, 1892)	Sicklefin devilray	4,7,8,11
Mobula thurstoni (Lloyd, 1908)	Bentfin or smoothtail devilray	4,5,7,11
MODERN CHIMAERAS RHINOCHIMAERIDAE - LONGNOSE CHIMAERAS *Harriotta raleighana* Goode & Bean, 1895	Narrownose chimaera, bentnose rabbitfish, bigspine spookfish, or longnose chimaera	3
Rhinochimaera pacifica (Mitsukuri, 1895)	Pacific spookfish or knifenose chimaera	3
CHIMAERIDAE - SHORTNOSE CHIMAERAS *Chimaera phantasma* Jordan & Snyder, 1900	Silver chimaera	3,7
Hydrolagus mitsukurii (Dean, 1904)	Mitsukuri's chimaera	3

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Appendix 2

Food and Agriculture Organization of The United Nations
Rome, 26-30 October 1998

International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks)

Introduction

1. For centuries artisanal fishermen have conducted fishing for sharks sustainably in coastal waters, and some still do. However, during recent decades modern technology in combination with access to distant markets have caused an increase in effort and yield of shark catches, as well as an expansion of the areas fished.
2. There is concern over the increase of shark catches and the consequences which this has for the populations of some shark species in several areas of the world's oceans. This is because sharks often have a close stock-recruitment relationship, long recovery times in response to overfishing (low biological productivity because of late sexual maturity; few off-spring, albeit with low natural mortality) and complex spatial structures (size/sex segregation and seasonal migration).
3. The current state of knowledge of sharks and the practices employed in shark fisheries cause problems in the conservation and management of sharks due to lack of available catch, effort, landings and trade data, as well as limited information on the biological parameters of many species and their identification. In order to improve knowledge on the state of shark stocks and facilitate the collection of the necessary information, adequate funds are required for research and management.
4. The prevailing view is that it is necessary to better manage directed shark catches and certain multispecies fisheries in which sharks constitute a significant bycatch. In some cases the need for management may be urgent.
5. A few countries have specific management plans for their shark catches and their plans include control of access, technical measures including strategies for reduction of shark bycatches and support for full use of sharks. However, given the wide-ranging distribution of sharks, including on the high seas, and the long migration of many species, it is increasingly important to have international cooperation and coordination of shark management plans. At the present time there are few international management mechanisms effectively addressing the capture of sharks.
6. The Inter-American Tropical Tuna Commission, the International Council for the Exploration of the Sea, the International Commission for the Conservation of Atlantic Tunas, the Northwest Atlantic Fisheries Organization, the Sub-regional Fisheries Commission of West African States, the Latin American Organization for Fishery Development, the Indian Ocean Tuna Commission, the Commission for the Conservation of Southern Bluefin Tuna and the Oceanic Fisheries Programme of the Pacific Community have initiated efforts encouraging member countries to collect information about sharks, and in some cases developed regional databases for the purpose of stock assessment.
7. Noting the increased concern about the expanding catches of sharks and their potential negative impacts on shark populations, a proposal was made at the Twenty-second Session of the FAO Committee on Fisheries (COFI) in March 1997 that FAO organise an expert consultation, using extra-budgetary funds, to develop Guidelines leading to a Plan of Action to be submitted at the next Session of the Committee aimed at improved conservation and management of sharks.
8. This International Plan of Action for Conservation and Management of Sharks (IPOA-SHARKS) has been developed through the meeting of the Technical Working Group on the Conservation and Management of Sharks in Tokyo from 23 to 27 April 1998 and the Consultation on Management of Fishing Capacity, Shark Fisheries and Incidental Catch of Seabirds in Longline Fisheries held in Rome from 26 to 30 October 1998 and its preparatory meeting held in Rome from 22 to 24 July 1998.
9. The IPOA-SHARKS consists of the nature and scope, principles, objective and procedures for implementation (including attachments) specified in this document.

Nature and scope

10. The IPOA-SHARKS is voluntary. It has been elaborated within the framework of the Code of Conduct for Responsible Fisheries as envisaged by Article 2 (d). The provisions of Article 3 of the Code of Conduct apply to the interpretation and application of this document and its relationship with other

international instruments. All concerned States are encouraged to implement it.

11. For the purposes of this document, the term "shark" is taken to include all species of sharks, skates, rays and chimaeras (Class *Chondrichthyes)*, and the term "shark catch" is taken to include directed, bycatch, commercial, recreational and other forms of taking sharks.
12. The IPOA-SHARKS encompasses both target and non-target catches.

Guiding principles

13. *Participation.* States that contribute to fishing mortality on a species or stock should participate in its management.
14. *Sustaining stocks.* Management and conservation strategies should aim to keep total fishing mortality for each stock within sustainable levels by applying the precautionary approach.
15. *Nutritional and socio-economic considerations.* Management and conservation objectives and strategies should recognise that in some low-income food-deficit regions and/or countries, shark catches are a traditional and important source of food, employment and/or income. Such catches should be managed on a sustainable basis to provide a continued source of food, employment and income to local communities.

Objective

16. The objective of the IPOA-SHARKS is to ensure the conservation and management of sharks and their long-term sustainable use.

Implementation

17. The IPOA-SHARKS applies to States in the waters of which sharks are caught by their own or foreign vessels and to States the vessels of which catch sharks on the high seas.
18. States should adopt a national plan of action for conservation and management of shark stocks (Shark-plan) if their vessels conduct directed fisheries for sharks or if their vessels regularly catch sharks in non-directed fisheries. Suggested contents of the Shark-plan are found in Appendix A of the IPOA-Sharks. When developing a Shark-plan, experience of subregional and regional fisheries management organisations should be taken into account, as appropriate.
19. Each State is responsible for developing, implementing and monitoring its Shark-plan.
20. States should strive to have a Shark-plan by the COFI Session in 2001.
21. States should carry out a regular assessment of the status of shark stocks subject to fishing so as to determine if there is a need for development of a shark plan. This assessment should be guided by article 6.13 of the Code of Conduct for Responsible Fisheries. The assessment should be reported as a part of each relevant State's Shark-plan. Suggested contents of a shark assessment report are found in Appendix B of the IPOA-Sharks. The assessment would necessitate consistent collection of data, including inter alia commercial data and data leading to improved species identification and, ultimately, the establishment of abundance indices. Data collected by States should, where appropriate, be made available to, and discussed within the framework of, relevant subregional and regional fisheries organisations and FAO. International collaboration on data collection and data sharing systems for stock assessments is particularly important in relation to transboundary, straddling, highly migratory and high seas shark stocks.
22. The Shark-plan should aim to:
    - Ensure that shark catches from directed and non-directed fisheries are sustainable;
    - Assess threats to shark populations, determine and protect critical habitats and implement harvesting strategies consistent with the principles of biological sustainability and rational long-term economic use;
    - Identify and provide special attention, in particular to vulnerable or threatened shark stocks;
    - Improve and develop frameworks for establishing and coordinating effective consultation involving all stakeholders in research, management and educational initiatives within and between States;
    - Minimise unutilised incidental catches of sharks;
    - Contribute to the protection of biodiversity and ecosystem structure and function;
    - Minimise waste and discards from shark catches in accordance with article 7.2.2.(g) of the Code of Conduct for Responsible Fisheries (for example, requiring the retention of sharks from which fins are removed);
    - Encourage full use of dead sharks;
    - Facilitate improved species-specific catch and landings data and monitoring of shark catches;
    - Facilitate the identification and reporting of species-specific biological and trade data.
23. States which implement the Shark-plan should regularly, at least every four years, assess its implementation for the purpose of identifying cost-effective strategies for increasing its effectiveness.

24. States which determine that a Shark-plan is not necessary should review that decision on a regular basis taking into account changes in their fisheries, but as a minimum, data on catches, landings and trade should be collected.
25. States, within the framework of their respective competencies and consistent with international law, should strive to cooperate through regional and subregional fisheries organisations or arrangements, and other forms of cooperation, with a view to ensuring the sustainability of shark stocks, including, where appropriate, the development of subregional or regional shark plans.
26. Where transboundary, straddling, highly migratory and high seas stocks of sharks are exploited by two or more States, the States concerned should strive to ensure effective conservation and management of the stocks.
27. States should strive to collaborate through FAO and through international arrangements in research, training and the production of information and educational material.
28. States should report on the progress of the assessment, development and implementation of their Shark-plans as part of their biennial reporting to FAO on the Code of Conduct for Responsible Fisheries.

Role of FAO

29. FAO will, as and to the extent directed by its Conference, and as part of its Regular Programme activities, support States in the implementation of the IPOA-Sharks, including the preparation of Shark-plans.
30. FAO will, as and to the extent directed by its Conference, support development and implementation of Shark-plans through specific, in-country technical assistance projects with Regular Programme funds and by use of extra-budgetary funds made available to the Organization for this purpose. FAO will provide a list of experts and a mechanism of technical assistance to countries in connection with development of Shark-plans.
31. FAO will, through COFI, report biennially on the state of progress in the implementation of the IPOA-Sharks.

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A volunteer network comprised of some 7,000 scientists, field researchers, government officials and conservation leaders from nearly every country of the world, the SSC membership is an unmatched source of information about biological diversity and its conservation. As such, SSC members provide technical and scientific counsel for conservation projects throughout the world and serve as resources to governments, international conventions and conservation organizations.

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IUCN Species Survival Commission
Rue Mauverney 28, CH-1196 Gland, Switzerland.
Tel: +41 22 999 00 00, Fax: +41 22 999 00 15
E-mail: ssc@iucn.org
http://www.iucn.org/themes/ssc/

IUCN Publications Services Unit,
219c Huntingdon Road, Cambridge, CB3 ODL, UK.
Tel: +44 1223 277894, Fax: +44 1223 277175
E-mail: info@books.iucn.org
http://www.iucn.org

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