OFFSHORE FISHERIES OF THE SOUTHWEST INDIAN OCEAN:

their status and the impact on vulnerable species

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Special Publication No. 10

Rudy van der Elst and Bernadine Everett (editors)

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1. INTRODUCTION

Rudy van der Elst[1] and Bernadine Everett[1]

Prologue

On 4 and 5 December 2000, Dr Bill Lane of the World Bank, invited a group of scientists and fisheries' administrators from countries in the Southwest Indian Ocean (SWIO) to a meeting in Maputo. The purpose of this gathering was to explore opportunities for collaborating at a regional level in the sustainable development of shared offshore fishery resources. It was acknowledged that the enlarged EEZs of West Indian Ocean countries had not yet been translated into direct benefits for the countries concerned, nor indeed had they resulted in significant socio-economic upliftment of communities. There was also concern about overfishing, illegal harvesting and especially fisheries' impacts on the region's rich but vulnerable biodiversity. Inadequate scientific knowledge and a lack of capacity handicapped most of the SWIO countries from undertaking explorations and stock assessments in the large EEZ region of their seas. There was strong support in all countries for this regional initiative, notwithstanding the invariable complexity of dealing with an enormous diversity of fisheries, species and many countries all within a very large study area. As a result, the development of a final proposal took several years before it was generously funded and implemented in 2008. What followed was an unprecedented level of collaboration between fisheries agencies and individuals throughout the region. The Southwest Indian Ocean Fisheries Project (SWIOFP) was structured to maximise partnerships and share responsibilities in the pursuit of researching key offshore fisheries resources. Joint projects, shared research cruises, co-supervision of students and multi-stakeholder workshops all contributed to the development of a "network" of scientific collaboration between the region's fisheries agencies and individuals. This network generated a suite of technical reports, consolidated historic fisheries data, produced numerous scientific publications, supported many students and, above all, provided important information to strengthen the regional management already initiated through the Southwest Indian Ocean Fisheries Commission (SWIOFC). One of the final tasks undertaken was the development of a Retrospective Analysis which would provide a compendium of information relating to the key offshore fisheries of the Southwest Indian Ocean, together with their impact on vulnerable elements of the region's biodiversity. This book represents an edited, collated and partially updated version of these Retrospective Analyses.

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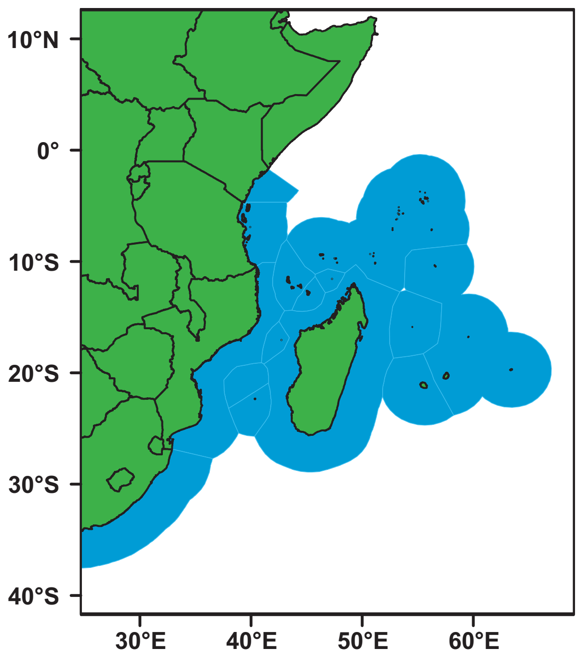
Geographic scope

The physical boundaries of SWIOFP were loosely defined at the outset as being the 200 nautical mile (nm) Exclusive Economic Zones (EEZs) of the nine participant countries: Comoros, Seychelles, Mauritius, France (La Réunion and other dispersed islands), Madagascar, Kenya, Tanzania, Mozambique and eastern South Africa (KwaZulu-Natal province) as in Figure 1. Broadly, the study region's south-western boundary aligns with the boundary of the FAO fisheries statistical area 51 (Western Indian Ocean; E of 30°E); its northern boundary is a seaward extension of the border between Kenya and Somalia, and the northern extreme of the Seychelles EEZ (approximately on the equator); its eastern boundary includes the furthest extent of the Mauritian EEZ (approx. 67°E). However, because fisheries and their resources do not naturally adhere to the project-defined boundaries, neighbouring areas also partially addressed included the Agulhas Bank and some areas in international waters e.g. seamounts of the South Madagascar Ridge (Walters Shoals) and the Southwest Indian Ridge. It was also initially proposed that only those resources harvested offshore would be considered, although it was recognised that some resources co-occur in both inshore and offshore waters. Examples include prawns, demersal fishes and a number of pelagic species.

Figure 1. Geographical scope of this study showing FAO areas.



The SWIOFP programme

Following the initial meeting in 2000 and additional deliberations relating to SWIOFP, it was agreed to secure a World Bank PDF-b grant in support of developing a full programme proposal with its attendant structures. This development phase was hosted by Mozambique and successfully resulted in a well-defined programme as reflected in the Project Advisory Document – PAD (www.swiofp.net). Significantly, the somewhat lengthy development phase created stronger linkages and positive collaboration between countries of the region. During this development phase it was noted that several other large research programmes were simultaneously being developed in the region, notably the WIOLab (West Indian Ocean Land-based Activities and Sources of Pollution) (www.unep.org/nairobiconvention/) and the ASCLME (Agulhas Somali Current Large Marine Ecosystem program) (www.asclme.org), hosted by UNEP and UNDP respectively. Discussions between the three programmes recognised the merits of closer collaboration within the framework of a Large Marine Ecosystem approach, with the Somali and Agulhas Currents as well as the Mascarene Plateau serving as the primary underlying ecosystems. Furthermore, this trio of programmes would then generate a single overarching Transboundary Diagnostic Analysis (TDA) and a subsequent Strategic Action Programme (SAP) comprising of fisheries, biodiversity, land-based sources of pollution and large marine ecosystem dynamics (van der Elst *et al*. 2009).

The final PAD was completed and signed on October 9th 2007, became effective on 16th April 2008, and was intended to run for 4-5 years. The fledgling Southwest Indian Ocean Fisheries Project (SWIOFP) was launched with the overall objective:

> "*To promote the environmentally sustainable use of fish resources through adoption by countries riparian to the Southwest Indian Ocean of a Large Marine Ecosystem (LME)-based approach to fisheries management in the Agulhas and Somali LMEs that recognizes the importance of preserving biodiversity*."

Within this overall global objective three project-specific objectives were identified:

- To identify and study exploitable offshore fish stocks within the SWIO, more specifically, to determine existing fishing pressure on these stocks and to investigate the role of environmental influences on the life histories, seasonal variability and health of stocks in order to differentiate between environmental and anthropogenic impacts;
- To develop institutional and human capacity through training and career opportunities; and
- To develop a regional fisheries management structure and associated harmonized legislation in collaboration with the Southwest Indian Ocean Fisheries Commission (SWIOFC).

The implementation phase of SWIOFP was hosted by Kenya on behalf of the nine participating countries. Funding of US$22.65 M was made available by the International Bank for Reconstruction and Development (on behalf of the GEF) with additional contributions from Norway, French GEF, FAO, and counterpart finance from participating countries.

Countries participating in, and contributing to SWIOFP were: Comoros, France (by virtue of its islands in the region), Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa (east coast only), the United Republic of Tanzania and, as an observer, Somalia. Each country established a national SWIOFP committee which was represented at the regional SWIOFP steering committee by senior government officials. In addition, each of the project's six Components was represented by a committee drawn from each country and facilitated by selected countries as tabulated.

Table 1. SWIOFP Components and sub-components.

Component	*Sub-components*	*Responsible country*
Component 1: Data GAP analysis, data archiving and information technology.	Fisheries data collection and evaluation. Compiling of a data atlas for SWIOFP. Establishment of Information Technology, data handling and communications systems.	Kenya
Component 2: Assessment and sustainable utilization of crustaceans.	Deep-water crustaceans. Shallow-water crustaceans.	South Africa
Component 3: Assessment and sustainable utilization of demersal fishes.	Deep-water demersal fish. Shallower water demersal fish.	Tanzania
Component 4: Assessment and sustainable utilization of pelagic fishes.	Large pelagic fish. Small pelagic fish.	Seychelles
Component 5: Mainstreaming biodiversity in national and regional fisheries management.	State of knowledge of non-consumptive resources and marine biodiversity. Key biodiversity indicators and values. Interactions with fisheries including bycatch. Bio-indicators of ecosystem health.	Mauritius
Component 6: Strengthening regional and national fisheries management.	National and international legislation and other instruments relevant to SWIOFP's goal. Harmonization of legislation between countries. Development of regional resource management structures and capacity.	Kenya

Terms of reference for this study

The various SWIOFP Component working groups each undertook a detailed Gap Analysis of the fisheries within their component. This multinational expert exercise identified the main gaps in data and information and played an important role in directing the activities of each component during the implementation phase of SWIOFP. As a result of the Gap Analyses and subsequent research activities, a number of important data sources were identified, additional information generated and a number of publications produced. These activities in turn underpinned one of SWIOFP's key primary tasks, which was to identify and interpret all available information relating to offshore fisheries and to assess the adequacy of such information in the management and possibly future development of new fisheries. Moreover, the impact of these fisheries on the biodiversity and vulnerable organisms of the SWIO was to form an integral part of the programme. This final activity involved a comprehensive Retrospective Analysis of the available information for each of the region's main fisheries as well as biodiversity related themes:

Fisheries	*Biodiversity*
Crustacean shallow-water trawl	Marine mammals
Crustacean deep-water trawl	Sea turtles
Crustacean deep-water trapping	Seabirds
Pelagic fisheries	Elasmobranchs
Demersal fisheries	Vulnerable teleost fishes
Bycatch update	Biodiversity hotspots

The task of conducting the Retrospective Analyses was contracted out to specialist scientists in the field relevant to the topic. More specifically, the following activities were envisaged as part of the Terms of Reference for fisheries:

- Assess the status and quality of existing databases, their present use, and their potential use for the development of long-term indices for fisheries management.
- Where existing databases have previously been analysed and relevant trends of fishing effort, catches and catch rates have already been determined, these should be illustrated and discussed.
- Where databases have not previously been analysed, a basic analysis of selected data to show long-term trends in fishing effort, catches by species (or species group), and catch rates relative to area, season and gear types should be undertaken. The limitations of the data and analyses to be highlighted.
- Wherever possible, biological data available on selected databases should be explored so as to calculate basic biological parameters of priority species, such as trends in length composition, sex ratios, length at sexual maturity, growth rates, mortality rates and reproductive seasonality.
- Identification of key biological reference points based on past stock assessment studies.
- Provide metadata information on all the datasets used in the study.
- Wherever possible prepare maps for each of the priority resources or species' fishing zones by gear and fishery sector.

Additional terms of reference for biodiversity:

- Assess the state of knowledge and status of vulnerable non-target species (such as seabirds, turtles and marine mammals) and their interaction with industrial fisheries.
- Assess regional bycatch in all fishery types; including potential impacts of changes in fishing technology.
- Identify critical habitats, biodiversity "hotspot" issues, such as spawning aggregations and nursery areas;
- Concurrent mapping of sensitive areas and zones under formal protection.

Considering that information and long-term databases are mostly held by the governments of SWIOFP member countries, NGOs and private researchers, the task included extensive consultation with relevant stakeholders in the region. In addition, detailed literature surveys, compilation of metadata, identification of fishing grounds, and analysis of biological data as well as temporal trends were important tasks. It was envisaged that these Retrospective Analyses would contribute to the Transboundary Diagnostic Analysis (TDA) and Strategic Action Plan (SAP) required as an end-of-project output from SWIOFP.

Primary data sources

National data

Each of the National Component 1 coordinators provided a list of all available datasets from their countries at the onset of the SWIOFP programme. A total of 170 datasets (Figure 2.) was identified and described in varying detail. Comoros declared that little formal collection of national fisheries data had taken place. The datasets were in various formats: paper data sheets and digitized versions, which in turn were stored in numerous formats from basic text files to MS Excel spreadsheets, MS Access databases and commercially sourced databases. Based on the accompanying metadata provided by the Component Coordinators, datasets were prioritised for their inclusion into StatBase.

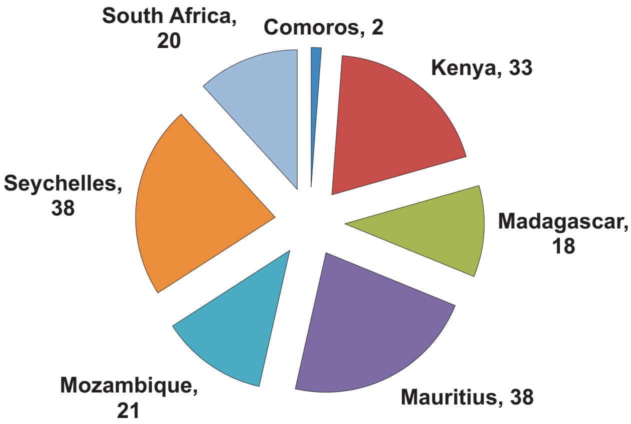


Figure 2. Number of datasets for which metadata was supplied by the National Component 1 coordinators. The number of datasets follows the country name.

Literature/EndNote

Much of the literature on fisheries of the western Indian Ocean is "grey literature" that is poorly available to the wider community of interested parties. One of the activities under Component 1 was, therefore, to develop a central database housing as many relevant publications, reports, etc. that could be easily accessed from anywhere in the region. After considerable deliberation it was decided to use the commercial package EndNote as the system to inventorise the many references. References were collected by each National Component Coordinator and forwarded to the Data Component Coordinator at KMFRI for inclusion in a central all-inclusive set. The complete set of 4,137 references is currently kept at KMFRI in Mombasa, Kenya and should be available online (Figure 3).

Figure 3. Composition of the 4137 scientific documents archived in EndNote.

StatBase

StatBase is an archival software system for fisheries statistics developed by Institut de recherche pour le développement (IRD) in West Africa. The database system was modified from the West African system to address the idiosyncrasies and needs of the East African context under SWIOFP. The aim of this database is to facilitate archiving and integration of existing fisheries statistics from national datasets for region-wide interpretation using software that is freely available and thereby minimising costs to developing countries. It also aimed at providing a mechanism for data gap analysis.

Data are organised in hierarchies (Annex 1) commencing with countries that have subdivisions under each category to provide statistics for the various fishing sectors. Each sector is then further divided to provide tables of catch, effort and vessel registers. The development of a comprehensive dataset for the WIO was hampered by numerous constraints encountered (e.g. highly variable time series of statistics, missing catch data, uncertain status of length measurements, some species breakdown missing). While clearly of value, the database remains to be fully validated and still has incomplete categories, some duplicate datasets for several fisheries and units for catch and effort are not specified. StatBase is maintained by Kenya Marine and Fisheries Research (KMFRI) in Mombasa, Kenya. The database can be accessed online at: http://statbase1.smartfish.d4science.org/statbase/StartPage.action?request_locale=en

WIOFish

WIOFish is a web-based inventory of fisheries and their characteristics in the SWIO region. When it was first conceived in 2000, very few of the small-scale fisheries of the western Indian Ocean (WIO) had been formally identified and described and, accordingly, even fewer could draw potential benefits from scientific assessment and management support promoting sustainable development. This lack of information regarding the fisheries was the driving force behind the development of the WIOFish project. Thus, the underlying rationale for WIOFish lies in the identification and documentation of small-scale fisheries to provide an annotated inventory of all fisheries of the WIO, thereby addressing some of these key issues. The objectives of WIOFish include:

- to identify each unique fishery type found in coastal waters and to describe the main features of each fishery;
- to maintain an up-to-date database of annotated fishery profiles for all fisheries of the region;
- to report annually on the "status" of the fisheries, including risk profiles and management needs;
- to establish a permanent regional partnership between national fishery nodes in SWIO countries;
- to foster development of small-scale fisheries co-management systems through establishment of an electronically and physically linked network of collaborators focusing around an interactive web-based system that allows for comprehensive public access and reporting.

WIOFish is intended to supplement regional initiatives of the Southwest Indian Ocean Fisheries Commission (SWIOFC) and other organisations/institutes operating in the western Indian Ocean by providing an information service to fishery resource managers, donors, researchers, including those with specific environmental concerns. The system provides a systematic overview of fishing activities in the WIO region and, based on a scoring system, highlights areas of fisheries that are either data-rich or data-poor. The purpose behind this is to provide a platform where interested parties can access the available data for the fisheries and also formulate informed decisions on where further research should be conducted.

WIOFish is managed by the Oceanographic Research Institute (ORI) in partnership with the Kenya Marine and Fisheries Research Institute (KMFRI – Kenya), Institute of Marine Sciences (IMS – Tanzania), Instituto Naçional de Investigaçao Pesqueira (IIP – Mozambique), the Seychelles Fishing Authority (SFA – Seychelles), Albion Fisheries Research Centre (Mauritius), Ministère de la Production Direction Regionale de la Peche Mohéli (Comoros) and the Ministère de la Pêche et des Resources Halieutiques (Madagascar). At this stage France is not a participant in WIOFish.

The WIOFish database is not a statistical fisheries database but instead is a repository for as much descriptive information as possible about each fishery that is currently operating or has operated in the western Indian Ocean. The information is collected under sections on catch, vessel type, gear type, habitats utilised, socio-economics, management and references, and includes a scoring system in which various questions are posed about each fishery with answers graded on a numeric scoring system to allow further analysis. The database structure is reviewed annually to incorporate any additional fishery aspects that the project partners feel need to be included. This provides a dynamic and expanding database that aims at being as comprehensive as possible.

A "fishery" is broadly defined on the basis of representing a "management unit" that involved specific species, gear types, habitats and geographic locations. The fisheries have been grouped into 12 separate sectors (Figure 4), ranging from subsistence shore gathering to full scale industrial operations. Each of these fisheries is comprehensively reviewed on an annual basis by the national nodes to ensure records are up to date and populated with the latest available catch and other information. Each year the full set of information is archived so as to provide a reference point for future assessment of trends in the evolution of these fisheries.

Food and Agriculture Organization of the United Nations (FAO)

Each year the FAO collects and collates fisheries statistics from individual countries and regions around the world. This extensive fifty-year time series reflects inter-alia capture production by species, country and statistical region. This valuable repository for fisheries information is accessible through various formats, tools and information products available at: http://www.fao.org/fishery/statistics/en.

Accordingly, capture data is available for the nine countries included in this study and are examined in this Retrospective Analysis. It should be noted that the statistical region relevant to this study is Area of 51: western Indian

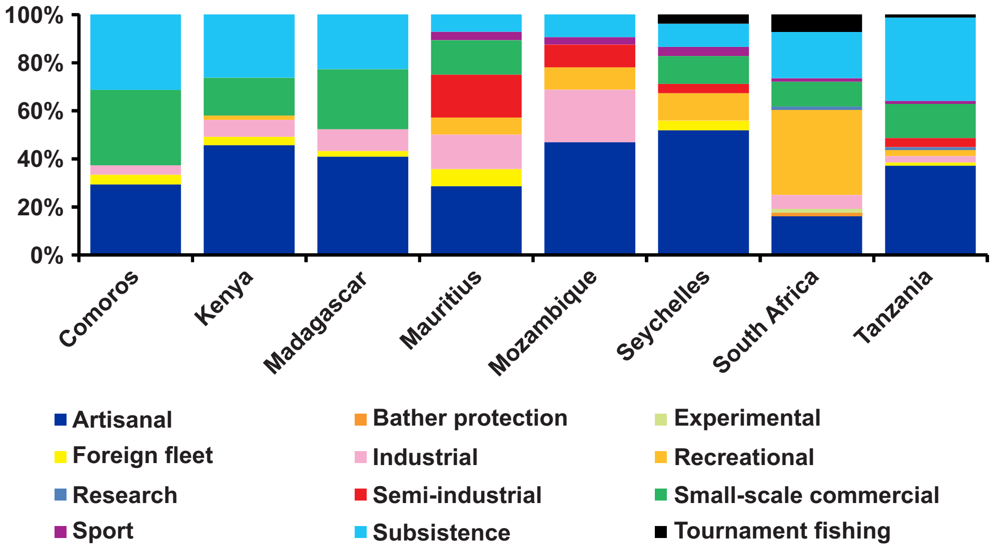


Figure 4. The various fisheries sectors operating in each SWIOFP country.

Ocean, which is considerably larger than the geographic extent of the SWIOFP study area.

Fishbase

Fishbase is a global information system that provides key information on the biology and critical life history parameters of most of the world's fish species. It was first developed in 1992 at the WorldFish Center in collaboration with the FAO and many other partners, and with support from the European Commission. It is available online at www.fishbase.org. Scientists throughout the western Indian Ocean use FishBase to access basic biological data. It has been used extensively in this book to describe the species that are of importance to the region.

Research cruises

One of the aims of SWIOFP was to gather as much information as possible about the region's marine resources and store this information in a central system accessible to all. This included the sourcing of historical research surveys and the acquisition of new data from commissioned research surveys during the project's lifespan. Early on in the project, the EAF-Nansen Project provided all the data from historical research surveys conducted by the Norwegian research vessel, Dr Fridtjof Nansen, in the western Indian Ocean. These data are stored using the Nansis software that the Institute for Marine Research (Norway) developed to capture the data on board the vessel. A copy of this dataset is lodged at KMFRI to be kept with all other datasets collected during SWIOFP. Other historical survey data are known to exist but were not repatriated during SWIOFP due to the high costs associated with such repatriation. During SWIOFP a total of 40 surveys were planned to collect new data for the region and 34 of these surveys were completed. These surveys covered aspects such as biodiversity, productivity, biomass estimates, migration, genetic sampling, etc. A full list of surveys is provided in Annex 2.

Harmonization of data sets

In order to provide regional consistency between datasets, a Memorandum of Understanding between SWIOFP and the participant countries was compiled in which the format and descriptors of existing and future metadata is standardised according to those used for StatBase, with the following fields: Database identifier; Dataset name; Country or regional body; Responsible agency; Source of information; Jurisdictional scale; Nature of the data; Gear type; Target Species; Biological data; Physical data; Type of dataset; Status of data; Data medium; Digital medium; Operating system; Database software; Digital format; Temporal coverage; Temporal resolution; Spatial coverage; Spatial resolution; Spatial extent; Locality; Language; Comments.

The regional management environment

Historically, there has been poor collaboration in the management of fisheries between nations of the region, despite the apparent and clear features that are common and shared between SWIOFP countries. In time, several initiatives evolved which recognised the need for greater collaboration in the management of shared, straddling and transboundary fish stocks. These have given rise to more formal management structures which at this stage remain only advisory. However, their growing success could well lead to more formal and legally binding management structures in the SWIO region in years to come. Some of the key structures that support management of fisheries and associated biota in the region are discussed.

Southwest Indian Ocean Fisheries Commission

– http://www.fao.org/fishery/rfb/swiofc

The Southwest Indian Ocean Fisheries Commission (SWIOFC) is a regional body established in 2004 under the auspices of FAO to promote the sustainable utilization of the living marine resources of the SWIO region. Its regions of competence are the national waters of its member states: Comoros, France, Kenya, Madagascar, Maldives, Mauritius, Mozambique, Seychelles, Somalia, South Africa, United Republic of Tanzania, and Yemen. It does not collate or host databases but its Scientific Committee does report regularly on the status of fishery resources and advises members of the Commission on a scientific basis for possible regulatory measures. Reports of the countries to the Scientific Committee and reports of the Scientific Committee to the Commission have been used as sources of information for this Retrospective Analysis. The SWIOFC promotes the application of the provisions of the FAO Code of Conduct on Responsible Fisheries, including the precautionary approach and the ecosystem approach to fisheries management. The Commission achieves its objectives through the following activities:

- assist fishery managers in the development and implementation of fishery management systems that take due account of environmental, social and economic concerns;
- keep under review the state of the fishery resources in the area and the industries based on them;
- promote, encourage and coordinate research related to the living marine resources in the area and draw up programmes required for this purpose;
- promote the collection, exchange, dissemination and analysis or study of statistical, biological, environmental and socio-economic data and other marine fishery information;
- provide a scientific basis to assist fisheries management decisions;
- provide advice on management measures and to promote co-operation on monitoring, control and surveillance of a regional or sub-regional nature;
- encourage, recommend and coordinate training in the areas of interest of the Commission;
- promote and encourage the utilization of the most appropriate fishing craft, gear, fishing techniques and post harvesting technologies.

Indian Ocean Tuna Commission

– http://www.iotc.org

The Indian Ocean Tuna Commission (IOTC) is an intergovernmental organization established in 1993 under the FAO constitution with the mandate to provide management decision support relating to tuna and tuna-like species and their environment. Its operations extend beyond the SWIOFP region to cover the entire Indian Ocean and adjacent seas, promoting cooperation among its 32 members in support of conservation and optimum utilization of stocks falling under its mandate. With the exception of South Africa, all SWIOFP members are full contracting parties to IOTC. The Commission has several substructures including scientific and compliance committees and working parties on statistics, billfish, ecosystems, bycatch and more. These structures facilitate the collection of statistics which are curated in a number of databases, a list of which can be found at http://www.iotc.org/data-and-statistics. Data are provided by the flag states of member countries fishing for tunas in the Indian Ocean. IOTC undertakes regular, comprehensive stock assessments of most of the key resources of tuna and tuna-like species, which are summarised in Executive Summaries on each species and reported to the Commission. For surface fisheries, catch weight by species is provided by 1° grid area and month strata, for longline fisheries these data are provided by 5° grid area and month strata, while for coastal fisheries data may be provided using an alternative geographical area if it represents the fishery concerned better than the grid areas.

Based on the information collected, the IOTC issues conservation and management measures accordingly. Whilst adherence to such measures is technically voluntary, a Compliance Committee is in place to monitor the compliance with respect to such management proposals. In this way the IOTC plays an important role in regional fisheries statistics and management.

SADC Fisheries Protocol

– http://www.nda.agric.za/doaDev/sideMenu/fisheries/03_areasofwork/Aquaculture/AquaDocumentation/SADC_ProtocolFisheries.pdf

In 2001, fourteen member countries of the Southern African Development Community (SADC) signed an agreement that recognises the important role of fisheries in the social and economic well-being and livelihood of the people of the region, in ensuring food security and alleviating poverty. Known as the SADC Protocol on Fisheries, it sets out agreed rules and principles dealing with national and international responsibilities, management of shared stocks, harmonisation of legislation, law enforcement, IUU fisheries, access to stocks, artisanal fisheries, environmental protection, scientific and institutional development amongst others. Whilst the Protocol has not enjoyed the high level of prominence and implementation that was originally envisaged, it nevertheless provides the basic building block for a regional fisheries management strategy that can command the highest level of political support necessary to implement operations.

The Nairobi Convention

– http://unep.org/NairobiConvention/about

As part of UNEP's Regional Seas programme the Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region was signed in 1985 and came into force in 1996. As all SWIOFP countries are Contracting Parties, the Convention provides a mechanism for regional cooperation, coordination and collaborative actions in the region's marine and coastal environmental protection, especially critical national and transboundary issues. The primary mechanism underlying the Convention is the development of protocols and their region-wide application. Examples include protocols on the protection of wildlife and flora, protection from land-based sources and activities as well as combating marine pollution. The Convention offers a regional legal framework and coordinates the efforts of the member states to plan and develop programmes that strengthen their capacity to protect, manage and develop their coastal and marine environment sustainably. Closer collaboration with fisheries agencies would substantially improve regional management and biodiversity protection.

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Tuna purse seiner, Seychelles. (Photo: Ross Wanless)

Annex 1:
The StatBase structure and data that are currently available for public access on the Internet.

Level 1	*Level 2*	*Level 3*	*Data type*	*Period*	*Comments*
IOTC					No data
Tanzania	Artisanal fishery	Artisanal Fishery Landings by both weight and values	Catch	1990-1996	
		Artisanal Fishery Landings by both weight and values	Catch	1990-1996	
	Artisanal landings in both weight and values	Weight in tonnes			No data
	INDUSTRIAL REGISTER	INDUSTRIAL REGISTER	Register of vessels	1990-2008	
	Industrial fishery	Industrial catch			
SWIOFP	INDUSTRIAL FISHERY				No data
	ARTISANAL FISHERY_2	catch and value			No data
		Fishing Gears Effort	Effort	2004-2008	Provides Year, Gear type and No. of gears but no country allocation
	SEMI INDUSTRIAL FISHERY				No data
	SPORT FISHERY				No data
Zanzibar	Z 100 AA		Effort	1994	
SWIOFC					No data
Seychelles	Semi industrial longline	Efforrt - number of hooks per gear	Effort	1995-2008	
		Catch by species and gear in Kgs	Catch	1995-2008	
		Catch by species in Kgs	Catch		No data
	Sea Cucumber Fishery	Catch by species by numbers	Catch	2000-2008	
	Lobster	Catch by species and gear in Kgs	Catch	2001-2008	
		effort - number of trips per gear	Effort	2001-2008	
	Artisanal Fishery	Catch by gears	Catch	2000-2008	
		Fishing Effort	Effort	2000-2010	
	Industrial Longline Fishery	Catch by species	Catch	2000-2008	
		Number of hooks per semester	Effort	1999-2008	
FAO	FAO data	Catches			No data
Mauritius	coastal fishery	catch			No data
		Coastal Fishery			No data
	effort	MUS3-coastal-Effort			No data
	Costal fishery	EFFORT IN DAYS	Effort	2003-2008	
		BOATS IN NUMBER	Register of vessels	2003-2008	
		CATCH PER FISHERMAN DAY IN KG	CPUE	2003-2008	
		Catches by gears	Catch	2003-2008	
	effort	MUS3-coastal-Effort			No data
	Mauritusdata				No data
	Mauritiuscoastalfishery				No data
	MUS-Bank fishery	CPUE in Kg	CPUE	1989-2007	
		CATCH PER FISHERMEN DAY IN KG	CPUE	1997-2010	
		Catch in Tons			No data
		Catches in tons			No data
		CATCH IN TONS	Catch	1996-2010	
		Effort in fishermen days			No data
		EFFORT IN FISHERMEN DAYS	Effort	1997-2010	
		Effort in days	Effort	1989-2007	
		Catches by zone	Catch	1989-2008	
	Mauritius Fisheries	Coastal Fishery			No data
	MUS-1	catch			No data
	MUS-1				No data

Level 1	Level 2	Level 3	Data type	Period	Comments
Other	MOZ1	TABLE 180			No data
	MOZ 1				No data
Comoros	Artisanal fisheries	Effort	Effort	1994	
		TABLE 278	Catch	1994	
		Cencus	Register of vessels	1993-1994	
Somalia					No data
Mozambique	Artisanal Fishery	CATCH	Catch	2003-2009	
		CENSUS	Register of vessels	2002-2007	
	Moz Sport Fish	Moz Sport Fish	Catch	2000-2009	
	Semi-Industrial Fishery	FLEET	Register of vessels	2000-2009	
		CATCH	Catch	2000-2009	
		EFFORT	Effort	2000-2009	
	Industrial Fishery	EFFORT	Register of vessels	2000-2009	
		CATCH	Catch	2000-2009	
		FLEET	Effort	2000-2009	
Kenya	Industrial register	Number of boats	Register of vessels	2004-2009	
	Semi industrial	Effort	Register of vessels	2001-2006	
	Ken-1	Ken-1 Industrial Purse seiners & Long liners			No data
	Artisanal fishery	Landings by species	Catch	1990-2008	
		Number of gears	Effort	2004-2008	
	Spot fishing	Catch and effort	Catch and Register of vessels	1987-2006	
South Africa	KwaZulu-Natal Industrial fisheries	Industrial fishery catches	Catch	1985-2011	
		Industrial fishery vessel register	Register of vessels	1985-2011	
		Industrial fishing effort	Effort	1985-2011	
Madagascar	PECHE TRADITIONNELLE AUX CREVETTES	EFFORT	Effort	1998-2000	
		CATCH	Catch	1998-2004	
	PECHE CREVETTIERE	EFFORT	Effort	2004-2010	
		FLOTTILLE	Register of vessels	1995-2010	
		CATCH	Catch	1995-2010	
	PECHE AUX POISSONS	CAPTURE	Catch	2005-2008	
	NOTE CONJONCTURELLE	FLOTTILLE	Register of vessels	2004-2008	
		CATCH	Catch	2004-2008	
		EFFORT	Effort	2004-2008	
France (Réunion)	Réunion	EFFORT 2005-2009	Register of vessels + fishers	2005-2009	
		TABLE 394	Catch	2005-2009	
		registre 2008	Register of vessels	2008	

Annex 2:
Research surveys completed during the lifespan of the South West Indian Ocean Fisheries Project.

Year	*Component*	*Countries*	*Survey Title*	*Dates*	*No of days*	*Survey Objectives*
2008	C2, C3, C4	South Africa, Madagascar	East Madagascar Current Ecosystem Survey	23 Aug -1 Oct	38	To establish the productivity, biodiversity and biomass of the pelagic ecosystem using the RV Dr Fridtjof Nansen.
	C3, C4, C5	Mauritius	Mauritius Ecosystem survey	4 - 7 Oct	4	To do preliminary investigations on species diversity on the demersal fish fauna over the Mascarene Plateau section using the RV Dr Fridtjof Nansen.
	C3, C4	Mauritius, Seychelles	Mascarene and Seychelles- Pemba survey	8 Oct -27 Nov	50	Use the RV Dr Fridtjof Nansen to investigate demersal and pelagic productivity, biodiversity and biomass.
	C4	International waters, French Territories, Madagascar	Mesoscale eddies pelagic and mesopelagic Survey of the Mozambique Channel	28 Nov -17 Dec	20	To establish, as far as possible, the productivity, diversity and biomass of the pelagic and mesopelagic ecosystem using the RV Dr Fridtjof Nansen.
	C4, C5	Mozambique Channel	Mesoscale eddies and large pelagic fish (swordfish & large tuna) in the Mozambique Channel Survey	27 Nov -18 Dec	22	Analyze role of eddies in the increase of biological production of the pelagic ecosystem and catchability of large pelagic fishes. Analyse interactions between the longline and the marine megafauna.
2009	C3, C4	Mozambique	Survey of the living marine resources of North Mozambique	6-20 Aug	15	To establish, as far as possible, the productivity, diversity and biomass of the pelagic and mesopelagic ecosystem using the RV Dr Fridtjof Nansen.
	C2, C3, C4	Madagascar	West Madagascar Pelagic Ecosystem Survey	25 Aug -3 Oct	40	To investigate demersal and small pelagic fish species diversity and abundance using the RV Dr Fridtjof Nansen.
	C3, C4	Comoros	Survey of the Comoros Gyre	5 Oct -3 Nov	29	To establish the productivity, diversity and biomass of the demersal, pelagic and mesopelagic ecosystem using the RV Dr Fridtjof Nansen.
2010	C3, C4, C5	Mauritius and Southern Mascarene Plateau Survey	Mauritius and Southern Mascarene Pelagic Ecosystem Survey	7-21 Dec	16	To establish the productivity, diversity and biomass of the demersal, pelagic and mesopelagic ecosystem using the RV Dr Fridtjof Nansen.
	C4, C5	South Africa	South Africa Large pelagics (swordfish & large tuna) Survey	22 Oct -10 Nov	20	With the use of the RV Ellen Khuzwayo, understand the distribution and movement of swordfish, big eye and yellowfin tuna within the SWIO region.
	C4, C5	Mozambique	SW Moz Channel Large pelagics (swordfish & large tuna) Survey	19 Oct -1 Nov	15	With the use of the RV Ellen Khuzwayo, understand the distribution and movement of swordfish, big eye and yellowfin tuna within the SWIO region.
2011	C2, C3, C5	Tanzania	Tanzania Shallow-water Crustacean Trawl Survey	5-20 Jan	15	Using a commercial vessel, establish the distribution and composition of crustacean species during the North West monsoon, collect biological and genetic samples of priority shallow water prawns.
	C2, C3, C5	Kenya	Kenya Shallow-water Crustacean Trawl Survey	21 Jan -4 Feb	15	Using a commercial vessel, establish the distribution and composition of crustacean species during the North West monsoon, collect biological and genetic samples of priority shallow water prawns.
	C4	Reunion (France)	Instrumented Longline Training survey on (Large pelagics)	27 Feb -3 March	7	Provide practical experience in instrumented longline data acquisition and analysis through participation in an at sea training cruise using the RV La Curieuse.
	C2, C3, C5	Kenya	Kenya Shallow-water Crustacean Trawl Survey	21 May -4 June	15	Using a commercial vessel, establish the distribution and composition of crustacean species during the South East monsoon, collect biological and genetic samples of priority shallow water prawns.
	C2, C3, C5	Tanzania	Tanzania Shallow-water Crustacean Trawl Survey	5-19 June	15	Using a commercial vessel, establish the distribution and composition of crustacean species during the South East monsoon, collect biological and genetic samples of priority shallow water prawns.

Year	*Component*	*Countries*	*Survey Title*	*Dates*	*No of days*	*Survey Objectives*
2011 -cont.	C2, C3, C5	Tanzania	Tanzania Acoustic and Demersal Trawl Survey	3-22 Aug	20	Using a commercial vessel, undertake trawl and acoustic methods to assess relative abundances of demersal fish stocks.
	C2, C3, C5	Mozambique	Mozambique Deep-water Crustacean Trawl Survey	21 Oct -11 Nov	23	Using a commercial vessel, establish the distribution and composition of crustacean species, collect biological and genetic samples of priority deep water crustaceans.
	C4, C5	South Africa	SW Moz Channel Large pelagics (swordfish & large tuna) Survey	11 Oct -2 Nov	23	Use the RV Ellen Khuzwayo to tag and release swordfish and collect biological and species distribution data. Collect information on orcas and seabirds.
	C2, C3, C5	Madagascar	Madagascar Deep-water Crustacean Trawl Survey	20 Nov -7 Dec	25	Using a commercial vessel, establish the distribution and composition of crustacean species, collect biological and genetic samples of priority deep water crustaceans.
2012	C2, C3, C5	Tanzania	Tanzania Deep-water Crustacean Trawl Survey	29 Jan -13 Feb	15	Using a commercial vessel, establish the distribution and composition of crustacean species, collect biological and genetic samples of priority deep water crustaceans.
	C2, C3, C5	Kenya	Kenya Deep-water Crustacean Trawl Survey	23 Feb -7 Mar	15	Using a commercial vessel, establish the distribution and composition of crustacean species, collect biological and genetic samples of priority deep water crustaceans.
	C2, C3, C5	Tanzania	Tanzania Deepwater Crustacean Trap survey	11-25 April	15	Using a commercial vessel, establish the distribution and composition of crustacean species, collect biological and genetic samples of priority deep water crustaceans.
	C2, C3, C5	Kenya	Kenya Deepwater Crustacean Trap survey	1-15 May	15	Using a commercial vessel, establish the distribution and composition of crustacean species, collect biological and genetic samples of priority deep water crustaceans.
	C2, C3, C5	Mozambique	Mozambique Deepwater Crustacean Trap survey	15 May -8 Jun	25	Using a commercial vessel, establish the distribution and composition of crustacean species, collect biological and genetic samples of priority deep water crustaceans.
	C2, C3, C5	Kenya	Kenya Demersal Trawl Survey	31 Oct -14 Nov	15	Using a commercial vessel, establish the distribution and composition of crustacean species, collect biological and genetic samples of priority crustaceans.
	C3, C5	Madagascar	Madagascar Acoustic and Dropline Survey	2-13 July	12	Using a commercial vessel, investigate the species composition and biology of deep slope demersal fish resources.
	C3, C5	Mauritius	Mauritius Acoustic and Dropline Survey	14-29 July	16	Using a commercial vessel, investigate the species composition and biology of deep slope demersal fish resources.
	C3, C5	Mozambique	Mozambique Acoustic and Dropline Survey	20 Oct -8 Nov	20	Using a commercial vessel, investigate the species composition and biology of deep slope demersal fish resources.
	C3, C5	Kenya	Kenya Acoustic and Dropline Survey	22-26 Nov	5	Using a commercial vessel, investigate the species composition and biology of deep slope demersal fish resources.
	C3, C5	Tanzania	Tanzania Acoustic and Dropline Survey	11-15 Nov	5	Using a commercial vessel, investigate the species composition and biology of deep slope demersal fish resources.
	C4, C5	Reunion (France), Madagascar	South-East Madagascar and South Reunion Large pelagics (swordfish & large tuna) Survey	9-22 Nov	15	Use the RV La Curieuse to tag and release swordfish and collect biological and species distribution data. Collect information on orcas and seabirds.

2.
CRUSTACEAN SHALLOW-WATER TRAWL FISHERIES

Contributors: Atanasio Brito, Nilza Dias, Johan Groeneveld, Edward Kimani, James Macharia, Xavier Manussa, Catherine Mwakosya, Collins Ndoro, Harrison Onganda, Bárbara palha de Sousa, Maria Lizette palha de Sousa, Herimamy Razafindrakoto, Denis Rouillard and Renison Ruwa.

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2. CRUSTACEAN SHALLOW-WATER TRAWL FISHERIES

A retrospective analysis of their status in the Southwest Indian Ocean

Sean Fennessy[1] and Bernadine Everett[1]

Abstract

Unlike for the deep-water crustaceans, many aspects of the shallow-water crustacean trawl fisheries in SWIOFP countries are remarkably similar in the five countries (South Africa, Mozambique, Tanzania, Kenya, Madagascar) in which they occur. The main target species in all five countries are *Penaeus indicus* and *Metapenaeus monoceros*. Bycatch levels are very high and many of these species are also found throughout all five countries. The trawlers and gear are also similar in all five countries. Excepting for South Africa, the prawns are exported and are a valuable source of foreign currency. Also excepting for South Africa, there are substantial artisanal/traditional fisheries which appear to be growing and increasingly targeting prawns, causing user-conflicts with the trawl sector; user-conflicts are exacerbated by the trawlers discarding large amounts of bycatch species, some of which form part of artisanal fisheries' catches. The ecological impacts of trawling in the region are unknown.

Long-term series of industrial catch and effort data are used for stock assessments and management recommendations, in some cases combined with data from surveys and observers. In each country, shallow-water prawn species are assessed and managed together because they co-occur in trawled catches. It is likely that the status of the shallow water prawns in all five countries is compromised due to one or more of the following: recruitment over-fishing, growth over-fishing, excess effort, habitat degradation and reduced profitability of the trawl sector.

While there are management measures and/or management plans in place for the trawl sector in each country, there are not always clearly quantified objectives, and compliance with some measures is poor. In the artisanal/traditional sector there is no effort limitation, few management measures and low compliance. The fisheries are all managed at a national level, with no regional management strategy. SWIOFP shallow-water prawn stocks could be shared between all five countries; however, the preferred habitats are widely separated by unsuitable habitats; genetic studies have yet to elucidate the extent or otherwise of connectivity between populations.

Introduction and objectives

Apart from fisheries for tuna, trawling for shallow water penaeid prawns is perhaps the most readily identifiable, offshore, industrial fishery in the SWIO region. All the participating African mainland countries as well as Madagascar have this type of fishery, and the export of prawns has earned some of these countries considerable foreign currency as well as providing formal local employment. Early utilization of the resource would have commenced with coastal and estuarine catches by artisanal fishers, followed by trawl surveys or experimental fishing, mainly by foreign vessels in the 1960s and 1970s, which identified the trawling grounds. The occurrence of the prawns in relatively shallow water has meant that they are accessible to both simple fishing techniques as well as increasingly sophisticated methods, which has led to user conflict between artisanal and industrial sectors. In recent years, the development of the mariculture industry for prawns has threatened the viability of industrial-scale fishing, and the increasing perception, particularly by foreign consumers, of the environmental impacts of trawling has further pressurised the trawl industry. Of the five SWIOFP countries in which shallow-water prawn trawling occurs, only Tanzania and Kenya requested SWIOFP ship-based surveys to advance their understanding of this sector.

In addition to the overall Terms of Reference as outlined in Chapter 1, the specific aim of this study was to identify and

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collate available information on shallow-water prawn trawl fisheries and the three identified priority species (*Penaeus indicus, Metapenaeus monoceros* and *Penaeus monodon*) in the SWIO region, to provide recommendations in support of regional management of this valuable resource and additionally to provide specialist advice for the development of the SWIOFP Transboundary Diagnostic Analysis and Strategic Action Plan.

GEOGRAPHICAL SCOPE

Given the distribution of the shallow water prawn resources, the scope of this report is effectively confined to the continental shelf of the African mainland and Madagascar; the island states do not permit trawling and the three shallow-water prawn priority species do not occur there naturally, so these countries are therefore excluded.

METHODS AND MATERIALS

A variety of data sources were identified and interrogated in order to maximise both the quantity and quality of data. This involved *inter-alia* the following:

- Consultative Workshops with relevant governmental and private fisheries institutes, scientists and data experts in Kenya, Tanzania, Mozambique and Madagascar to obtain information and insights into local fisheries.
- Comprehensive literature survey using the SWIOFP Endnote database as a starting point to identify key references in each country.
- Compilation of metadata of relevant existing databases, including SWIOFP StatBase and other datasets identified during the Consultative Workshops (Annex 2).
- Spatial and temporal trends in fishing effort, catches, and catch rates were extracted from historical data and published documents. The information was contextualized and where necessary updated with the assistance of local scientists, data managers and the databases. The location and extent of fishing grounds were based on published maps and documents. Basic biological parameters describing average size, sex ratios, size at sexual maturity, growth and mortality rates, fecundity, and reproductive activity were tabulated for the priority species.

The three crustacean species addressed in this Retrospective Analysis were identified as priority species during the Gap Analysis process, as reported by Groeneveld *et al.* (2010), namely: *P. indicus, M. monoceros* and *P. monodon,* which are trawled in South Africa, Mozambique, Madagascar, Tanzania and Kenya.

Results

DESCRIPTION OF SHALLOW-WATER TRAWL FISHERIES IN THE SWIO REGION

SOUTH AFRICA

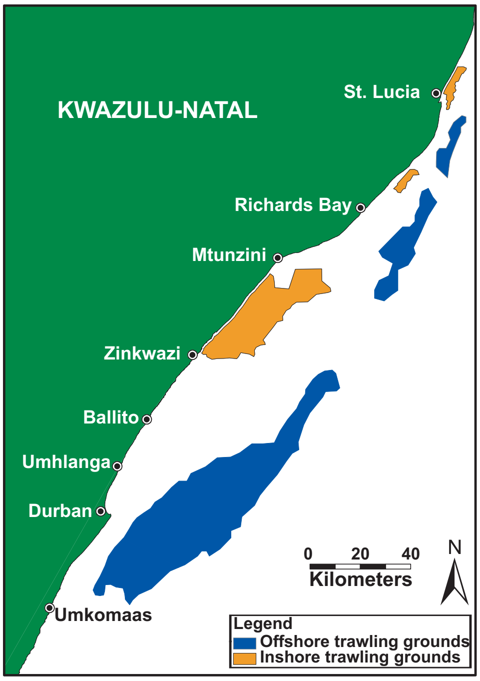
Target species:
- *Penaeus indicus*
- *Metapenaeus monoceros*

Common bycatch species:
- *Otolithes ruber*
- *Johnius* spp
- *Trichiurus lepturus*
- *Secutor* spp
- Elasmobranchs

SPATIAL EXTENT OF FISHERY

The East Coast of South Africa showing the trawl grounds – the inshore grounds (orange) are for shallow-water penaeid prawns, based on logbook data submitted to the Department of Agriculture, Forestry and Fisheries. Fishing on the inshore grounds takes place in water < 50m deep; the largest inshore grounds (Thukela Bank) are approximately 650 km^2 in extent.

Refs: Oceanographic Research Institute, unpubl. data.



FISHING VESSELS AND GEAR

Trawling: Large steel Durban-based vessels (25-40m length, up to 1,500 hp) at sea for up to 35 days at a time. Vessels tow demersal otter trawls (either single trawls or potentially up to four; historically some vessels used booms, 25-60m footrope lengths) with small mesh throughout (currently a minimum of 50mm stretched), at speeds of 2-3 knots; modern navigational equipment is used (GPS, track plotters), with accommodation for a crew of ~20. Average trawl duration is 4-5 hours, day and night; catch is sorted, graded and packed by hand, and blast frozen onboard; prawns may be headed, and are dipped in anti-oxidising agent before freezing; bycatch is retained depending on economic value and freezer space.

Small-scale: Although historically there were bait fisheries for prawns in Richards Bay and St Lucia estuaries, these no longer operate. Artisanal fishing for prawns occurs at very low levels in estuaries using nets, and is illegal; no quantitative information is available on this.

Refs: Mann 1995, Fennessy 1999, 2001, Forbes & Demetriades 2005

HISTORY OF FISHERY

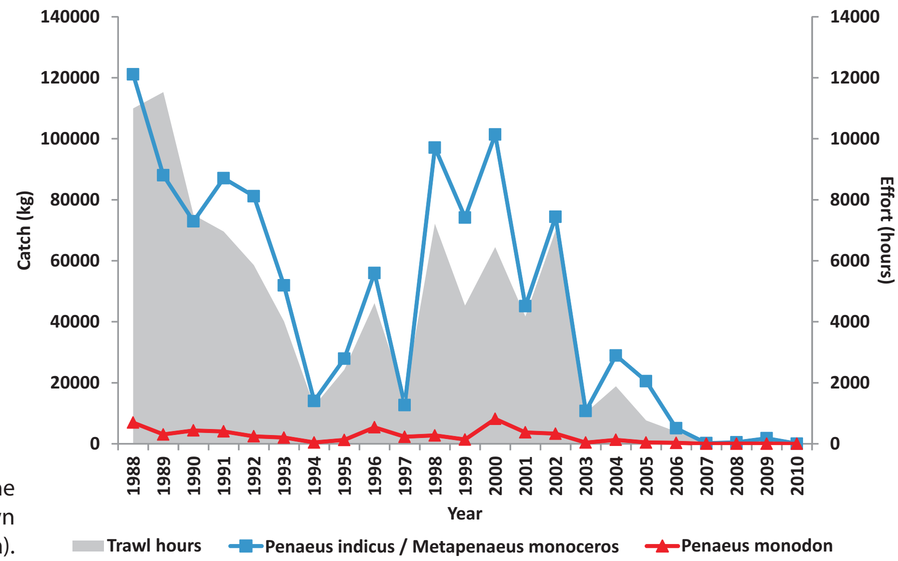
Although exploratory surveys were undertaken in the 1920s and 1930s, and again in the 1960s, commercial trawling for crustaceans in KZN commenced in tandem with the development of prawn trawling in Mozambique in the early 1970s. The early efforts in KZN were initially sporadic, with most of the Durban-based vessels preferring to fish in Mozambique waters. Permits were first issued by the Department of Sea Fisheries in 1972, although there was no distinction made between vessels which fished in Mozambique or KZN. Initial trawling efforts in KZN appeared to focus on the deep-water grounds (see Chapter 3: Crustacean deep-water trawl fisheries). In 1976, the number of KZN-based vessels operating in Mozambique declined sharply and regular trawling by two vessels began on the inshore Thukela Bank grounds in KZN. By 1982, there were twenty vessels with permits based in Durban, four of which were allowed to operate in KZN waters, while the rest operated in Mozambique. In 1983, there was a moratorium on South African vessels fishing in Mozambique, and the total number of trawlers allowed to operate in KZN was set at ten, with only eight (inshore) vessels allowed within 7nm on the Thukela Bank. In 1987, only six permits (inshore and offshore) were utilised in KZN waters, with another nine permits being utilised mainly in Mozambique. In 1989 and 1990, eight inshore and seven offshore permits were issued for KZN, although the number actually used is not apparent. Currently seven permits are issued for KZN, but only three vessels are being used, with two of these operating in Mozambique most of the time. The catch is mostly sold locally.

Refs: Groeneveld &Melville-Smith 1995, Fennessy &Groeneveld 1997, Fennessy 1999, Fennessy 2001

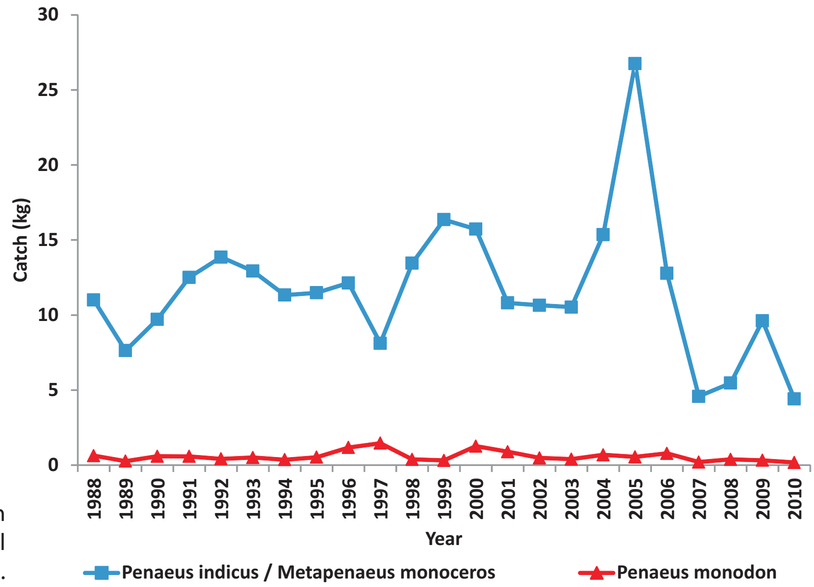
TRENDS IN CATCH, EFFORT AND CPUE

Prawn catches are seasonal, linked to prawn movement out of the estuaries, with highest catches traditionally being made from April to June. Trawlers move to the deep water (>200m) trawl grounds if inshore/Thukela Bank catches are not economically viable. The prawn catch is dominated by *P. indicus*, which contributes in excess of 70%, with *M. monoceros* averaging around 16%, increasing its contribution later in the season. *P. monodon* contributes < 5% to catches, and *P. japonicus* and *P. semisulcatus* contribute negligibly. Species are not separated when being packed, except for *P. monodon*. The annual prawn catch on the Thukela Bank previously averaged about 100t per annum, but catches have declined in recent years, coinciding with a substantial decrease in effort after drought-induced closure of the large St Lucia estuary in 2001, from which about half of the prawns recruit. Additionally, there have been substantial imports of farmed prawns which have further made the inshore fishery non-viable. Consequently, shallow-water trawling has almost stopped. No stock assessments have been carried out for this fishery. In terms of dependence on riverine flow, prawn catches could be reduced by up to 11% if additional dams are built on the Thukela River, owing to the dependence of prawns on this river's output of nutrients and sediments.

Refs: de Freitas 1984, de Freitas 1980, de Freitas 1986, Benfield et al.*1989, Demetriades 1990, Demetriades & Forbes 1993, Fennessy 2001, (DWAF 2004), Forbes & Demetriades 2005, Turpie & Lamberth 2010*



Annual catch and effort for the South African shallow-water prawn trawl fishery (ORI, unpubl. data).



CPUE for the South African shallow- water prawn trawl fishery (ORI, unpubl. data).

MANAGEMENT CONTROLS AND REGULATIONS

Skippers are required to fill in catch logbooks and landing sheets and submit them to the Department of Agriculture, Forestry and Fisheries, and staff of Ezemvelo KwaZulu-Natal Wildlife (the provincial conservation agency) are required to be informed when a trawler discharges its catch, so that it may be inspected. Observers have to be permitted onboard when requested; VMS is compulsory; no trawling is allowed within 0.5nm of the coast.

Total Allowable Effort (TAE) limited entry fishery, only South African citizens may own fishing rights; a maximum of seven annual permits may be issued, of which only four may operate within 7 nautical miles of the coast (i.e. in the shallow-water grounds) at any one time; no trawling allowed < 0.5 nm offshore; the Thukela Bank grounds are closed from September to February inclusive, in order to reduce bycatch of selected Linefish species. No quotas. Minimum stretched mesh size of 50mm knot to knot. Certain fish species are protected and may not be landed or sold (Marine Living Resources Act- 1998). Permits are issued annually; Rights are issued for seven years.

Refs: Fennessy 2001, Sauer et al. *2003.*

BYCATCH AND ECOLOGICAL IMPACTS

The discarded component of catches generally comprises organisms that are of low commercial value, being unmarketable, inedible or too small. Discards comprise almost 75% of total catch. Owing to barotrauma and crushing in the trawls, most of the organisms are dead when they are returned to the water, although some elasmobranchs and crustaceans do survive shallow-water trawls. The discarded catch comprises mainly fishes, with lesser quantities of small, commercially unimportant crustaceans, echinoids and molluscs. Most of the fishes are demersal, shoaling, slow-swimming species. The Thukela Bank grounds have been shown to be a nursery area for some species, particularly fishes from the family Sciaenidae; at least one fish species has been over-exploited by trawling, and trawling impacts on other fisheries' sectors. Little is known about the bycatch on shallow-water Richards Bay and St Lucia grounds, although preliminary studies indicate that the bycatch species composition is substantially different from the Thukela Bank bycatch.

Refs: Fennessy 1994a, b, Fennessy et al. *1994, Fennessy 1995, Fennessy & Groeneveld 1997, Fennessy 2000, Fennessy 2004a,b, Fennessy* et al. *2004, Mkhize 2006, Fennessy & Bianchi 2007, Fennessy* et al. *2008, Oceanographic Research Institute, unpubl. data.*

KENYA

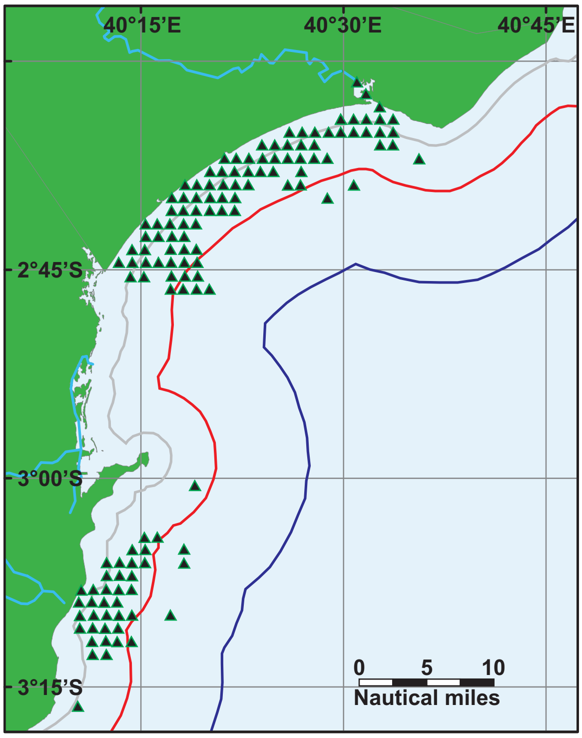
Target species:
- *Penaeus indicus*
- *Metapenaeus monoceros*
- *Penaeus semisulcatus*
- *Penaeus monodon*
- *Penaeus japonicus*

Common bycatch species:
- *Elasmobranchs*
- *Secutor insidiator*
- *Caranx spp*
- *Drepane spp*
- *Haemulidae*
- *Lethrinidae*
- *Scomberomorus spp*

SPATIAL EXTENT OF FISHERY

Located off Malindi and Ungwana Bay, the prawn grounds are between 3-7nm offshore in water <70m deep, and in area are about 350nm^2. The artisanal fishery operates out to 5nm offshore, while trawling is restricted to beyond 3nm or 5nm depending on the size of vessel.

Refs: Fulanda et al. *2011, Munga* et al. *2012*



The Malindi-Ungwana Bay trawling grounds (taken from Fisheries Department and Moi University 2006)

FISHING VESSELS AND GEAR

Trawling: The fleet is mainly comprised of double-rigged vessels with booms, ranging from 25 to 40m in length and all are equipped with blast freezers and storage freezers. The vessel engines are up to 1,500 hp while the catch storage capacity is between 30 and 350t. Mesh sizes range from 55 - <40mm and Turtle Excluder Devices have been compulsory since 2003. Trips range between 16-30 days in an 8-10 month season. Most are operated as joint ventures with foreign companies, and vessels are based at the Kilindini port of Mombasa.

Small-scale: Small wooden boats are used to deploy small-meshed gill nets and beach-seines capable of catching prawns, although the latter are technically illegal.

Refs: Fulanda et al. *2009, 2011*

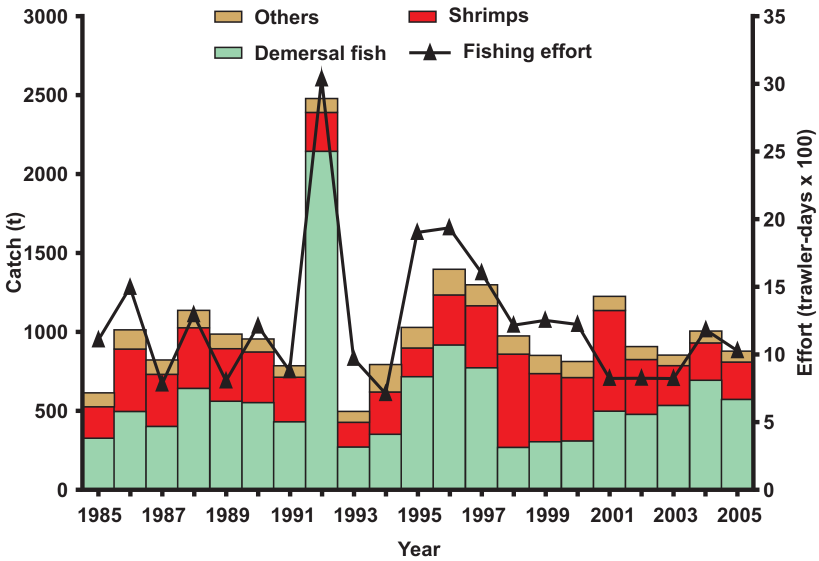
HISTORY OF THE FISHERY

During the late 1960s, deep-sea fisheries development was initiated in Kenya, but regular fishing only commenced in the 1980s, peaking at 17 vessels (seven companies) in 1989-1992. On average, only five vessels operated from 1998-2005. Because of clashes with artisanal fishers, the trawl fishery was intermittently closed in 2000 and 2001, and again in 2006; after re-opening in 2007, it was closed again in 2008-2010. Most recently (2011) only three vessels were licensed of which only two fished in 2011. The catch is mainly exported.

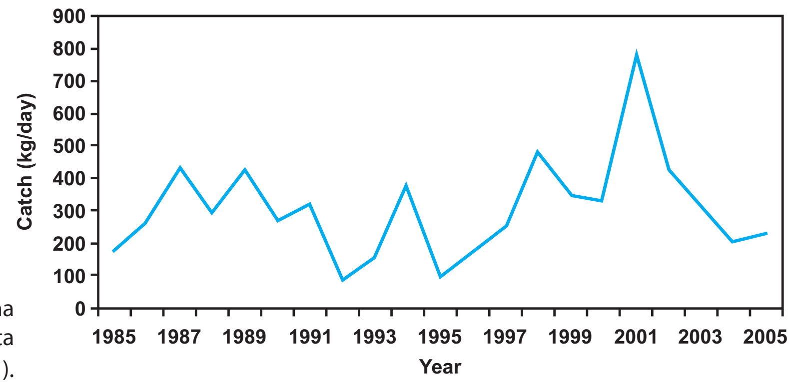
Refs: Fulanda et al. *2009, 2011; Fennessy* et al. *2008*

TRENDS IN CATCH, EFFORT AND CPUE

P. indicus accounts for 55-70% of the trawled prawn catches, *M. monoceros* 10-15%, *P. semisulcatus* <10%, *P. monodon* <10% and *P. japonicus* <5% (Fulanda *et al.* 2011). Munga *et al.* (2013) found distinct species composition and abundance patterns near the Sabaki and Tana Rivers, attributed mainly to depth, turbidity and season. Effort was variable from 1985-2005, and catch and cpue declined towards the end of this period (Fulanda *et al.* 2011). The fishery does not distinguish between the various *Penaeus* spp when packing the prawns.

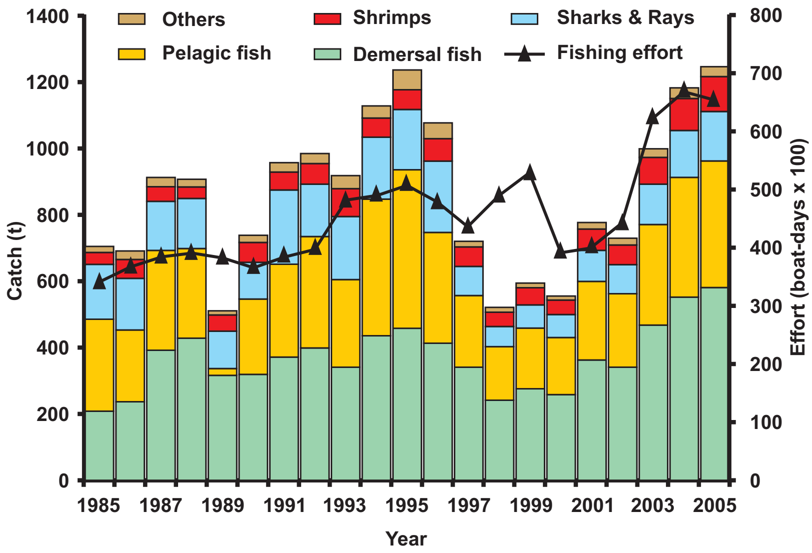


Trends in catch and effort in the Ungwana Bay trawl fishery. Taken from from Fulanda *et al.* (2011).



Trends in prawn cpue in the Ungwana Bay trawl fishery. Based on data in Fulanda *et al.* (2011).

Artisanal catches of prawns are dominated by *P. indicus* and *P. monodon*, depending on sampling locality, with far lesser quantities of *M. monoceros*. Although artisanal cpue showed no trend from 1985 to 2005, varying from 1–1.7 kg/boat-day, artisanal catch gradually increased from around 50 to around 100t p/a as effort increased. From 2006-2008 the estimated artisanal cpue was 1.3-1.7 kg/boat-day (based on 2005 effort) and catch ranged from 46-71t (B. Fulanda, KMFRI, unpubl. data), while an early draft of the management plan estimated annual catch at around 150t.



Trends in catch and effort in the Ungwana Bay artisanal fishery. Taken from Fulanda *et al*. (2011).

Refs: KMFRI KDCP unpublished reports, Munga et al. *2012*

MANAGEMENT CONTROLS AND REGULATIONS

There is a closed season for trawling from November to March, a trawling exclusion zone inshore of 3nm (maximum vessel power 300 GRHP, maximum of four vessels) and inshore of 5nm (maximum vessel power 500 GRHP, maximum of four vessels) and night trawling is not allowed, although these restrictions were often transgressed, exacerbating clashes with small-scale fishers, and leading to trawl closures (see above). Use of TEDs was legislated in 2003, although compliance was initially poor; VMSs are required. An early draft of the management plan recommends, *inter alia*, setting of an annual TAC, a trawl closure of 1 November to 1 April (coinciding with the period when artisanal catches are made), minimum trawl codend mesh of 38mm, and a conflict resolution mechanism, although these are not mentioned in the finalized (2012) version.

Refs: Fisheries Department & Moi University 2006, Fulanda et al. *2011, Munga* et al. *2012.*

BYCATCH AND ECOLOGICAL IMPACTS

Almost 200 trawl bycatch species have been recorded, and bycatch is estimated to be around 7 times greater than prawn catches, mostly comprising fish which are <20cm in length and which are discarded. The main fish species discarded are *Leiognathus* spp, *Pellona ditchela*, *Arius* spp, *Galeichthys* sp and *Trichiurus lepturus*. The main retained fish are *Johnius* spp, *Otolithes ruber*, *Upeneus* spp, *Scomberomorus* spp and *Sillago sihama*. Some of the bycatch species are caught by artisanal fishers, who regard trawlers as being responsible for their declining catches. While some reports refer to the potential damaging effect of trawling, no formal study has been undertaken on ecological impacts; the only study to examine trawl impacts on benthos concluded that there was disturbance but without detailed analysis. The artisanal fishery reportedly catches very low proportions of prawns, with the main focus being on fish, so the prawns themselves appear to be a bycatch in the artisanal fishery, although there is probably targeting of prawns in some areas of the coast.

Refs: KMFRI 2002, Mwatha 2002, Fennessy et al. *2004, Fisheries Department & Moi University 2006, Kimani* et al. *2011a, Kimani* et al. *2011b, Munga* et al. *2012, Munga* et al. *2014, Munga* et al. *(in review).*

TANZANIA

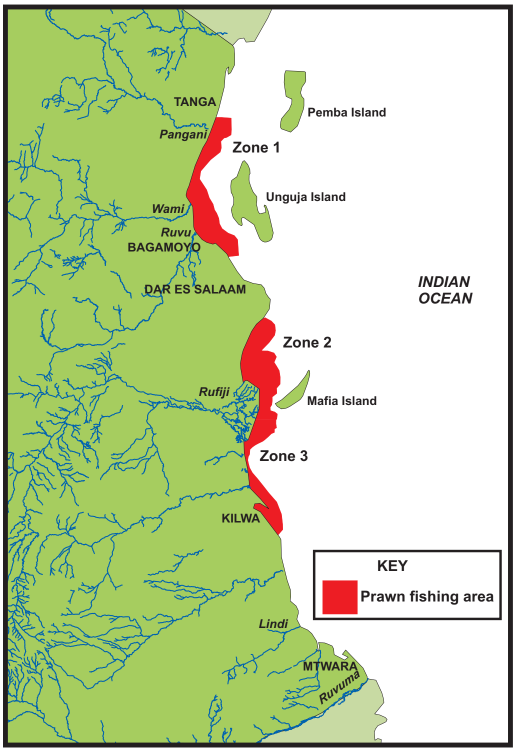
Target species:
- *Penaeus indicus*
- *Metapenaeus monoceros*
- *Penaeus monodon*

Common bycatch species:
- *Gazza minuta*
- *Leiognathus spp*
- *Hilsa kelee*
- *Terapon spp*
- *Upeneus spp*
- *Thryssa vitrirostris*

SPATIAL EXTENT OF FISHERY

The industrial prawn/shrimp fishery is located in three trawling areas totalling around 2 000nm^2, and is confined to three fishing zones shown in the map provided; Zone 1 = Bagamoyo & Sadani, Zone 2 Kisiju = Mafia channel and Rufiji delta and Zone 3 = Jaja and Kilwa; the small-scale (artisanal) fishery occurs along the whole coast.

Refs: Sanders et al. *1988, Bwathondi* et al. *2002, Silas 2011*



Location of the Tanzanian prawn trawling zones (taken from Silas 2011)

FISHING VESSELS AND GEAR

Trawling: Vessel lengths currently range from 24-35m, and up to 600hp, and twin-rigged outrigger trawls are used, although previously up to six nets per trawler were used; minimum mesh size is currently 50mm stretched; tickler chains are used at times. The catch is blast frozen on board; hold capacity is around 30mt, and crew size is up to 25; a standard range of electronic aids is used (GPS, track plotters, radar, etc.). Trawled depths are mainly 4-10m. Vessels are based in Dar es Salaam, and return to port approximately once a month to discharge; most of the catch is exported.

Small-scale: As in Kenya, small wooden boats are used to deploy small-meshed gill nets and beach-seines for prawns, although seines are illegal; cast nets are also used. There is an extensive, well-developed system whereby artisanal prawn catches are sold to dealers in Dar es Salaam for export.

Refs: Richmond et al. *2002, Bwathondi* et al. *2002, Mwakosya* et al. *2009*

HISTORY OF THE FISHERY

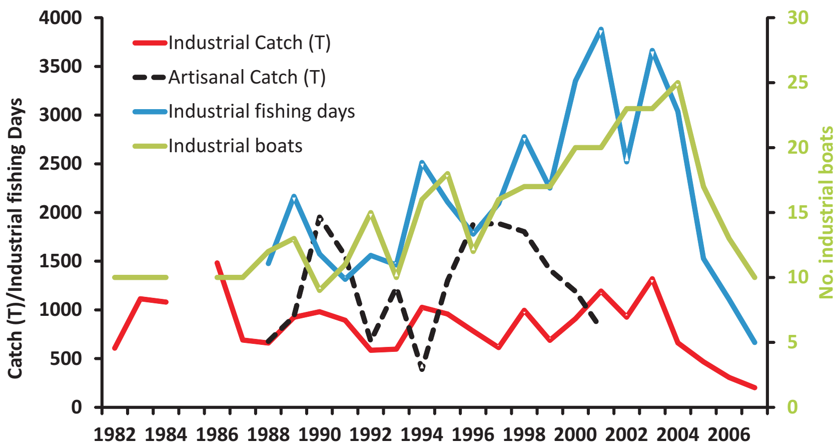
Following surveys undertaken with Japanese assistance in 1968, commercial trawling with a Japanese joint-venture company commenced in 1969. Over the years, a combination of locally-owned, private (foreign-ownership) and joint-venture ownership of licenses has existed. The numbers of licenses increased to 20 in the mid-1990s and up to 25 licenses were issued in 2004; the fishery was closed in 2008 owing to declining catch rates and user-conflict with artisanal fishers. It is unclear when the small-scale fishery commenced, but it has been in operation for several hundred years (albeit not only for prawns).

Refs: Sanders et al. *1988, Bwathondi* et al. *2002, Richmond* et al. *2002*

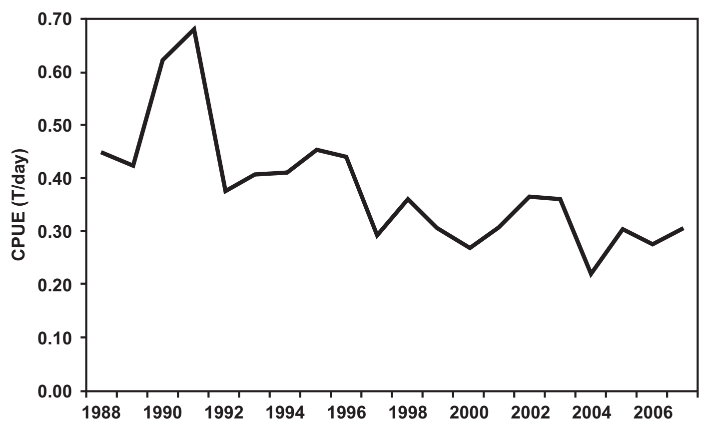
TRENDS IN CATCH, EFFORT AND CPUE

P. indicus and *M. monoceros* generally dominate trawled prawn catches (~ 80-90%) with *P. monodon*, *P. semisulcatus* and *P. japonicus* together contributing the remainder. At times, and depending on the area being trawled and the time of day, these other species can assume greater prominence. Catch rates are highest from April to June (coinciding with the rainy season), declining towards the end of the year; Zone 2 consistently produces the highest catches. Continuous trawl catch records (no. of boats and catch) are available from 1982; prawns are not identified to species level. Trawling effort (in terms of numbers of boats and fishing days) increased steadily from the mid-1990s, despite recommendations to the contrary, and despite declining cpue, until, by the mid-2000s, effort and catch dropped sharply, and the trawl fishery was closed in 2008 in order to allow stock recovery. The artisanal catch (mainly *P. indicus* and *P. monodon*) information is less informative, being very variable; without effort data, these data cannot be easily interpreted but it is clear that the artisanal catch is substantial.

Refs: Sanders et al. *1988, Bwathondi* et al. *2002, TAFIRI, unpubl. data, Mwakosya* et al. *2009*



Trends in catch and effort of Tanzanian prawn fisheries. Data from 1982-1987 are from Sanders *et al*. 1988; data from 1988 onwards are from Tanzanian Dept of Fisheries.



Trend in cpue for the Tanzanian trawl fishery. Data from 1982-1987 are from Sanders *et al*. 1988; data from 1988 onwards are as above.

MANAGEMENT CONTROLS AND REGULATIONS

Trawling effort is allocated on a monthly basis to individual boats for one of the three fishing zones (see map), and is designed to spread fishing effort and reduce excessive harvesting in one area. Trawlers are not supposed to fish in depths shallower than 5m and are required to stop fishing at 18h00; there is a minimum mesh size of 50mm. The amount of bycatch landed is taken into account when an application for the annual trawling license is reviewed. Trawlers are required to maintain logbooks recording catches and effort, and a fisheries officer/observer is required to accompany trawlers on fishing trips. There is a closed season from December to February inclusive, and an exclusion zone in the Tanga province, but no other inshore trawling limit (other than depth). There are no quotas and the fishery has been closed since 2008.

Refs: Iversen et al. *1984, Sanders* et al. *1988, Bwathondi* et al. *2002, Fennessy* et al. *2008, Mahika 2008*

BYCATCH AND ECOLOGICAL IMPACTS

Between 40-80% of the catch of prawn trawlers comprises fish, most of which are juveniles. Well over 100 species occur in trawl catches and species that are most commonly caught include *Leiognathus* spp, *Gazza minuta, Pellona ditchela, Upeneus* spp, *Terapon* spp, *Pomadasdys* spp, *Otolithes ruber, Johnius* spp, Carangidae (including *Decapterus* spp), *Saurida* spp and *Sphyraena* spp. Many of these feature in the artisanal catches as well and trawling companies are encouraged to land bycatch for sale in local markets. The bycatch ratio can be as high as 1: 8 depending on the time and locality of trawling. There is no information on ecological impacts of the Tanzanian trawl fishery.

Artisanal catches are similarly diverse, but there is considerable targeting of prawns, particularly in areas such as the Rufiji Delta; the relative proportions of prawns to bycatch species are not known.

Refs: FAO unpubl., Bwathondi et al. *2002, Richmond* et al. *2002, Fennessy* et al. *2008, Mahika 2008, Castro & Parker 2008, Silas 2011*

MADAGASCAR

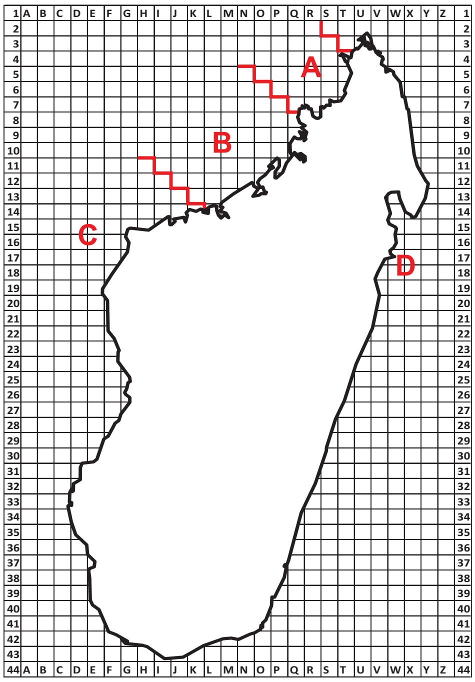
Target species:
- *Penaeus indicus*
- *Metapenaeus monoceros*
- *Penaeus japonicus*

Common bycatch species:
- *Arius madagascariensis*
- *Johnius dussumieri*
- *Leiognathus equula*
- *Nemipterus delagoae*
- *Otolithes ruber*
- *Polydactylus madagascariensis*
- *Pomadasys hasta*
- *Pomadasys maculatum*
- *Saurida undosquamis*
- *Trichiurus lepturus*
- *Upeneus* spp

SPATIAL EXTENT OF FISHERY

The fishery operates along most of the west coast of Madagascar which is divided into 3 zones: Cap d'Ambre to Baie d'Ampasindava, Baie d'Ampasindava to Baie de Boeny, Baie de Boeny to Baie de St-Augustin (Zones A, B & C respectively). The industrial fishery also operates on the east coast in Antongil Bay in the north to Mananjary in the southern part (Zone D). The trawlers operate along the coastal fringe and in bays from 2 to 30m depths, total trawling area about 6800km^2; 85% of the shrimp trawl grounds are in the coastal zone (inside 2 nautical miles), creating conflict with the other sectors. The artisanal fishery is most active in zones B and C while the traditional fishery is active in zone A, C and D, particularly in Ambaro Bay, the Morondava region and Antongil Bay.

Refs: Caverivière et al. *2008*



Madagascan fishing zones/management areas.

FISHING VESSELS AND GEAR

Industrial: The fleet is comprised mainly of twin outrigger vessels, with an average length of 17m and all are equipped with blast freezers and storage freezers, and standard navigational equipment; all vessels have VMS. From 1994, the freezer trawlers began using a double-twin trawl rig consisting of two pairs of nets separated by a trawl skid. Since 2005, a return to the twin net system was introduced (industry-enforced). Since 2007, the use of turtle excluder devices (TEDs) has been mandatory. Trawlers can deploy two to four otter trawls, with total footrope length not to exceed 69m. The minimum stretched mesh size allowed is 40mm in the codend, but currently all vessels use meshes of 50mm. Average engine power is currently 440hp. The industry has introduced numerous measures (e.g. plastic trawl doors, reduced tow durations, larger mesh sizes) in order to reduce fuel consumption and to improve economic viability. An attempt to initiate a closed area programme with traditional fishers has failed to date. The catch is mostly exported.

Artisanal: Although defined as artisanal, these fishers use mini-trawlers with inboard engines of 25 to 50hp, with steel hulls (9 -16t and ~11m in length) or wooden and/or fibreglass hulls (7-8t and 8-10m long). Most use a single trawl net. The length of the headropes range from 10 to 11m and most do not have a winch system. The larger artisanal trawlers tow two trawls using a Florida rig, equipped with side booms and hydraulic winches.

Traditional: The range of gear includes seines, gill nets, fence traps, sometimes deployed from wooden dugouts (no motors). The traditional fishery is similar to that in Tanzania and Kenya in terms of vessel type and gear, although fence traps (*valakira*) are extensively used in shallow water.

Refs: Caverivière et al. *2008, Ranavaison* et al. *2006, Fennessy & Bianchi 2007, Banks & Macfadyen 2010*

HISTORY OF THE FISHERY

Industrial: The fishery started with 11 vessels in 1967 in the northwest and in Morondava, and by 1971 there were 32 trawlers operating. By 1975, 44 vessels were operating, and by 1993, the number of trawlers was 64 on the west coast and five on the east coast; the latter increased to 13 by 1997. From 2003, the number of vessel licenses was capped at 71, although actual numbers are now less than this (42 in 2008); in 2009, trawling stopped in Zones A + B because of very low cpue attributed to traditional fishing.

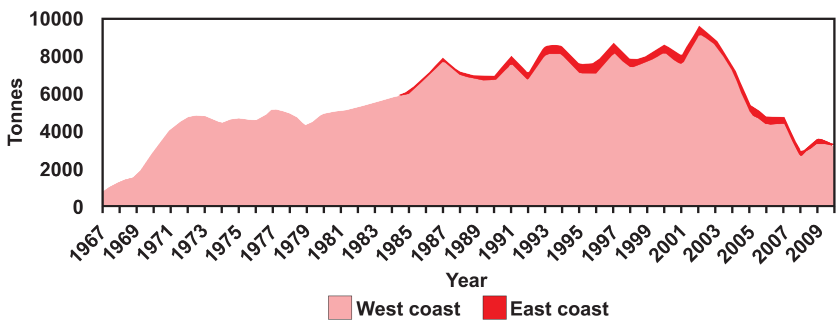
Artisanal: The artisanal fishery began in the early 1970s with 20 vessels in very shallow areas where the industrial trawlers could not operate, but conflicts with the shore-based fence trap fishery forced these small boats to operate in depths greater than 6m. An arrangement with the industrial companies was formed for both the financing of the vessels and gears and also for the sale of the catch. These days the artisanal fishery is mostly controlled by the industrial fishing companies and is active in zones B and C.

Traditional: The traditional fishery dates far back in history. In the past it utilised fence traps but has now incorporated the use of various types of nets, including gills and seines. Effort has reportedly increased substantially in recent years.

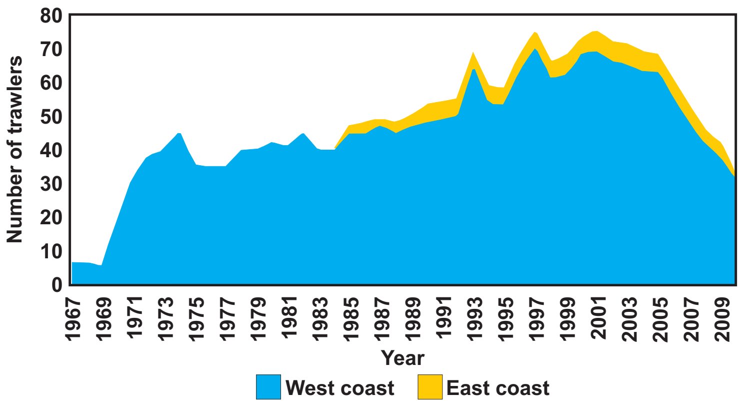
Refs: Caverivière et al. *2008, Kaspryzck (2008), Banks & Macfadyen 2010, Le Manach* et al. *(2011).*

TRENDS IN CATCH, EFFORT AND CPUE

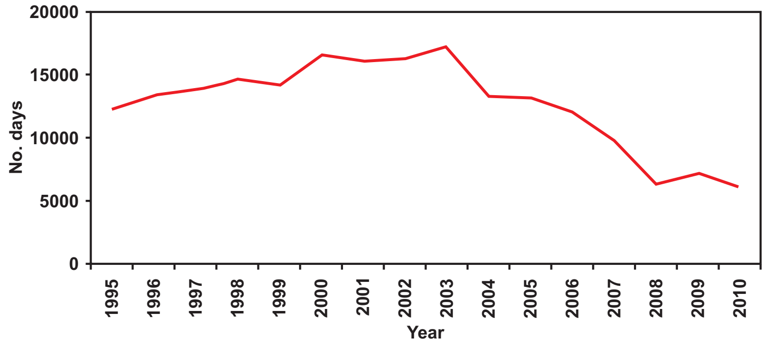
Industrial: Catches are dominated by *P. indicus*, *M. monoceros* and *P. semisulcatus*, although *P. monodon* and *P. japonicus* are also caught; traditionally 50% of catches have been made in the first three months of the fishing season and 84% of the prawn trawl catches came from Zone A on the west coast. The available time series of catches shows a gradual increase from 1967, peaking at 9,500t and declining to 5,000t in 2005 with subsequent further declines to 3,000t in 2008, but recovering to 4,300t in 2011. Effort peaked at close to 80 vessels in the mid-2000s, but by 2008 had already declined to 42 vessels; trawling in zones A and B ceased in 2009 owing to poor catch rates.



Annual industrial trawled catch of prawns from the west and east coasts (Razafindrakoto unpubl.)

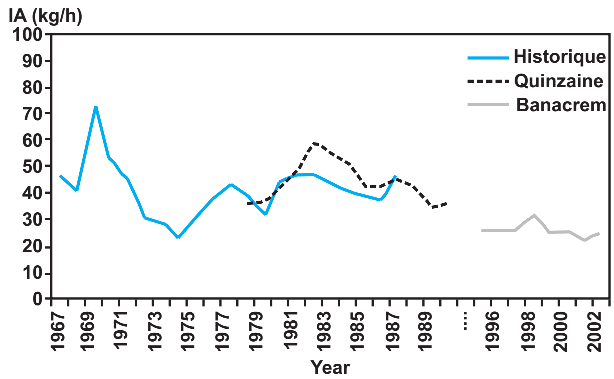


Total numbers of industrial trawlers from the west and east coasts (Razafindrakoto unpubl.)



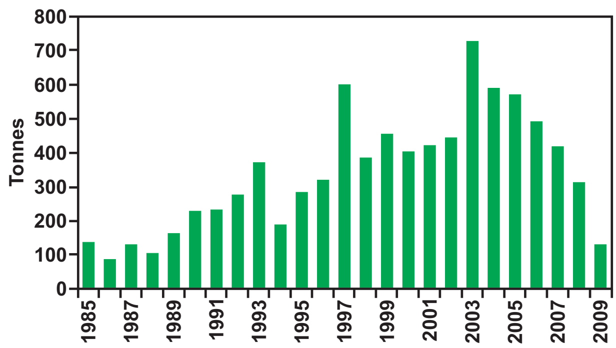
Total numbers of industrial fishing days (Razafindrakoto unpubl.)

Up to 2002, standardised cpue indices are available from three databases to account for the effects of annual changes in engine power, month and area. The results for the entire west coast (where 95% of the catches are made) are shown below; cpue decreases markedly over the period available from 50-70 kg.h^{-1} of fishing to 30 kg.h^{-1} in 2002. Since then, nominal cpue fluctuated between 410 and 580 kg/day from 2004 – 2011, while total landed prawn catch over this period ranged from 3,131 – 8,476t; landings of 4,307t in 2011 represent the highest since 2007, while the nominal cpue of 580 kg/day in 2011 is the highest in the period 2004-2011.

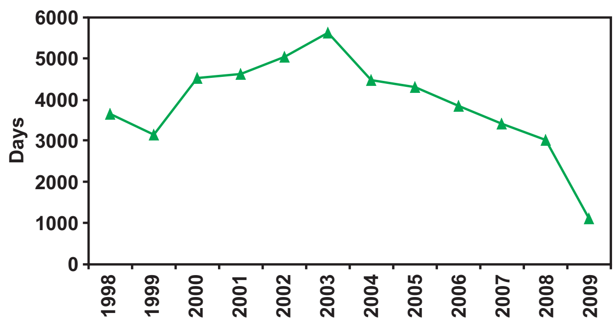


Annual abundance indices (cpue kg/hr) of prawns (all species) from three data sources for the west coast of Madagascar (from Caverivière *et al.* 2008)

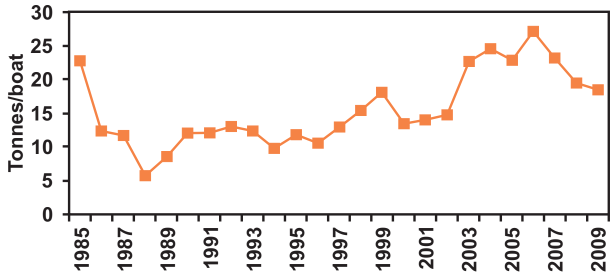
<u>*Artisanal*</u>: *P. indicus* accounts for 90% of catches in the artisanal fishery. Annual catches of prawns have increased since 1985 to a peak in 2003 of 750t, matched by a peak in effort in that year; a catch of just over 100t was reported for 2009. CPUE peaked in 2004 at 25 tonnes per vessel per year; by 2009, the number of vessels had dropped to nine.



Annual catches of prawns by the artisanal fishery (from Razafindrakoto unpubl.)



Annual effort for the artisanal prawn fishery (from Razafindrakoto unpubl.)



Annual catch per boat for the artisanal fishery (from Razafindrakoto unpubl.)

Traditional: There are no annual catch and cpue data available for this sector of the fishery; the number of seasonal (migratory) participants is estimated at 200,000 in Zone A alone, with 8,000 boats being used (Caverivière *et al.* 2008 – although this appears to be an excessive figure), and annual catches are reportedly up to around 3,000t.

Refs: Caverivière et al. *2008, Fennessy & Bianchi 2007, Banks & Macfadyen 2010, WIOFish 2011.*

MANAGEMENT CONTROLS AND REGULATIONS

A co-operative industry-management organisation, GAPCM, was set up in 1995 to facilitate dialogue between the role players. There is a regulatory closed season for trawling (including artisanals) from December to February, but the industry has additionally imposed a longer closed season in some years. Industrial sector effort is capped at 65 vessels in total (although numbers of vessels is currently far less) with fixed numbers per zone, and around 36 vessels in the artisanal fleet; since 2007 in the industrial sector there has been a system of maximum licensed engine units (Gear Fishing Effort Units) linked to vessel horse power and headrope length; no one company can own more than 40% of the GFEUs, but can own up to 1 million GFUEs. Acknowledged reduction in effort required because of declining catch rates, and a buy-back system was suggested by industry, but there was resistance from government.

Catch returns for each drag are mandatory and are submitted to the Fisheries Ministry. Fisheries observers are present on 30% of all industrial outings and 50% of landings are inspected. Industrial trawlers may have two to four otter trawls, whose total headrope length may not exceed 69m. The mesh of the codend of trawls is a minimum of 40mm stretched. Currently, all vessels use meshes of 50mm. Night fishing is prohibited. Fishing permits are issued per zone and vessels may only operate in the zone of their respective permits. All trawl nets are legally required (and enforced) since 2005 to have turtle excluder devices (TEDs) installed, and, increasingly, bycatch reduction devices (BRDs); the TEDS reportedly have caused a 10-15% reduction in trawled prawns. It is required that each kg of trawled prawn landed must be accompanied by 0.5 kg of landed fish.

A management plan is in place which is based on the principle of maximum sustainable yield, incorporating trends in catches, economics and yield per recruit information. A pre-evaluation for Marine Stewardship Council certification was undertaken in 2009. For the traditional fishery any fishing gear which stops the migration of juveniles between the estuary and the sea is prohibited, as well as the use of mosquito nets. While licenses are issued authorising the use of traditional gears, there does not appear to be a cap on this.

Refs: Caverivière et al. *2008, WIOFish 2012, Razafindrainibe 2010, Banks & Mafadyen 2010*

BYCATCH AND ECOLOGICAL IMPACTS

A wide variety of bycatch species is caught, mainly fishes, with the dominant species being *Otolithes ruber*, *Terapon* sp., *Pelates quadrimaculatus*, *Pomadasys kaakan*, *Nemipterus bleekeri, Leiognathus equula, Gerres* sp., *Upeneus* sp., *Johnius* spp, *Trichiurus lepturus* and *Saurida* sp. in both the industrial and artisanal sectors. The species composition varies with fishing zone, and the proportion of retained bycatch increases as the season progresses due to a decline in the abundance of prawns. The ratio of discarded catch: retained catch (prawns and fish) ranges between 0.86 and 0.36. Total bycatch of the industrial fleet for 2005 was estimated at just over 14,000t, but in previous years has been as high as 20,000 – 30,000t. Bycatch levels have reportedly declined with the requirement that vessels land part of their bycatch, and because of the requirement to use TEDs; the artisanal sector catches about 4,000t of bycatch. There is no readily-available information on ecological impacts of prawn trawling in Madagascar.

Refs: FAO unpubl., Fennessy et al. *2004, Ranavaison* et al. *2006, Caverivière* et al. *2008, Banks & Macfadyen 2010, Razafindrainibe 2010*

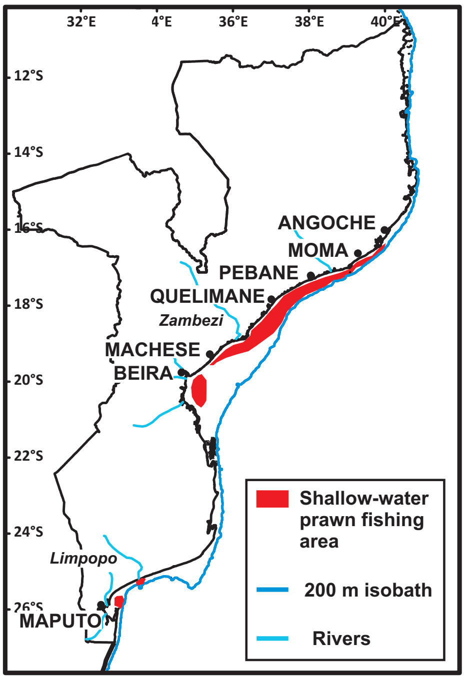
MOZAMBIQUE

Target species:
- *Penaeus indicus*
- *Metapenaeus monoceros*
- *Penaeus latisulcatus*
- *Penaeus monodon*
- *Penaeus japonicus*

Common bycatch species:
- *Otolithes ruber*
- *Johnius dussumieri*
- *Johnius amblycephalus*
- *Arius* spp
- *Leiognathus equula*
- *Nemipterus bleekeri*
- *Pomadasys kaakan*
- *Pomadasys maculatum*
- *Saurida undosquamis*
- *Trichiurus lepturus*
- *Upeneus* spp

SPATIAL EXTENT OF FISHERY

The main trawling areas are on the very large (~50,000km^2) Sofala Bank grounds in the north, with smaller grounds off the Limpopo River and in Maputo Bay (381km^2) in the south; maximum depth trawled is 70m. The larger industrial vessels only operate on the Sofala Bank while semi-industrial trawlers operate on all three grounds; the Limpopo grounds are trawled to a very limited extent. Trawlers are based at the ports of Beira, Quelimane, Angoche and Maputo. Artisanal harvesting (equivalent to traditional harvesting in Madagascar) of prawns occurs in estuaries and shallow coastal waters, beaches and mud flats in close proximity to rivers wherever they occur on the Mozambican coast.



Mozambican shallow-water prawn trawling grounds (IIP, unpubl).

FISHING VESSELS AND GEAR

__Industrial__: historically, semi-industrial trawlers were motorized steel vessels up to 20m overall length, and catches were preserved on board using ice, requiring the boats to return to port each day. Industrial trawlers are steel or fibreglass motorized vessels more than 20m in overall length, using refrigeration methods to preserve the catch, thereby being able to stay at sea for up to a month, or longer if they were replenished by mother vessels. Since 1996, the distinction between semi-industrial and industrial became increasingly blurred as the sophistication of the semi-industrial vessels has increased (e.g. some are now made from fibreglass), and some trawlers which are < 20m in length are now designated as industrial because they are able to freeze their catch on board and hence are able to stay at sea for long periods. Both types use otter trawls, with either single trawls in the case of simple semi-industrial vessels, but up to four trawls on outrigger booms in the case of larger vessels. Initial mesh size for trawling was 37mm, but is currently 55mm. Standard navigational equipment (GPS, chart plotters, SatNav, radar) and fishing equipment (echo sounders, net sondes) are used, but generally more often on the industrial fleet.

Artisanal: A range of non-motorized wooden vessels <10m in length is used to deploy a variety of nets to catch prawns, including seine nets and gill nets; nets may also be set without a boat i.e. from the shore. There are also motorized vessels <10m in length, so technically designated as artisanal, which trawl for prawns. The artisanal seine net fishers are supposed to use 37mm mesh, but they often use smaller sizes.

Refs: Palha de Sousa et al. *1992*

HISTORY OF THE FISHERY

Industrial: The first industrial-type trawlers started fishing in 1964, and numbers increased very rapidly after independence in 1974 to attain a fleet size of 70-80 trawlers by 1980; catches by the trawl sector peaked at 9,377t in 1981. There was a peak of 97 trawlers in 1999, despite declining catch rates; the number of industrial vessels subsequently declined, reaching 55 industrial trawlers in 2010; numbers of semi-industrial licenses fluctuate around 50-60, but not all these vessels are operational. Prior to 1991, only daytime hauls were made but, after that year, night-time hauls became common practice, and the number of nets increased from two to four. Associated with the night hauls was a change in catch composition to increased proportions of the nocturnal species *P. latisulcatus* and *P. japonicus*, particularly in the latter part of the season when catch rates of *P. indicus* and *M. monoceros* decline. Most of the semi-industrial and industrial catch is exported, catches from the former mainly to southern Africa, the latter currently mainly to Europe, and there are joint venture arrangements between foreign-owned companies and local counterparts.

Artisanal: Artisanal fishing for prawns has occurred for many years, but monitoring in areas other than Maputo Bay only commenced in 1998, and then only in a single area; monitoring has gradually expanded into the rest of the coast. Maputo Bay annual prawn catches fluctuated between 100-300t up until the early 2000s, and is currently estimated to be around 1,400t. Presently, estimates indicate numbers of artisanal fishers in the Sofala Bank area alone to be over 80,000. An unspecified part of the artisanal catch is processed on land for national distribution and also for the southern African region.

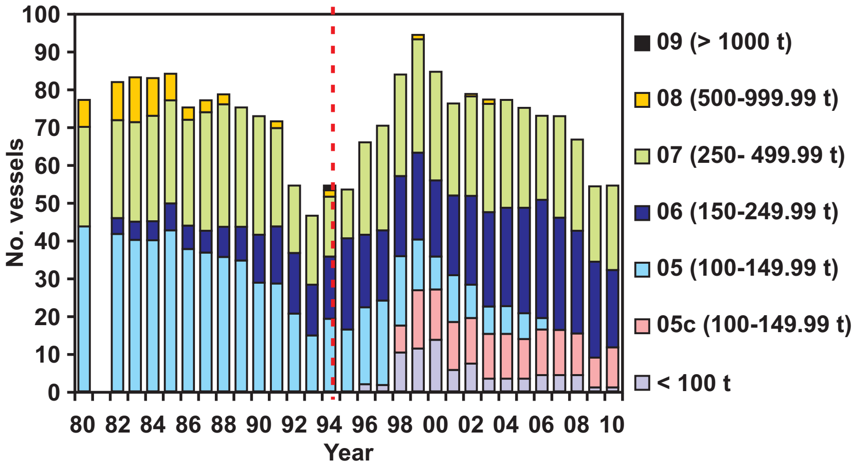
Refs: *Ulltang* et al. *1985, Skagen & Palha de Sousa 1997, Palha de Sousa* et al. *2006, Photopoulos & Peterson 2010, Palha de Sousa* et al. *2011*

TRENDS IN CATCH, EFFORT AND CPUE

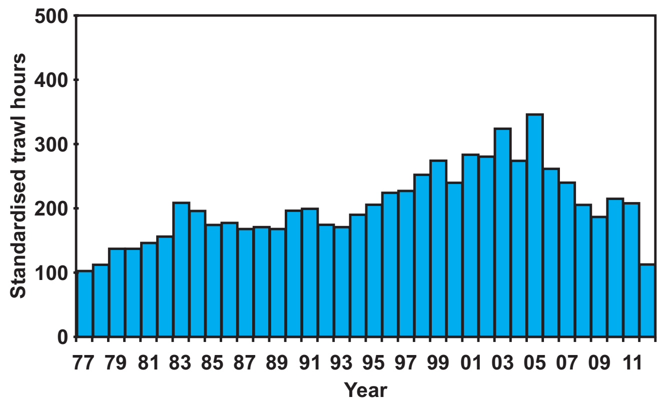
Industrial: The majority (~90%) of trawled prawn catches comprise *P. indicus* and *M. monoceros*, with *P. latisulcatus* and *P. japonicus* comprising around 9-13%; *P. monodon* appears to constitute a very small part of catches. The trawl fleet accounts for around 75% of total prawn landings, and of this, around 80% is made by the industrial fleet. Numbers of licenses declined in the mid-1990s, then increased until 2000, whereafter they declined. Standardised effort remained static until the mid-1990s, then increased (with the advent of night trawling and the use of four nets), and then started to decline towards the 1980s levels. Catches peaked at around 9 500t in 1982, declined until 1990 and then peaked again at almost 9,000t in 2000/2001; then there was a steady decline until the lowest recorded level in 2008, with a slight recovery thereafter. Standardized cpue declined sharply from the late 1970s to the late 1980s, then declined more slowly to 2004, whereafter it remained steady.

Limited annual information on semi-industrial prawn catches for Maputo Bay is available prior to the late 1980s; the fishery commenced in the mid-1960s, from when catches rapidly escalated to a maximum of around 800 t/annum by the early 1970s. Prawn catches from 1989 to 1998 fluctuated between 100 and 150t per annum, increasing to a maximum of 250t in 2005. Effort remained at between 15-25 boats until 2006, and cpue closely tracked catches. Semi-industrial catch records for the Sofala Bank indicate increasing effort and catch from 1992 to 2005, whereafter there were declines in effort and catch.

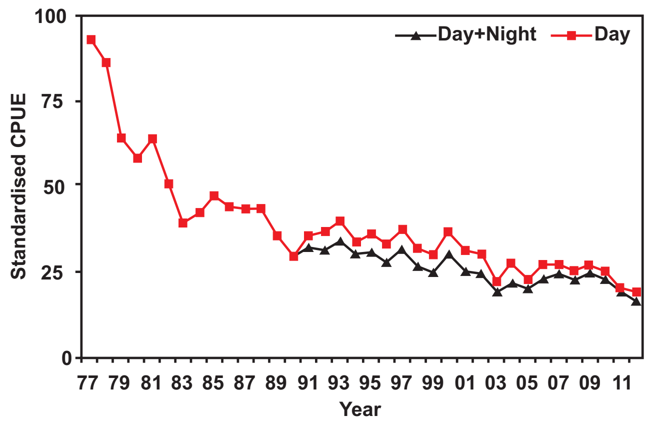
Artisanal: Only a short time series of artisanal catch and effort is available; intermittent surveys have occurred, with regular monitoring only commencing in the late 1990s, and then only in limited localities, although the monitoring system is expanding. Catches are dominated by *P. indicus* (~90%), although this proportion varies spatially and temporally. Prawn catches comprise 1-20% by weight of total artisanal catches, also depending on area and season. The data available indicate that artisanal catches from the Sofala Bank area between 2000 and 2008 fluctuated between 100 and 1,000t per annum, and in 2010 was around 1,400t; there are indications of increased targeting of prawns in some areas, with consequent increased catches by this sector; however, the data are incomplete and must be treated with caution.



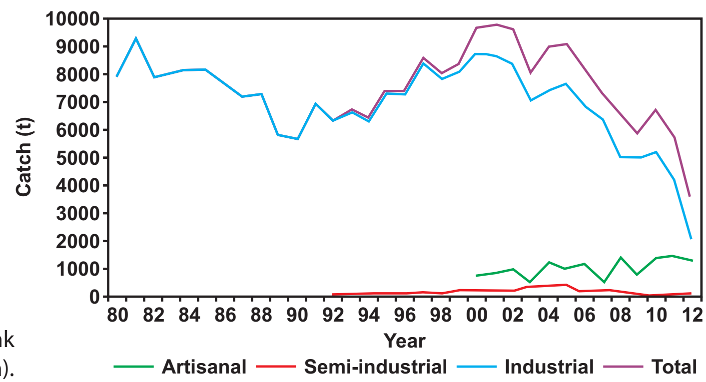
Annual numbers of licenses of industrial trawlers on the Sofala Bank by gross tonnage category (Palha de Sousa *et al.* 2011)



Annual numbers of standardised trawling hours by industrial trawlers on the Sofala Bank; (from the management plan).



Standardised cpue on industrial trawlers on the Sofala Bank by day (red) and day and night combined (black) (from the management plan).



Total prawn catch by sector for the Sofala Bank (from the management plan).

MANAGEMENT CONTROLS AND REGULATIONS

The trawling fleet is managed by a combination of effort limitation (vessel numbers), seasonal closures and a company-based catch quota TAC (the latter is for industrial vessels only, dependent on historical involvement in the fishery); the TAC is based on annual stock assessments, but is often increased by the fisheries department; in recent years the effective TAC has been fixed for three years to provide stability for the industry. The TAC is frequently not attained, so effort control is the main management tool. All trawlers require an annual license and a fishing right, the latter may be issued for up to three years; as of 2000, no new trawling licenses were allowed i.e. the number of vessels is capped. Vessels are required to report catches and effort every 10 days; fisheries inspectors accompany most trips. Although TEDs are required by law, this is not enforced; VMSs are required by law. Mesh size has increased from 37mm in the codend prior to 1989, to 55mm currently. Trawling by industrial and semi-industrial vessels inshore of 3nm and 1nm respectively is prohibited. Bycatch should be landed in the ratio of 2:1 relative to prawn landings, and companies may be fined if this is not achieved. There is a closed season of variable timing and application per sector; this was initially (in 1991) from January to February inclusive, but for the semi-industrial and industrial fleet is now from September to February/March; for the artisanal sectors the closed season is from December to January. Certain net types and mosquito mesh linings of nets are banned in the artisanal fishery (minimum mesh size is 37 mm), and they may not fish beyond 3nm of the coast, but compliance is believed to be low. It is intended to ultimately cap artisanal effort. There is an EAF-supported management plan in place (May 2014), which emphasizes the need to reduce industrial trawling effort to 140,000 hours per year and to achieve a spawning stock of 20% of the virgin biomass (ADNAP 2014).

Refs: Photopoulos & Peterson 2010, Brito 2010, Palha de Sousa et al. *2006, Palha de Sousa* et al. *2011*

BYCATCH AND ECOLOGICAL IMPACTS

Although it is required that 2kg of bycatch is landed for every kg of prawns, around 30,000-40,000 tonnes of unwanted catch is discarded each year. Approximately 80% of the trawler catch consists of small, juvenile, low-value fish, most of which is discarded. Both semi-industrial and industrial trawlers sell bycatch to local fishers on small boats on the Sofala Bank. This bycatch is offloaded frozen and enters a semi-formal network distributing it as far inland as Malawi. The species most commonly caught include *Otolithes ruber*, *Johnius amblycephalus*, *J. dussumieri*, *Trichiurus lepturus*, *Arius* sp, *Pellona ditchela*, *Thryssa vitrirostris, Pomadasys maculatum*, *Upeneus* spp. There is apparently little bycatch in the artisanal fishery, as fishers maintain that they target fish, and prawns are considered a bycatch – although it is apparent that in some areas prawns are targeted. No ecological impacts of trawling are recorded, although *O. ruber* was reported as being over-exploited by trawlers in the 1980s.

Refs: FAO unpubl., Schultz 1992, Fennessy et al. *2004, Moody Marine 2008, Chaúca* et al. *2011, Palha de Sousa* et al. *2011,* ADNAP 2014.

PRIORITY SPECIES PROFILES

Note: Estimates of biological parameters in the available literature sometimes varied from survey to survey owing to differences in timing or in research approaches adopted in a particular study; for this reason, in some instances, review publications are cited rather than the original authors; where possible the "typical" values for trawled populations are provided here, particularly when they are still being used for stock assessments, even though the values may be from earlier research.

PENAEUS INDICUS

Target fisheries:

Kenya:
- Industrial nets, inshore, prawns
- Small nets, cast nets, fish & prawns
- Small nets, gillnets, crustaceans
- Small nets, seine nets, crustaceans

Madagascar:
- Industrial nets, inshore, shrimps
- Small nets, cast nets, fish & shrimps
- Small nets, mosquito nets, fish
- Traps, barrages, mangroves
- Traps, fence traps, Valakiras (Barrage côtier)

Mozambique:
- Industrial: nets, trawl, shrimps
- Semi-industrial: trawler, shrimps, Maputo Bay
- Artisanal: small nets, bottom gillnet
- Small nets, gillnet, shrimp

South Africa:
- Small nets, gate net/trawl, shrimp/prawn
- Industrial nets, inshore, crustaceans

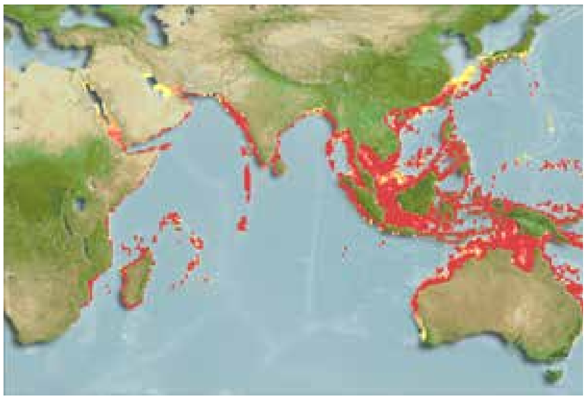
Tanzania:
- Industrial nets, inshore, crustaceans
- Small nets, seine nets, crustaceans

Common names:
- Indian white prawn (FAO)
- Thukela prawn (RSA)
- Kamba weupe (Kenya, Tanzania)
- Makamba, Patsa (Madagascar)
- Camarão branco (Mozambique)

DISTRIBUTION AND HABITAT

Widely distributed: E. and S.E. Africa to S. China, New Guinea and N. Australia. Habitat: soft bottom mud. Adults are marine, juveniles are estuarine.
Maximum depth of 75 m.

Refs: http://www.sealifebase.org



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

General: Mating occurs offshore between a freshly moulted female and a hard-shelled male, often at night; the latter transfers a spermatophore to the female, which is broken open when the eggs are released offshore in deeper water; an individual can spawn several times in its life.

South Africa: Few biological studies done, all from 1970s. Female maturity starts at around 23mm carapace length CL, the majority of females are mature at 35-36mm CL. Spawning occurs throughout the year, but with a peak in May and again in August-November. Fecundity approximately 228,000 ova (no. ova = $9.262 \times CL^{2.7599}$).

<u>*Mozambique*</u>: *Maputo Bay* - female maturity commenced at 21-22mm CL; female size at 50% maturity = 37-38mm CL, males considered mature from 25-26mm CL; *Sofala Bank* – various studies found onset of female maturity at 14-15cm TL (equivalent to 30-33mm CL); spawning mainly from April to July, declining until August, then gradually increasing until another less pronounced peak in December.

<u>*Tanzania*</u>: Spawning peaks in January to March. In 2001, females from Bagamoyo reached 50% sexual maturity at 15.5cm total length TL while those from Rufiji attained 50% maturity at 14.7cm TL. Fecundity varies between 98,000 and 222,000 eggs for prawns of 15.8–37.9g body weight and between 40,000 to 222,000 eggs for prawns of CL 3.5–4.2cm.

<u>*Kenya*</u>: A large proportion of the trawled prawns are immature, while there are suggestions that higher proportions of "berried" prawns (presumably mature) occur in 25-30m and 40-45m water depths.

<u>*Madagascar*</u>: Females mature from 20mm CL (3.2 months). The size at 50% maturity is 32mm CL (6.6 months). Between 0.5 and 1 million eggs are produced per female.

Refs: Champion 1970a, Emmerson 1980, Le Reste & Marcille 1976, de Freitas 1980, de Freitas 1984, Brinca & Mascarenhas 1985, de Freitas 1986, de Freitas 1995, Cyrus & Forbes 1996, Bwathondi et al. *2002 , Teikwa & Mgaya 2003, Fisheries Department and Moi University 2006, Hough and Marin 2009, Mwakosya* et al. *2009*

LARVAL DISTRIBUTION & RECRUITMENT

<u>*General*</u>: Once the female releases her fertilised eggs into the marine environment they develop into pelagic larvae, followed by 1.5-2mm CL post-larvae which are transported into estuaries (ideally with mangroves) where they remain for a few months before emigrating out to sea as juveniles (~15-20mm CL), in response to reduced salinities, and they mature in large inshore bays or the open sea. Recruitment is very variable for shallow-water prawns, and is closely linked to river flow.

<u>*South Africa*</u>: A tagging study indicated that juveniles recruited mainly from the St Lucia and Richards Bay estuaries to the Thukela Bank trawl grounds; larvae produced on the Thukela Bank recruit back mainly to these estuaries, apparently semi-continuously in the case of St Lucia, where juveniles start to feature in estuarine catches in September-October. Generally, juveniles (post-larvae) migrate into St Lucia in spring (September-November) and migrate as adults out to sea in late summer-autumn (February-June). Recruitment to the offshore grounds is apparent in catches in March-May, from sizes at small as 12mm CL, but more commonly 20-32mm CL.

<u>*Mozambique*</u>: Recruitment varies both inter- and intra-annually; in most years the recruitment of *P. indicus* on the Sofala Bank peaks in March although the extended spawning period means there is a lengthy recruitment period, which starts with recruits from the February-April spawning first appearing on the trawl grounds in October/November of that year. This group continues recruiting to the trawl grounds during summer and with growth forms a significant cohort of intermediate size shrimp when fishing begins in the next season. Spawning after winter (from August to November) results in the second and major peak of recruitment, which enters the fishery from March to May and obscures the small number of larger autumn spawned recruits. These spring-spawned recruits appear to make up the larger part of the annual recruitment for the *P. indicus* stock. New recruits are found closer inshore, and move offshore as the season progresses. There are conflicting findings regarding correlation of recruitment with the run-off of the Zambezi river.

<u>*Tanzania*</u>: Spawning peaks from January to March and new recruits appear in the coastal waters from February to May. Adults and pre-adults are found in large numbers along the coast during the heavy rain season (March-May). The post-larvae in Zanzibar show maximum recruitment influx from spawning areas to protected bays and estuaries (nursery areas) from February to March.

<u>*Kenya*</u>: Not available; based on highest trawl catch rates in July-November, it is assumed there is recruitment from the inshore nurseries prior to these months.

<u>*Madagascar*</u>: Study of the movement of *P. indicus* shows that there is no polarized displacement for this species in Madagascar. However, the diffusivity of prawns is not negligible, and is lower in the north than in the south. The prawns could move from month to month in the three contiguous management zones along the west coast. The study of the movement of the prawns from mark recapture studies indicates that the west coast of Madagascar has a continuous distribution of abundance in the southern part and a discontinuous distribution in the north. In the northern

part of Madagascar, Ambaro Bay to Cape St. Andre, prawns seem to be confined to each bay. In the north, strong recruitment of *P. indicus* occurs in March and April. From June until the end of the year, recruitment is almost nil. In the northwest area, maximum recruitment occurs in May. Recruitment of low intensity occurs from September to December. In the southwest area, recruitment is spread over the whole year but there is a peak period from June to August. Strong recruitment may also occur from March to April as well as in October.

Refs: Champion 1970b, Le Reste & Marcille 1976, Brinca et al. *1981, da Silva 1986, Sousa 1986, Gammelsrod 1992, Forbes* et al. *1994, Forbes & Demetriades 1995, Palha de Sousa* et al. *2006, Brito & Pena 2007, Caverivière* et al. *2008, Silas 2011, Palha de Sousa 2011*

MOULTING AND GROWTH

General: A very fast-growing species, most individuals completing their life cycle within one year
South Africa: Thukela Bank (1970s) – growth rates of 4mm and 2mm/month for females and males respectively.
Mozambique: Sofala Bank: Females L_{inf} = 48.2-53.6mm CL, K 2.52-1.9 yr^{-1}, Males L_{inf} = 39-41.9mm CL, K 3.0-2.8 yr^{-1}
Tanzania: In 2001, highest proportions of post-moult prawns were encountered in Bagamoyo in April, and in October in Rufiji. Females and males combined: Zones 1 and 2 (2008): L_{inf} 22.49 – 24.64 cm TL, K 1.31-1.71 yr^{-1}
Kenya: Not available; use has been made of Madagascan growth parameters
Madagascar: *Warm season:* Females L_{inf} = 47mm CL, K 0.11-0.278 $month^{-1}$, Males L_{inf} =33-35mm CL, K 0.121-0.225 $month^{-1}$ *Cold season:* Females L_{inf} = 47mm CL, K 0.055-0.181 $month^{-1}$, Males L_{inf} =33-35mm CL, K 0.156-0.194 $month^{-1}$

Refs: Champion 1970b, Sousa & Palha de Sousa 1992, Munguambe 1995, Bwathondi et al. *2002, Caverivière* et al. *2008*

MAXIMUM SIZE

South Africa: 55mm CL
Mozambique: 56mm CL
Tanzania: 20 cm TL
Kenya: 47mm CL
Madagascar: In the warm season maximum lengths ranged between 41.0 and 50mm CL, while in the cold season they were 32.2-39.0mm CL (depending on zone).

Refs : Champion 1970 b, Munguambe 1995, Bwathondi et al. *2002, Caverivière* [et al]*. 2008, Mwakosya* et al. *2009, Kimani* et al. *2011c*

NATURAL MORTALITY

South Africa: Not available
Mozambique: A generalised figure of 2.16 yr^{-1} is used
Tanzania: Males and females combined 1.37 yr^{-1} in Bagamoyo and 1.26 yr^{-1} in Rufiji (2001), although Mwakosya *et al.* (2009) used values of 2.14 – 2.64 yr^{-1}, and Sanders *et al.* (1988) used a figure for combined prawn species of 3.0 yr^{-1}.
Kenya: Not utilised, as stock status is estimated using production modelling
Madagascar: A median value of M=0.2 $month^{-1}$ is used with a range of 0.1-0.3 $month^{-1}$

Refs: Sanders et al. *1988, Palha de Sousa* et al. *1995, Bwathondi* et al. *2002, Caverivière* et al. *2008*

LENGTH-WEIGHT

South Africa:

	CL/TL(mm):	CL/W(mm/g):
Males	TL = 4.293 CL + 19.172	$W = 0.973 \times 10^{-3} CL^{2.9509}$
Females	TL = 3.596 CL + 33.941	$W = 1.848 \times 10^{-3} CL^{2.73157}$

Mozambique: (Maputo Bay)

	CL/TL:	CL/W(mm/g):	TL/W:
Males	TL = 4.036 CL + 23.938	$W = 1.424 \times 10^{-3} CL^{2.814}$	$W = 1.0 \times 10^{-6} TL^{3.387}$
Females	TL = 3.769 CL + 29.538	$W = 1.214 \times 10^{-3} CL^{2.882}$	$W = 4.0 \times 10^{-7} TL^{3.549}$
Combined	TL= 3.839 CL + 28.231	$W = 1.330 \times 10^{-3} CL^{2.830}$	$W = 6.0 \times 10^{-7} TL^{3.483}$

Tanzania:

Combined sexes: $W\ g = 1.264 \times TL\ cm^{2.973}$

Kenya:

Not available

Madagascar:

Females	log Wt = 2.6337	log CL- 2.6060
Males	log Wt = 2.7739	log CL- 2.7645
Combined	log Wt = 2.6378	log CL- 2.5977

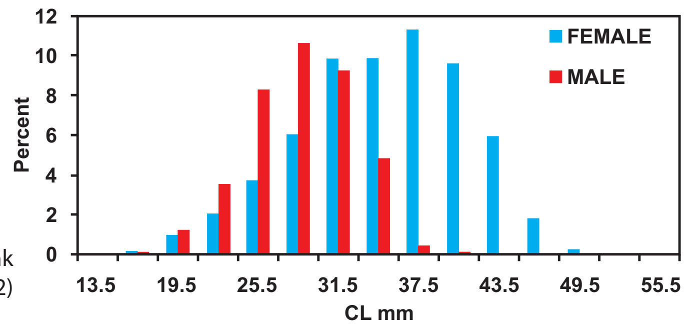
Refs: Champion 1970, Le Reste et al. *1974, de Freitas 2004, Teikwa & Mgaya 2003*

POPULATION SIZE STRUCTURE

General: Because prawns are so fast-growing, there is great variability in size structure depending on where and when the prawns are caught and the characteristics of the gear used; generally, estuarine and inshore prawns are smaller in size than those offshore; prawns gradually move into deeper water as they grow. Where possible overall annual length frequencies for trawled catches are presented.

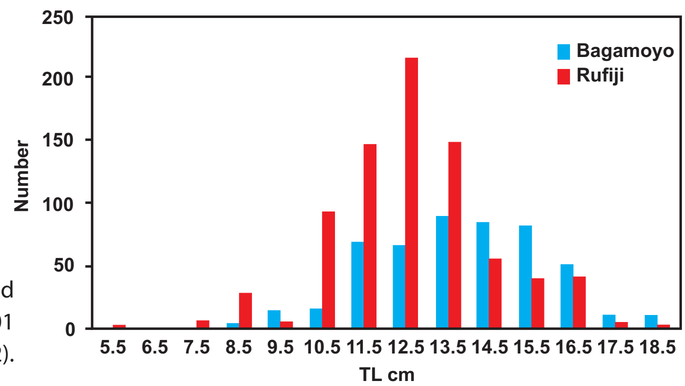
South Africa: Not available

Mozambique: On the main trawling grounds (Sofala Bank), females dominate the larger length classes, and size composition also differs from north to south, with bigger individuals (females 32-44mm CL, males 28-36mm CL) occurring in the north; further south, the distribution is bimodal, and the size range for females is 24-32mm CL and for males between 24-28mm CL.



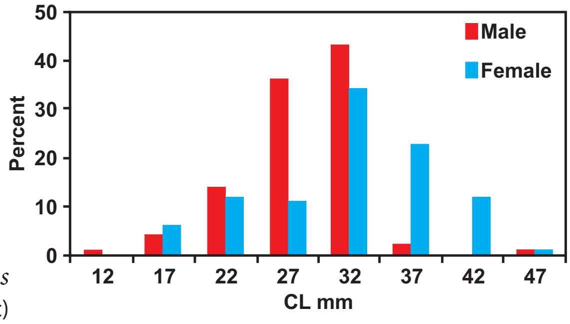
Length frequency of *P. indicus* on the Sofala Bank (from Silva & Palha de Sousa 1992)

Tanzania: Size composition in the two main trawled areas of Rufiji and Bagamoyo is similar.



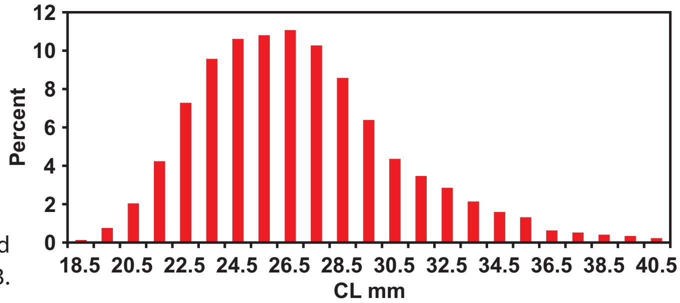
Length frequency distribution of trawled *P. indicus* between March – November 2001 (from Bwathondi *et al.* 2002).

Kenya: Females dominate the larger size classes, but modal length is the same for both sexes.



Length frequency distribution of trawled *P. indicus* from Ungwana Bay in 2010 (from Kimani *et al.* 2011c)

Madagascar: Classically the offshore length frequencies are unimodal, with most prawns at a CL of 22-29 mm.



Length frequency distribution of industrially-trawled *P. indicus* in Madagascar Zone B in 2003.

Refs: Bwathondi et al. *2002, Caverivière* et al. *2008*

SEX RATIO

General: This is highly dependent on size class (see population size structure graphs), so gear selectivity, as well as sampling locality, can influence ratios
South Africa: Limited offshore sampling on the Thukela Bank in the 1970s - M:F 1:1
Mozambique: overall sex ratio is in the region of 1:1.
Tanzania: M:F ranged from 1:0.5 – 1:1.4 and 1:1.08 – 1:1.5 for Bagamoyo and Rufiji respectively
Kenya: During the SWIOFP trawl survey in January-February 2011, a ratio of M:F of 1:0.4 was obtained but may not be representative of the general situation.
Madagascar: The birth sex ratio is theoretically 50%; males dominate the smaller size classes because their growth is slower.

Refs: Champion 1970 b, Bwathondi et al. *2002, de Freitas 2004, Caverivière* et al. *2008*

MIGRATIONS

No specific information on migrations, other than that presented under larval distribution and recruitment above, since only localised migrations occur.

GENETIC STOCK STRUCTURE

A mitochondrial genetic study showed that estuarine and offshore specimens from Malindi-Ungwana Bay in Kenya were from the same population; a follow-up to this SWIOFP study is underway to establish the extent of connectivity of this species between countries of the WIO, using markers developed in the Kenyan study.

Refs: Mkare et al. *2013, Mkare 2013*

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

South Africa: No stock assessments undertaken. One study predicted declines in prawn catches of up to 11% if further damming of the Thukela River occurred (although this river is not an estuary, it provides nutrients to the trawling grounds).

Mozambique: Numerous Sofala Bank surveys have been undertaken virtually annually since 1977 to asses *inter alia* species composition, distribution and biological parameters, mesh selectivity and biomass (Malawene *et al.*, Instituto de Investigaçao Pesqueira, unpublished). A pre-season recruitment survey of abundance is undertaken each year to monitor the annual variations in prawn abundance on the Sofala Bank. Logbook data (from some vessels) and vessel characteristics are also utilised, after catch rates of vessels are standardized according to fishing power. Increasing levels of complexity of modelling assessments have been undertaken over the years, frequently with the help of foreign consultants, including yield/biomass/value per recruit to set biological reference points; age and length-structured modelling to investigate historical stock levels and the impact of various management options; spawning stock-recruitment relationships to maintain adequate spawning stock levels; depletion-based assessment of stock size using Leslie methods to assess fleet efficiency, total stock size and remaining biomass; projected catch levels modelling to set TACs. The decline in prawn catches (which are dominated by *P. indicus*), notwithstanding the apparent reduction in numbers of vessels, and despite a reasonable level of spawning stock biomass, is ascribed to growth overfishing early in the season when this species is particularly vulnerable to trawlers and when fishing effort is highest.

Tanzania: Prawn biomasses from trawl survey estimates for all species combined (based on swept-area) declined from around 2,000t in 1988 to around 300t in 2004, increasing to around 1,160t (all three zones) in 2008. It has been suggested that the declines were not only due to over-fishing but also due to reduction in riverine flow. The initial MSY estimate in 1977 was around 2,000t, with subsequent estimates (1982, 1988, 1990) being around 900t. The most recent published stock assessment available estimated MSY from surveys using the Garcia *et al.* (1987) formula (an adaptation of the Fox production model) incorporating natural mortality, catch and biomass estimates; it suggested that the MSY (all prawn species) was around 1,250t; recommendations are that only 60% of this should be caught, which would necessitate a reduction in effort to 8 vessels. A management plan for the prawn fishery is currently in preparation, and the trawl fishery will remain closed until it is ready for implementation. Results of SWIOFP surveys in February and June 2011 are not yet available. Bwathondi *et al.* (2002) provide individual biomasses per species.

Kenya: Surplus production modelling of trawler catch and effort for 1985-2005 indicates that mean annual trawl landings of prawns of about 330t represent about 90% of the model MSYs of 352-391t (a previous assessment in 2002 put MSY at 433t). Therefore, the trawl fishery is likely fully exploited (current effort is estimated at >0.7 fMSY); annual catch exceeded the MSY of that year in several years, indicating overfishing in those years. Artisanal prawn catch and effort were substantially below MSY and fMSY respectively for the 1985-2005 period, but there was uncertainty because of the use of multiple gears. Confidence in the surplus production models for both sectors was constrained by the multispecies nature of the prawn stock, and by the underlying model assumptions, particularly relating to distribution of fishing effort. Trawl biomass estimates based on surveys over the years, commencing in the 1970s (reviewed in Venema 1984), were mostly around 112-353t, although these were very rough estimates; more recently a KCDP survey (2009) and a SWIOFP survey (January-February 2010) produced estimates of around 120t.

Madagascar: Assessments are not based on a single species; in 1995-1998 and 2003-2004, trawled stocks were assessed as being harvested at close to the MSY of around 8,200t (established based on industrial trawl catches over the period 1967-1992). In 1996 a VPA analysis was done integrating the data of the three sectors (industrial, artisanal and traditional), the results indicating that stocks (all species by sex) were exploited at an optimal level. By 2005, a bio-economic management model had been developed which simulated 10 years of operation subject to repeated biological or economic pressures in conjunction with management decisions. The model incorporates, amongst others, maximum sustainable yield, trends in catch rate, trends in species composition, yield per recruit information, prawn growth, fishing input costs, level of taxes and management measures, and outputs include the effects of various management strategies on state and company revenue and jobs. Nonetheless, there have been subsequent declines in catch (in both industrial and artisanal fleets) due to recruitment overfishing of juveniles by the traditional inshore fisheries. In 2007 a monthly VPA was done for each management area and for each stock (species/sex) with data collected from 2001 to 2005. The results show that levels of exploitation are quite similar in the four areas and that there was growth overfishing and recruitment overfishing.

Refs: Venema 1984, Sousa 1986, KMFRI 2002, Bwathondi et al. *2002, Caverivière* et al. *2008, Mwakosya* et al. *2009, Hough & Marin 2009, Turpie & Lamberth 2010, Kimani* et al. *2010, Silas 2011, Palha de Sousa* et al. *2011, Fulanda* et al. *2011, Kimani* et al. *2011c, Mwakosya* et al. *2011a, Mwakosya 2011b*

FISHING MORTALITY

South Africa: No data
Mozambique: Increased from about 1.6 yr^{-1} in the 1980s to peaks of almost 5 yr^{-1} in 1997, 2001 and 2005; since declined to 2.8 yr^{-1} in 2010
Tanzania: 11.1 yr-1 (Zone 1) and 6.16 yr^{-1} (Zone 2)
Kenya: Not available; stock assessed using production modelling
Madagascar: Monthly averages of the respective years by age class range from 0.38 – 0.61 yr^{-1} for males and from 0.51 – 0.59 yr^{-1} for females, for 2001 to 2005.

Refs: Makwabi 1988, Bwathondi et al. *2002, Caverivière* et al. *2008, Mwakosya* et al. *2009, Palha de Sousa* et al. *2011, Fulanda* et al. *2011*

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

South Africa: All shallow-water prawn species managed jointly; TAE of seven vessels applies to both shallow-water and deep-water crustacean vessels; because effective effort for both sectors is very low (and has been so for several years), the *status quo* has remained unchanged.

Mozambique: $F_{0.1}$ is set at 2.1 yr^{-1}; spawning stock biomass not to fall below 20% of virgin level; trawling effort of 180,000 standardized fishing hours; TAC of 5,000-5,700t (all species) depending on the timing of onset of the season. Management Plan broad objective: The prawn fishery should "..provide a maximum net benefit overall (economic, social and financial) to society for poverty reduction within a framework of sustainability of the resource in particular and the aquatic ecosystem in general" (ADNAP 2014).

Tanzania: All penaeid prawn species are managed jointly. No output controls (quotas or TACs). Based on the various estimates of biomass and MSY levels (all species combined), recommendations for reduction in effort have been made at times e.g. a proposed effort reduction of 14 vessels to 8 was made in 1992, and from 20 to 8 vessels of standard size (500HP) in 2002 (the latter to attain a recommended exploitation level of 60% of the MSY); but few management recommendations have been implemented, other than minor input control measures such as seasonal and diurnal closures.

Kenya: The management plan refers to management reference points (MSY, the level and distribution of fishing mortality, TAC, ITQs) but target levels are not specified. Management plan broad objective: "..to ensure the continuation of a biologically sustainable and economically viable prawn fishery in order to benefit Kenyans in terms of creation of employment, wealth, national revenues and foreign exchange earnings, fish products and the protection of the prawn fishery and habitat over the long term."

Madagascar: The shallow-water penaeid species are managed jointly. The reference point for the trawl fishery is for catch not to exceed MSY, and is achieved by adjusting fishing effort, timing of the closed season, diurnal duration of fishing and mesh size. The broad objective is to maximize economic benefits but to minimize impacts on non-target species, particularly endangered organisms such as turtles.

Refs: Bwathondi et al. *2002, Cavarivière* et al. *2008, Silas 2011, Palha de Sousa* et al. *2011*

DATABASES

DATA COLLECTION

South Africa: Companies submit drag logbooks and landing sheets to the fisheries department; observer coverage target of 10% of trips, mainly for bycatch monitoring.

Mozambique: Trawling catch records are submitted to the fisheries administration (ADNAP); annual research recruitment survey undertaken with biological sampling; biological sampling of the industrial prawn catches and landed bycatch are conducted at ports; observers are on board to collect bycatch information; fisheries inspectors accompany trawlers and monitor landings; VMS required. Surveys of the artisanal fisheries (catch, effort and biological sampling) are conducted at the main landing sites. Irregular student projects on various biological aspects.

Tanzania: Trawling catch records are submitted to the Department of Fisheries; frame surveys of the artisanal fisheries (gear type and number) are conducted every three years, while artisanal catches are monitored at some landing sites. Student projects undertaken at times, largely on biological aspects of estuarine components of the fishery.

Kenya: Trawling logbooks are submitted to the fisheries department; fisheries inspectors accompany trawlers and monitor landings. Student projects undertaken at times, largely on biological aspects of estuarine components of the fishery.

Madagascar: Catch returns for each drag are mandatory and are submitted to the fisheries ministry. Observers are on board trawlers for 30% of all trips by agreement between the fishing industry and the ministry i.e. it is not a regulation. Landings are inspected for 50% of trips. All vessels have VMS installed. The national programme for prawn fisheries research (PNRC) is in charge of the collection of data (effort, catch and biological) for the traditional fishery.

KNOWN DATABASES

A list of all the most pertinent data sets provided by the participating countries is presented in the metadata below; the data sets cover a variety of information, but the most extensive in terms of the amount of data and duration are those recording catch and effort information by the industrial fleets; many of the other data sets are of short duration, and have only been collected intermittently.

METADATA

The metadata are presented in Annex 2 as a summary of the datasets available, the main databases in terms of data are marked in yellow. See also Chapter 1 for more information on data sources.

METAPENAEUS MONOCEROS

Target fisheries:

Kenya
- Industrial nets, inshore, prawns
- Small nets, cast nets, fish & prawns
- Small nets, gillnets, crustaceans
- Small nets, seine nets, crustaceans

Madagascar
- Industrial nets, inshore, shrimps
- Small nets, cast nets, fish & shrimps
- Traps, fence traps, Valakiras (Barrage côtier)

Mozambique
- Industrial nets, trawl, shrimps
- Semi-industrial, trawler, shrimps, Maputo Bay

South Africa – KwaZulu-Natal
- Small nets, gate net/trawl, shrimp/prawn
- Industrial nets, inshore, crustaceans

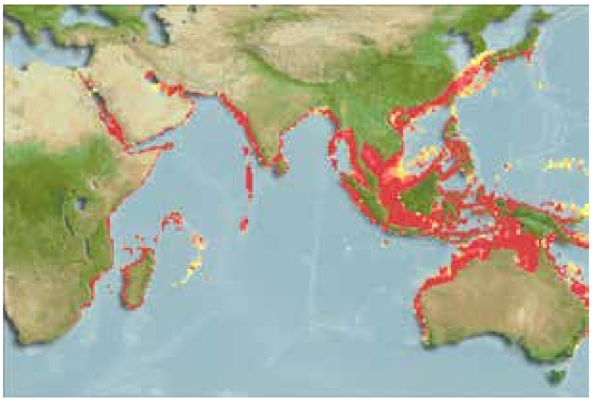
Tanzania
- Industrial nets, inshore, crustaceans
- Small nets, seine nets, crustaceans

Common names:
- Speckled shrimp (FAO)
- Thukela prawn (South Africa)
- Brown shrimp (Mozambique)
- Camarão castanho (Mozambique)
- Patsanorana (Madagascar)
- Kamba, Kamba ndogo (Kenya, Tanzania)

DISTRIBUTION AND HABITAT

Southeast Atlantic, Indian Ocean and the Mediterranean. Bottom mud or sand. Adults marine, juveniles estuarine. Depth: 1-170m (questionable), usually 10-30m.

Refs: *http://sealifebase.org*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

South Africa: Limited data; Thukela Bank (1970s) - majority of females are mature at 37-38mm CL.
Mozambique: Maputo Bay – female maturity commenced at 21-22mm CL; female size at 50% maturity 35-36mm CL; Sofala Bank – various studies found onset of female maturity at 26mm CL; spawning peaks in April, declining gradually to November when it has virtually ceased.
Tanzania: Off Bagamoyo, offshore females attained size at 50% maturity at 11.5cm TL and first maturity at 7.5cm TL. Highest proportions of mature prawns were caught off Bagamoyo in March and September/October, while very low proportions of mature prawns were caught off Rufiji.
Kenya: Few reports available; during the SWIOFP trawl survey in January-February 2011, a large proportion of the prawns were immature.
Madagascar: Females can reach maturity at 17mm CL or at 4 months of age. Their average size at sexual maturity is 28mm CL (age 8.4 months). Between 0.5-1 million eggs are produced.

Refs: Brinca & Palha de Sousa 1984, Munguambe 1995, Bwathondi et al. *2002, Hough & Marin 2009, Silas 2011, Rafalimanana 2003*

LARVAL DISTRIBUTION & RECRUITMENT

General: Eggs and sperm are released by adults in the sea, the pelagic post-larvae 1.5–2mm CL are transported into estuaries where they remain for a few months before emigrating out to sea as juveniles (~15–20mm CL), and they mature in large inshore bays or the open sea.
South Africa: No data available (likely to be similar to *P. indicus* although the timing of recruitment differs, as this species peaks in catches later in the year)
Mozambique: Recruitment to the Sofala Bank is continuous in the first half of the year peaking in May, and is completed by June. Recruitment is significantly correlated with the run-off of the Zambezi River in the previous wet season.
Tanzania: Migration to the open sea begins during the short rainy season (October to December)
Kenya: Not reported
Madagascar: Recruitment occurs throughout the year but with two major spawning periods: in September/October and May.

Refs: Le Reste& Marcille 1976, Le Reste & Marcille 1976b, Brinca et al. *1981, Demetriades & Forbes 1993, Palha de Sousa* et al. *2006.*

MOULTING AND GROWTH

General: A very fast-growing species, most individuals completing their life cycle within one year
South Africa: No data available
Mozambique: Sofala Bank: Females L_{inf} 48.9-48.3mm CL, K 2.9-1.7 yr^{-1}, Males L_{inf} 31.9-36mm CL, K 3.4-3.0 yr^{-1}
Tanzania: In 2001, highest proportions of post-moult prawns were encountered in Bagamoyo in May and September, and in October/November in Rufiji. Females and males combined: Bagamoyo – Rufiji (2001): L_{inf} 15.52–15.00cm TL, K 0.46-0.42 yr^{-1}
Kenya: Not reported
Madagascar: Females L_{inf} 32.4-50.2mm CL, K 0.074-0.361 $month^{-1}$, Males L_{inf} 29.8-35mm CL, K 0.099-0.175 $month^{-1}$

Refs: Brinca & Palha de Sousa 1984b, Munguambe 1995, Caverivière et al. *2008*

MAXIMUM SIZE

South Africa: No data available
Mozambique: 52mm CL
Tanzania: 16.5cm TL in Bagamoyo and Rufiji (2001)
Kenya: 42mm CL
Madagascar: Females 44mm CL, males 32mm CL East Coast

Refs : Munguambe 1995, Bwathondi et al. *2002, Caverivière* et al. *2008, Kimani* et al. *2011c*

NATURAL MORTALITY

South Africa: No data available
Mozambique: (Maputo Bay) F: 2.4 yr^{-1}, M: 4.14 yr^{-1}
Tanzania: Males and females combined 1.29 yr^{-1} in Bagamoyo and 1.23 yr^{-1} in Rufiji (2001), although Mwakosya *et al.* (2009) used a value of 2.85 yr^{-1} and Sanders *et al.* (1988) used a figure for combined prawn species of 3 yr^{-1}.
Kenya: Not reported
Madagascar: Median value of M=0.2 yr^{-1} is used.

Refs: Brinca & Palha de Sousa 1984a, Bwathondi et al. *2002, Caverivière* et al. *2008, Mwakosya* et al. *2009*

LENGTH-WEIGHT

South Africa: No data available

Mozambique: *(Maputo Bay)*

	CL/TL:	CL/W(mm/g):	TL/W:
Males	TL = 4.257 CL + 8.593	$W = 1.515 \times 10^{-3} CL^{2.75}$	$W = 8.3 \times 10^{-6} TL^{2.95}$
Females:	TL = 4.223 CL + 7.652	$W = 1.216 \times 10^{-3} CL^{2.81}$	$W = 7.0 \times 10^{-6} TL^{3.0}$
Combined	TL = 4.246 CL + 8.190	$W = 1.328 \times 10^{-3} CL^{2.79}$	$W = 7.7 \times 10^{-6} TL^{2.98}$

Tanzania: Not reported

Kenya: Not reported

Madagascar:

Females	logWt = 2,5284 logCL- 2,5416 (r = 0,981)
Males	logWt = 2,7020 logCL- 2,7779 (r = 0.995)
Combined	logWt = 2,5760 logCL- 2,6103 (r = 0,986)

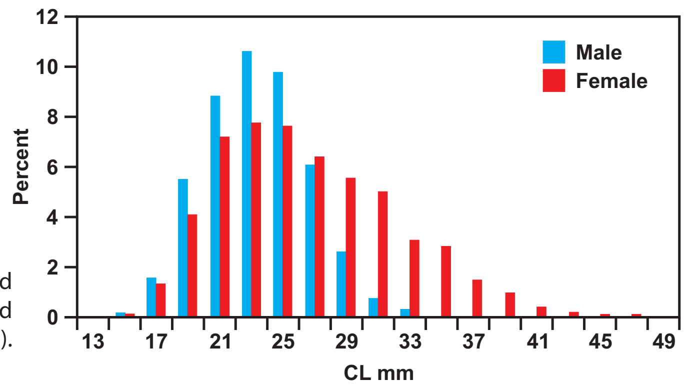
Refs: Le Reste et al. *1974, de Freitas 1987*

POPULATION SIZE STRUCTURE

General: Because prawns are so fast-growing, there is great variability in size structure depending on where and when the prawns are caught, and the gear characteristics used; where possible overall annual length frequencies for trawled catches are presented.

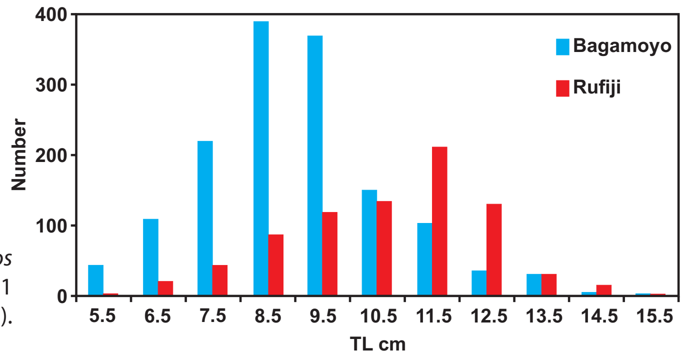
South Africa: No data available

Mozambique: Females attain substantially larger sizes than males, and on the northern part of the Sofala Bank females were mostly between 20-40mm CL, males were smaller, mostly 16-28mm CL. In the south towards the Zambezi River, a higher proportion of smaller individuals was found (12-48mm CL for females, and 12-40mm CL for males).



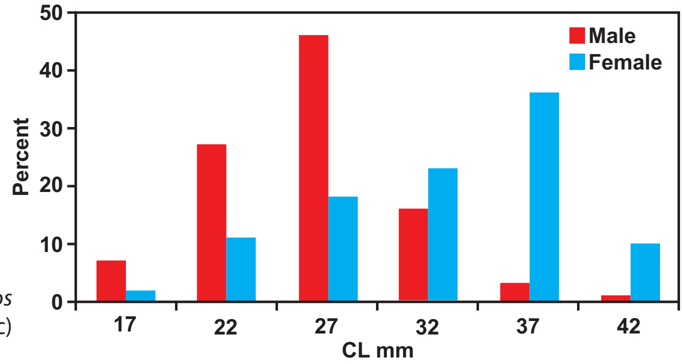
Length frequency of *M. monoceros* males (M) and females (F) from Maputo Bay (from Brinca and Palha de Sousa 1984a).

Tanzania: Trawled prawns off Bagamoyo are considerably smaller than those found off Rufiji, and prawns from both areas are considerably smaller than those from other countries, possibly because of the timing and location of sampling.



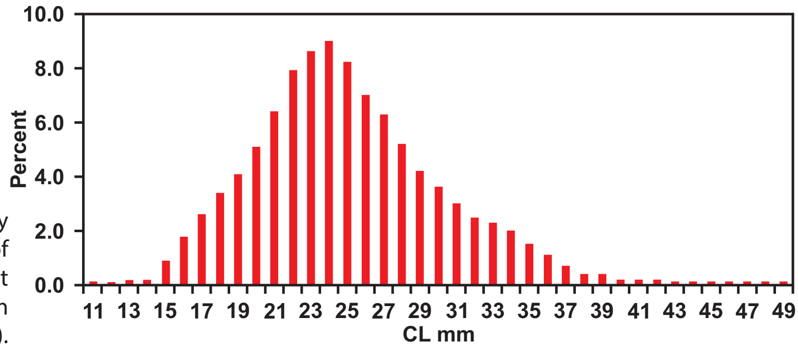
Length frequency distribution of trawled *M. monoceros* from Tanzania between March – November 2001 (from Bwathondi *et al*. 2002).

Kenya: Considerable disparity in length frequency by sex, with females dominating the larger size classes.



Size frequency (CL mm) of trawled *M. monoceros* from Ungwana Bay (from Kimani *et al*. 2011c)

Madagascar: Overall, unimodal distributions consistently obtained in offshore catches.



Combined annual length frequency distributions (2002-2005) for catches of *M. monoceros* from Zone C on the West coast, both sexes combined (from Cavarivière *et al*. 2008).

Refs: Brinca et al. *1981, Brinca & Palha de Sousa 1984a, Bwathondi* et al. *2002, Caverivière* et al. *2008*

SEX RATIO

General: Very variable depending on size (see population size structure graphs), which is often a function of sampling area, season and gear selectivity; at times very biased ratios can result.
South Africa: Limited offshore sampling on the Thukela Bank in the 1970s – M:F 1:1
Mozambique: M:F 1:1
Tanzania: M:F ranged from 1:1-1:1.8 and 1:1.1-1:2 for Bagamoyo and Rufiji respectively.
Kenya: During the SWIOFP trawl survey in January-February 2011, a ratio of M:F of 1:2.3 was obtained but may not be representative of the general situation.
Madagascar: 52% of industrially caught prawns over the period December 1971 to January 1973 were female.

Refs: Champion 1970b, Le Reste & Marcille 1976, Brinca et al. *1984, Bwathondi* et al. *2002, Caverivière* et al. *2008, Kimani* et al. *2011c*

MIGRATIONS

No specific information available; follows the generic penaeid prawn estuarine-offshore cycle as indicated under larval distribution and recruitment i.e. only localised migration

GENETIC STOCK STRUCTURE

A mitochondrial genetic study showed that estuarine and offshore specimens from Malindi-Ungwana Bay in Kenya were from the same population; a follow-up to this SWIOFP study is currently underway to establish the extent of connectivity of this species between countries of the WIO, using markers developed in the Kenyan study.

Refs: Mkare et al. *2013, Mkare 2013*

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

South Africa: No data available
Mozambique: Although assessed separately from *P. indicus*, results are combined for management purposes. Gradual decline in catches (~ 4,000–1,800t from 1980s–2010), attributed to declining effort in the latter half of the season (when *M. monoceros* is more commonly caught), but some growth overfishing likely.
Tanzania: Assessed and managed jointly with *P. indicus* (see information for that species), although Bwathondi *et al.* (2002) provide separate biomasses per species from a 2001 survey.
Kenya: See *P. indicus* – all prawn species are assessed together.
Madagascar: A monthly VPA for the three management areas (A, C and D) and for each sex showed that stocks from these three areas are fully exploited.

Refs: Bwathondi et al. *2002, Palha de Sousa* et al. *2011, Caverivière* et al. *2008*

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

In Mozambique, fishing mortality $F_{0.1}$ is set at 2.2 yr^{-1}, but other management objectives are for penaeid stocks as a whole (spawning stock biomass not to fall below 20% of virgin level; trawling effort of 180,000 standardized fishing hours). For all other countries, the shallow-water penaeids have combined reference points/management objectives as specified for *P. indicus*.

Refs: Palha de Sousa et al. *2011*

DATA COLLECTION

South Africa: Companies submit drag logbooks and landing sheets to the fisheries department; observer coverage target of 10% of trips, mainly for bycatch monitoring.

Mozambique: Trawling catch records are submitted to the fisheries administration (ADNAP); annual research recruitment survey undertaken with biological sampling; biological sampling of the industrial prawn catches and landed bycatch are conducted at ports; observers are on board to collect bycatch information; fisheries inspectors accompany trawlers and monitor landings; VMS required. Surveys of the artisanal fisheries (catch, effort and biological sampling) are conducted at the main landing sites. Irregular student projects on various biological aspects.

Tanzania: Trawling catch records are submitted to the Department of Fisheries; frame surveys of the artisanal fisheries (gear type and number) are conducted every three years, while artisanal catches are monitored at some landing sites. Student projects undertaken at times, largely on biological aspects of estuarine components of the fishery.

Kenya: Trawling logbooks are submitted to the fisheries department; fisheries inspectors accompany trawlers and monitor landings. Student projects undertaken at times, largely on biological aspects of estuarine components of the fishery.

Madagascar: Catch returns for each drag are mandatory and are submitted to the fisheries ministry. Observers are on board trawlers for 30% of all trips by agreement between the fishing industry and the ministry i.e. it is not a regulation. Landings are inspected for 50% of trips. All vessels have VMS installed. The national programme for prawn fisheries research (PNRC) is in charge of the collection of data (effort, catch and biological) for the traditional fishery.

DATABASES

Data collection: As for *P. indicus*
Known databases: As for *P. indicus*
Metadata: As for *P. indicus*

PENAEUS MONODON

Target fisheries:

<u>*Kenya*</u>
- Industrial nets, inshore, prawns
- Small nets, cast nets, fish & prawns
- Small nets, gillnets, crustaceans
- Small nets, seine nets, crustaceans

<u>*Madagascar*</u>
- Industrial nets, inshore, shrimps
- Small nets, cast nets, fish & shrimps
- Traps, fence traps, Valakiras (Barrage côtier)

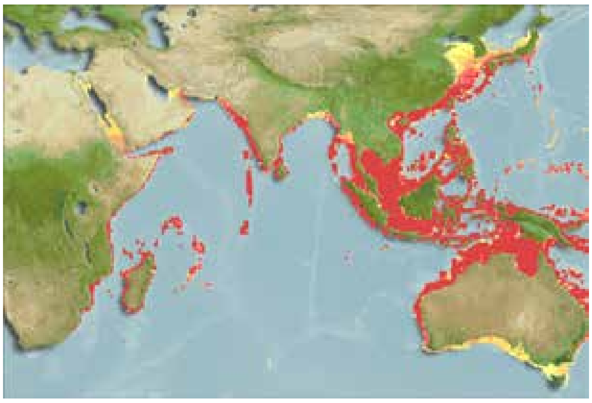
<u>*Mauritius*</u>
- Small nets, hoop nets, shrimp
- Mozambique
- Industrial nets, trawl, shrimps
- Semi-industrial, Trawler, Shrimps, Maputo Bay

<u>*South Africa –KwaZulu-Natal*</u>
- Small nets, gate net/trawl, shrimp/prawn
- Industrial nets, inshore, crustaceans

<u>*Tanzania*</u>
- Industrial nets, inshore, crustaceans
- Small nets, seine nets, crustacean

Common names:
- Giant tiger prawn (FAO)
- Tiger prawn (South Africa, Kenya, Mozambique)
- Kamba ndogo (Kenya, Tanzania)
- Makamba, Patsa (Madagascar)
- Camarão tigre (Mozambique)

DISTRIBUTION AND HABITAT



Benthic/demersal on soft bottom (sand; mud), juveniles in estuaries, adults offshore to depths of 60m.

Refs: *http://sealifebase.org*

BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

<u>South Africa</u>: No data available
<u>Mozambique</u>: *Maputo Bay* – female maturity commenced at 37-38mm CL; female size at 50% maturity 55-56mm CL; very limited data available suggest spawning from December to April.
<u>Tanzania</u>: The average size at first maturity in Bagamoyo coastal waters 2.8cm CL and 3.5cm CL for males and females respectively. Fecundity ranged from 72,000 to 314,000 eggs for individuals ranging from 3.6 to 4.5cm CL.
<u>Kenya</u>: Few data available; during the SWIOFP trawl survey in January-February 2011, a considerable proportion of the prawns were assessed as mature.
<u>Madagascar</u>: No data available

Refs: Bwathondi et al. *2002, de Freitas 2004, Teikwa & Mgaya 2003, Kimani* et al. *2011c*

LARVAL DISTRIBUTION & RECRUITMENT

General: Fertilised eggs are released by females into the marine environment, the pelagic larvae develop into post-larvae 2-3mm CL which are transported into estuaries where they remain for a few months before emigrating out to sea as juveniles 17-18mm CL, in response to reduced salinities, and they mature in large inshore bays or the open sea. No specific SWIO data available; in South Africa, post-larval recruitment occurs into St Lucia, Richards Bay and Durban harbour estuaries.

Refs: de Freitas 2004, Forbes et al. *1994, Forbes & Demetriades 2005*

MOULTING AND GROWTH

L_{inf} 28.8–30cm TL (M), 30.5-32.1cm TL (F) (Bangladesh)
K 0.94-1.2 yr^{-1} (M), 0.97-1.7 yr^{-1} (F) (Bangladesh)

Only available for Kenya (Estuarine, Mombasa):

Male:	L_{inf} 71.6mm CL, K 1.1 yr^{-1}
Female:	L_{inf} 62.9mm CL, K 1.0 yr^{-1}

Refs: Makwabi 1988, www.sealifebase.org

MAXIMUM SIZE

Mozambique: *(Maputo Bay)* > 30cm TL

Refs: de Freitas 2004

NATURAL MORTALITY

1.72-2.03 yr^{-1}(M), 1.72-2.51 yr^{-1} (F) (Bangladesh)
SWIO: Only available for an estuarine population in Kenya: M: 1.49 yr^{-1-}, F: 1.46 yr^{-1-}

Refs: Makwabi 1988, www.sealifebase.org

LENGTH-WEIGHT

South Africa: No data available
Mozambique: *(Maputo Bay)*

	CL/TL:	CL/W(mm/g):	TL/W:
Male	TL =3.594 CL + 30.366	$W = 1.880 \times 10^{-3} CL^{2.709}$	$W = 1.3 \times 10^{-6} TL^{3.338}$
Female	TL = 3.418 CL + 33.361	$W = 1.514 \times 10^{-3} CL^{2.759}$	$W = 1.2 \times 10^{-6} TL^{3.369}$
Combined	TL = 3.443 CL + 33.687	$W = 1.627 \times 10^{-3} CL^{2.744}$	$W = 1.2 \times 10^{-6} TL^{3.362}$

Tanzania:

Male	$W(g) = 0.915\ TL(cm)^{3.106}$
Female	$W(g) = 0.751\ TL(cm)^{2.299}$

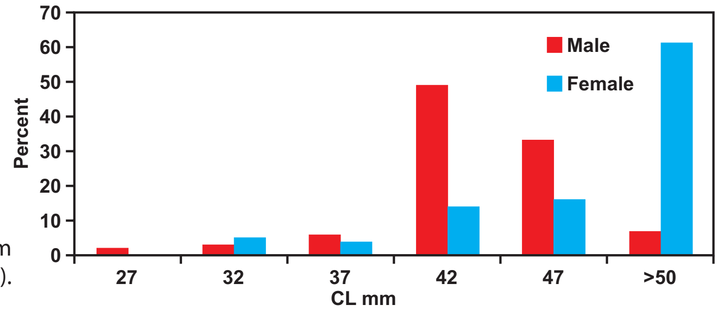
Kenya: (*Estuarine, Mombasa*)

Male	$W(g) = 2.95\ TL(cm)^{2.86}$
Female	$W(g) = 2.67\ TL(cm)^{2.66}$

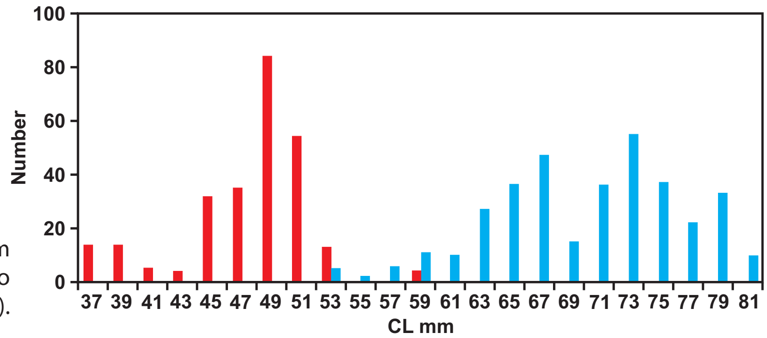
Madagascar: No data available

POPULATION SIZE STRUCTURE

Length frequencies are only reported from Kenya and Mozambique; females dominate the largest size classes, and in Mozambique this is particularly marked.



Size frequency of trawled *P. monodon* from Ungwana Bay (from Kimani et al. 2011c).



Size frequency of trawled *P. monodon* from the Sofala Bank (Instituto de Investigaçao Pesqueira, unpubl. data).

SEX RATIO

General: This is very variable depending on size (see population size structure) and hence gear selectivity and sampling locality can affect the ratios.
South Africa: No data available.
Mozambique : *Maputo Bay* – 1:1
Tanzania: Bagamoyo coastal waters F:M 0.92:1
Kenya: During the SWIOFP trawl survey in January-February 2011, a ratio of M:F of 1:0.5 was obtained but may not be representative of the general situation.
Madagascar: No reports available.

Refs: de Freitas 2004, Teikwa & Mgaya 2003

MIGRATIONS

No specific information available; follows the generic penaeid prawn estuarine-offshore cycle as provided under larval distribution and recruitment i.e. only localised migration.

GENETIC STOCK STRUCTURE

A mitochondrial genetic study showed that estuarine and offshore specimens from Malindi-Ungwana Bay in Kenya were from the same population. Earlier studies which included microsatellite information showed that WIO populations appear genetically distinct from the rest of the Indian Ocean and the Pacific, but the diversity of the WIO populations was the lowest of all these populations; allozyme frequencies suggested no separation.

Refs: Duda & Palumbi 1999, Forbes et al. *1999, Benzie* et al. *2002, You* et al. *2008, Mkare* et al. *2013, Mkare 2013*

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

South Africa: No data available.
Mozambique: Catches declining slightly (250-200 t from 1999-2010) in recent years, attributed to the heavy effort in the beginning of the season in the same grounds where *P. indicus* occur, hence some growth overfishing likely.
Tanzania: Assessed and managed jointly with *P. indicus* (see information for that species), although Bwathondi *et al.* (2002) provide separate biomasses per species from a 2001 survey.
Kenya: See *P. indicus* – all prawn species are assessed together.
Madagascar: No published data available – *P. monodon* constitutes a very small fraction of the catch.

Refs: Bwathondi et al. *2002, Palha de Sousa* et al. *2011*

FISHING MORTALITY

Only reported SWIO data are from an estuarine study in Kenya, so are not appropriate for general use:
M: 8.14 yr^{-1}, F: 7.92 yr^{-1}

Refs: Makwabi 1988

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

None – managed as part of the combined *Penaeus* stocks.

DATABASES

Data collection: As for *P. indicus*
Known databases: As for *P. indicus*
Metadata: As for *P. indicus*

Recommendations

Considerable amounts of survey and fisheries data exist for Mozambique and Madagascar, sufficient for the management of the trawl fishery for shallow water prawns in those countries; while of lesser quantity and less regularly collected, survey data for Tanzania and Kenya are also adequate for the management of the trawl target species; for South Africa, there are no survey data, but catch and effort data are adequate. However, there are several issues around data and information which limit the relevant agencies' abilities to manage their stocks and the prawn trawl sector:

- ***Availability of data on small-scale (traditional) catches***
  There is direct overlap between this sector and the trawl sector, so stock assessments need to incorporate both, which does not currently happen in any of the SWIOFP countries because of a lack of data (excluding South Africa where the small-scale sector is not significant); this needs to be resolved by improving surveys of the small-scale sector, particularly since it is open-access, which means that effort levels can keep increasing (and appear to be doing so)

- ***Implementation of research recommendations***
  While management plans are in place for several countries, and recommendations of sustainable levels of trawling effort and catch are made for the trawl sector in most SWIOFP countries, there is generally poor implementation, and also poor compliance with fisheries regulations, particularly in the traditional sector. This needs to be improved dramatically if the declining trawl catches throughout the region are to be improved.

- ***Environmental effects***
  There is limited understanding of the nature of the relationship between prawn catches and environmental factors – particularly the oceanographic conditions which affect recruitment to nurseries, and river flow which *inter alia* affects recruitment to coastal fisheries. However, even if this understanding is improved radically in the short-term, it will be problematic to implement compensatory management measures, so it is recommended that more attention be focussed on the preceding recommendations before addressing this complex issue.

- ***Fisheries prioritisation***
  Governments of SWIOFP countries (excluding South Africa) need to decide whether the foreign revenue generated from exports of trawled prawns justifies the increasing user-conflict with the small-scale sector which catches many of the same species as the trawlers. The value of exports is available, but it is doubtful that adequate socio-economic information exists to undertake a cost-benefit analysis of the situation; such information should be collected and the analysis undertaken to assist with governance. This would include analysis of the increasing threats posed by mariculture of prawns, increasing fuel prices and consumer-driven requirements for eco-certification. While there is little that SWIOFP countries can do about prawn and fuel prices, they can facilitate the implementation of eco-certification measures in the trawl sector, and should be doing this in order to begin to address EAF principles. However, the example of Madagascar should be borne in mind – despite implementation of bioeconomic modelling recommendations for the management of the large and valuable trawl sector (including fuel efficiency and eco-certification measures and appropriate trawling effort levels) as well as a strong industry-management association, the trawl fishery continues to decline because of the failure of management to curtail over-fishing by the traditional small-scale sector.

- ***Species identification***
  It is apparent from the various survey reports and the literature that outdated (incorrect) names of many species are still being used, particularly for fishes associated with prawn catches; there is a need to update and standardize the use of the correct names of organisms in the region, particularly since many of them co-occur in SWIOFP countries. Museums and fisheries institutions in each country should work through the check lists of species recorded to check for validity of names and ensure that there is conformity; this would include following up on the status of voucher specimens and results of genetic barcoding that was undertaken during the ASCLME surveys in the SWIO.

- ***Ecological impacts***
  There is no clear understanding of the impacts of trawling on the environment in the SWIO region, although it is widely perceived to be damaging. While it was intended that SWIOFP would provide an opportunity to investigate this, other issues were prioritized. There remains a need to investigate impacts of trawling in the region, particularly on the benthos.

- ***Shared stocks***
  At this stage there is no genetic evidence to indicate that the three priority shallow water prawn species are shared between two or more countries in the region. From a stock perspective, they are managed in each country as a single-species stock, since the species occur in the same habitats, co-occur in catches and are seldom separated when being packed. From a fisheries perspective, they are not distributed continuously along the coastline of mainland Africa, but are concentrated in viable densities in specific habitats associated with river mouths; in the case of Madagascar they are potentially isolated from the mainland stocks by a deep channel; so it is appropriate that the stocks in each country continue to be managed separately until such time as the genetic studies are complete.

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Annex 1:

List of research trawl surveys in the SWIOFP region post-2005 from which shallow-water prawn data were obtained.

Survey date	*Country*	*Ship*	*Data type*	*Institution*
Jan-Feb 2011	Kenya	MFV VEGA (commercial vessel charter)	Prawn biomass, composition, bycatch	KMFRI (SWIOFP)
Feb 2011	Tanzania	MFV VEGA (commercial vessel charter)	Prawn biomass, composition, bycatch	TAFIRI (SWIOFP)
May-Jun 2011	Kenya	MFV VEGA (commercial vessel charter)	Prawn biomass, composition, bycatch	KMFRI (SWIOFP)
Jun 2011	Tanzania	MFV VEGA (commercial vessel charter)	Prawn biomass, composition, bycatch	TAFIRI (SWIOFP)
Jan-Feb 2010	Mozambique	AVIA (commercial vessel charter)	Prawn biomass, composition, bycatch and discards	IIP
Jan-Feb 2009	Mozambique	PESCAMAR XI (commercial vessel charter)	Prawn biomass, composition, bycatch and discards	IIP
March, May-Jul 2009	Tanzania	MFV HELENA + SERENA (commercial vessel charter)	Prawn biomasses, composition, bycatch	TAFIRI
Aug 2009	Mozambique	Fridtjof Nansen	Demersal catches	IIP
Aug-Sep 2009	Madagascar	Fridtjof Nansen	Demersal catches	ASCLME
Dec 2009	Kenya	MFV VEGA (commercial vessel charter)	Prawn biomass, composition, bycatch	KMFRI (KCDP)
Jan-Feb 2008	Mozambique	PESCAMAR XI (commercial vessel charter)	Prawn biomass, composition, bycatch and discards	IIP
Aug-Sep 2008	Madagascar	Fridtjof Nansen	Demersal catches	ASCLME
Sep-Dec 2007	Mozambique	Fridtjof Nansen	Demersal survey	IIP
Jan-Feb 2007	Mozambique	ULLA (commercial vessel charter)	Prawn biomass, composition, bycatch	IIP
Jul-Aug 2007	Tanzania	MFV MAFUNZO (commercial vessel charter)	Fish biomass (prawn bycatch)	TAFIRI (MACEMP)
Jan-Feb 2006	Mozambique	ARPEM IV (commercial vessel charter)	Prawn biomass, composition, bycatch	IIP
Oct-Nov 2006	Tanzania	MFV MAFUNZO (commercial vessel charter)	Fish biomass (prawn bycatch)	TAFIRI (MACEMP)

Annex 2:

Metadata describing the various databases compiled into StatBase as agreed in terms of the Memorandum of Understanding between SWIOFP and the participant countries, as explained in Chapter 1. Interrogation of StatBase and consultation with the various SWIOFP crustacean fisheries stakeholders over the course of the project identifying numerous datasets that were relevant to shallow water crustacean fisheries. These are listed below with those highlighted yellow representing primary information sources with extensive data. These datasets were compiled according to a standardised set of descriptors as outlined Chapter 1.

DDD Identifier	Country	Dataset name	Source of information	Nature of data	Gear type	Target species	Coverage
ZAF-D007	South Africa	KZN Crustacean trawl fisheries database	Fishing logbook	Effort/ Catch/Capture/ Species composition	Bottom trawl	Shallow water crustaceans	1988-
ZAF-D010	South Africa	KZN Crustacean trawl demersal fish bycatch data	Onboard observers	Effort and yield/Catch/ Capture Species composition	Bottom trawl	Shallow water crustaceans	2003-
MDG-D001	Madagascar	BANACREM	Fishing logbook	Effort and yield	Bottom trawl	Prawns & shrimps	1995-
MDG-D002	Madagascar	Données VMS	Other	Other	Bottom trawl	Prawns & shrimps	2001-
MDG-D003	Madagascar	Observateurs Embarqués	Onboard observers	Effort and yield	Bottom trawl	Prawns & shrimps	2000-
MDG-D004	Madagascar	Données Economiques	Other	Other	Bottom trawl	Prawns & shrimps	2001-
MDG-D005	Madagascar	Echantillonnage Captures Pêche Traditionnelle	Artisanal fisheries: sampling	Effort and yield	Gillnets and entangling nets, Seine nets	Prawns & shrimps	2007-
MDG-D006	Madagascar	Note Conjoncturelle	Other	Yield	Bottom trawl	Prawns & shrimps	2006-
S001	Tanzania	Marine Frame Survey	Artisanal fisheries: Census & Frame survey	Census	Unknown or unspecified	Other	199 -2007
D001	Tanzania	Artisanal CAS Data	Artisanal fisheries: sampling	Effort and yield	Unknown or unspecified	Other	2007-
D003	Tanzania	Export-Fisheries Products	Industrial fisheries: Register	Catch/Capture	Unknown or unspecified	Other	1995-2007
D004	Tanzania	Industrial Fisheries-Prawns	Fishing logbook	Effort and yield	Bottom trawl	Shallow water crustaceans	1988-2007
D005	Tanzania	Artisanal + Industrial fisheries sampling	Other	Biological data	Bottom trawl	Crustaceans	1992
S007	Tanzania	Prawn Abundance and Distribution	Research ship	Biological data	Bottom trawl	Crustaceans	2001, 2008
S012	Tanzania	Rapid assessment of by-catch from commercial prawn trawl	Industrial fisheries: Sampling	Catch/Capture	Bottom trawl	Other	2007
D010	Tanzania	Industrial prawn monitoring	Industrial fisheries: Sampling	Catch/Capture	Bottom trawl	Prawns & shrimps	2006
D001	Kenya	Industrial prawn trawling at Ungwana bay	Fishing logbook	Effort and yield	Bottom trawl	Prawns & shrimps	1979-1985
D028	Kenya	Frame Survey	Artisanal fisheries: Census & Frame survey				2004
D029	Kenya	Frame Survey	Artisanal fisheries: Census & Frame survey				2006
D030	Kenya	Artisanal Catch	Artisanal fisheries: sampling				1963-1989
D031	Kenya	Artisanal Catch	Artisanal fisheries: sampling				1990-2007
D034	Kenya	Artisanal Catch Assessment Survey	Artisanal fisheries: sampling				2002-2007
	Kenya	Prawn Abundance and Distribution	Research ship	Biological data	Bottom trawl	Crustaceans	

DDD Identifier	Country	Dataset name	Source of information	Nature of data	Gear type	Target species	Coverage
D101	Mozambique	MOZ Industrial shallow-water shrimp	Fishing logbook	Effort and Catch, Species & Size Composition	Bottom trawl	Shallow waters crustaceans	1974-1990
D102	Mozambique	MOZ Industrial shallow-water shrimp	Fishing logbook	Effort and Catch, Species & Size Composition	Bottom trawl	Shallow waters crustaceans	1991-
D103	Mozambique	MOZ Artisanal fishery	Artisanal fisheries: sampling	Effort, Catch, cpue, Species Composition	Seine nets	Prawns & shrimps	1997-
D104	Mozambique	MOZ industrial shallow water shrimp biological sampling	Industrial fisheries: Sampling	Biological data	Bottom trawl	Shallow water crustaceans	1976-
D105	Mozambique	MOZ industrial shallow water shrimp bycatch	Industrial fisheries: Sampling	Catch/Capture, species and size composition	Bottom trawl	Shallow water crustaceans	1985-
D2	Mozambique	Industrial register	Industrial fisheries: Sampling				
S101	Mozambique	MOZ shallow-water shrimp	Wet-leased commercial vessel	Catch/Capture, size composition, production/ Oceanographic data	Bottom trawl	Shallow water crustaceans	1979-1983, 1989-1995, 1998-
S801	Mozambique	MOZ General	Research ship	Catch/Capture, size composition, production/ Oceanographic data	Bottom trawl	Miscellaneous	1976-

3.
CRUSTACEAN DEEP-WATER TRAWL FISHERIES

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Previous page: Typical deep-water crustacean trawl catch. Photo by James Robey.

3. CRUSTACEAN DEEP-WATER TRAWL FISHERIES

A retrospective analysis of their status in the Southwest Indian Ocean

Johan Groeneveld[1] *and Bernadine Everett*[1]

Abstract

Deep-water bottom trawl fisheries for crustaceans in the Southwest Indian Ocean (SWIO) catch a mixture of high-value prawns, langoustines, lobsters and crabs. Teleosts and elasmobranchs caught as a bycatch are retained if they can be sold, or discarded if of low commercial value. Four sectors were identified for this study: industrial trawl fisheries in South Africa (east coast) and Mozambique; trawl surveys using research vessels; and short-term exploratory deep-water trawl fisheries. Good quality data from skipper logbooks, landed weights, and biological sampling by fisheries observers were available for the industrial fisheries. Nominal fishing effort and catches in Mozambique and South Africa declined between 1990 and 2010, but the cpue of key crustaceans remained stable or increased, possibly because of increasing fishing efficiency. Mozambican trawl grounds have often been surveyed by research vessels, such as the RV Dr Fridtjof Nansen, providing oceanographic, biodiversity and biomass information. These data have been used to assess the stock status of key crustacean resources, and for fisheries management advice. Fewer surveys have been undertaken in Madagascar, Tanzania and Kenya, and these have been exploratory in nature. Many of the same species found in commercial quantities in Mozambique have been identified in these countries, but in smaller quantities. Fisheries management in the SWIO has traditionally been at national level, with little integration across the region. SWIOFP collected historical catch, effort and species composition information from five riparian countries, and also undertook four deep-water trawl surveys (Mozambique, Madagascar, Tanzania and Kenya) to assess fisheries potential, and determine whether stocks are distinct or shared regionally. The accumulated information is a large step towards regional integration, but clear gaps remain. This study summarizes historical information by fishery and species, and highlights the remaining gaps. Recommendations for future research and management strategies are provided.

Introduction and objectives

Deep-water bottom trawl fisheries for crustaceans in the SWIO are industrial in nature, and operate at depths of 200-600m (sometimes to 800m) to catch a mixture of high-value crustacean species. Target species vary by depth and area, but generally consist of deep-water knife (or pink) prawns (*Haliporoides triarthrus*), several other deep-water prawns (*Aristeus virilis, A. antennatus*, *Aristaeomorpha foliacea*, and *Plesiopenaeus* and *Heterocarpus* spp.), langoustines (*Metanephrops mozambicus*), deep-water lobsters (*Palinurus delagoae*) and deep-sea crabs (*Chaceon macphersoni*). Many other crustacean species are caught in smaller numbers, and are mostly discarded. Apart from crustaceans, the trawlers catch considerable quantities of teleosts and elasmobranchs, which are retained if they can be sold, or discarded if considered of low commercial value.

Known trawling grounds for deep-water crustaceans are restricted to eastern South Africa (approx 1,750 km^2), Mozambique (15,000 km^2), Madagascar (small enclaves along the west coast), Tanzania (between Mafia Island and Zanzibar) and Kenya. Long-term fisheries exist only in Mozambique and South Africa, and in Madagascar and Tanzania trawling in the deep appears to be occasional, limited to a few vessels, and usually short-lived. Only anecdotal information was available for Kenya.

Several research vessels have undertaken surveys in the SWIO, and although not always focussed on crustaceans, bottom trawls have frequently been made at 100 to 600 m depth. The RV Dr Fridtjof Nansen is the best known of these research vessels, and between 1980 and 2010 it undertook numerous surveys in the region. For the purposes of this

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study, four distinct deep-water crustacean trawling sectors have been defined. These are:

Industrial deep-water crustacean trawl fishery (South Africa, east coast): Small fishery of <5 vessels (3-4 active in 2011) restricted to local fishing companies with fishing rights. Total landings of crustaceans range between 200 and 400t per year. Target species are *H. triarthrus, M. mozambicus* and *P. delagoae,* with lesser quantities of other prawn species (*A. foliacea, Aristeus* spp*)* and deep-sea crabs *Chaceon macphersoni.*

Industrial deep-water crustacean trawl fishery (Mozambique): Much larger fishery than in South Africa with catches ranging between 1,000 and 3,000t per year. The target group is "deep-water prawns", which includes a mix of species. *Haliporoides triarthrus* is most abundant in catches, followed by *A. foliacea, A. virilis and A. antennatus.* The langoustine *M. mozambicus* and lesser quantities of deep-sea crabs and spiny lobsters are also caught as a retained bycatch. All of these species have an apparent transboundary distribution, occurring both in Mozambique and in South Africa.

Deep-water trawl surveys using Research Vessels (SWIOFP region, including Kenya, Tanzania, Mozambique, Madagascar, Mauritius, Comoros): A large number of surveys have been undertaken in the region, by the RV Dr Fridtjof Nansen and by other vessels. Many of these surveys were undertaken by foreign or wet-leased vessels in Mozambican waters (e.g. by the RV Visconde de Eza in 2007 to 2009), often for stock assessment purposes.

Exploratory deep-water trawl fisheries, including short-term fisheries (SWIOFP region, Madagascar and Tanzania): Limited data are available for short-term deep-water trawl fisheries in Tanzania and Madagascar. The purposes of these fisheries were commercially driven, as opposed to research and stock assessments shown in the category above.

A growing number of peer-reviewed publications on the deep-water trawl fisheries of the SWIO are available in the literature. Many survey and stock assessment reports, spanning from the 1970s to date, are potentially available. References to all accessible published information (journal articles and reports) are available in the SWIOFP *Endnote* collection, and have been extracted for deep-water trawl fisheries for this study. Several long-term databases exist under the custodianship of the South African and Mozambique governments, metadata are stored on the SWIOFP GeoNetwork system and summarisations of catch and effort are stored in the online StatBase programme (see www.swiofp.net).

This chapter aims to identify and collate all the relevant available information on deep-water trawl fisheries and their target species in the SWIO region to provide specialist advice to support and underpin a regional approach towards sustainable management of this valuable resource.

GEOGRAPHICAL SCOPE

Within the larger SWIOFP geographic study area as described in Chapter 1, only small patches within a 100-800 m depth range are suitable for bottom-trawling. Accordingly, the scope of this report is effectively confined to the continental shelf of the African mainland and Madagascar; the island states do not permit trawling.

METHODS AND MATERIALS

Multi-sector consultative workshops were held in Mozambique and Kenya to gather information on all available literature, reports and extant databases. *Endnote* was used as a starting point for the literature survey, and StatBase was used to identify relevant databases in each country. The information was contextualized with the assistance of local scientists and data managers. Tanzania and Madagascar have very limited deep-water crustacean trawl sectors, and it was decided that information from these two countries could be accessed electronically, with the assistance of the respective SWIOFP coordinators in these countries.

The location and extent of fishing grounds were mapped using GIS Software wherever the information was available and of good quality. Spatial distribution maps of the abundance of selected species were developed where data allowed. Spatial and temporal trends in fishing effort, catches, and catch rates were extracted from historical data. Fishing area, depth and gear-type were taken into account where possible. Basic biological parameters describing average size, sex ratios, size at sexual maturity, growth and mortality rates, fecundity, and reproductive activity were tabulated for priority species. Eight priority species were identified in the four deep-water trawling sectors, based on the earlier SWIOFP data gap-analysis process (Groeneveld *et al*. 2010). In the sector X species matrix below, all four sectors have reported catches of each of the priority species. However, the quantities per species vary depending on the area and depth range targeted. In the Table below, the main target species per sector are coloured in blue.

Main target species per sector	*Haliporoides triarthrus*	*Aristaeomorpha foliacea*	*Aristeus antennatus*	*Aristeus virilis*	*Metanephrops mozambicus*	*Nephropsis stewarti*	*Palinurus delagoae*	*Chaceon macphersoni*
Sector 1: Industrial deep-water crustacean trawl fishery (South Africa, east coast)								
Sector 2: Industrial deep-water crustacean trawl fishery (Mozambique)								
Sector 3: Deep-water trawl surveys using Research Vessels (SWIOFP region)								
Sector 4: Exploratory deep-water trawl fisheries, including short-term fisheries (SWIOFP region)								

Results

COUNTRY SUMMARY

The country summary tabulated below shows all the deep-water trawl fisheries and scientific surveys for crustaceans that could be located in the SWIO region. Commercial trawl fisheries that are presently active are coloured in blue. The main target species of these commercial fisheries are shown in bold font. Scientific surveys were often multi-disciplinary in nature, and bottom trawling was not always the main objective.

A full listing of scientific surveys undertaken as part of the SWIOFP project is given in Chapter 1, noting especially those surveys marked as C2 being directed in all or part to crustacean resources. The large number of additional and historic scientific surveys, particularly in Mozambique (26 surveys) or across the region by the Dr. Fridtjof Nansen (18 surveys, of which 6 were in Mozambique) are identified in the Table below, and are described later.

SWIOFP Country	Fishery	Time period	Species (present)
South Africa	Industrial deep-water crustacean trawl fishery	Exploration since 1920. Reliable data from 1988-date	***Haliporoides triarthrus*** *Aristaeomorpha foliacea* ***Metanephrops mozambicus*** ***Palinurus delagoae*** *Chaceon macphersoni* Other retained and discarded species
Mozambique	Industrial deep-water crustacean trawl fishery	1968-date	***Haliporoides triarthrus*** ***Aristaeomorpha foliacea*** ***Aristeus antennatus*** ***Aristeus virilis*** *Metanephrops mozambicus* Other retained and discarded species, incl. *P. delagoae* and *C. macphersoni*.
Mozambique	Scientific surveys by RV Visconde de Eza	2007, 2008, 2009	Surveys were multi-disciplinary but included deep-trawls. Target spp. were deep-water prawns.
Mozambique	Scientific surveys by RV Dr Fridtjof Nansen	1977-78, 1980, 1982, 1983, 1990, 2009	Surveys were multi-disciplinary but included deep-trawls. No target spp.
Mozambique	Scientific surveys by Ernst Haeckel (GDR)	1980, 1981, 1982, 1988	*Haliporoides triarthrus* *Aristaeomorpha foliacea* *Aristeus antennatus/ virilis* Other deep-water prawns
Mozambique	Scientific surveys by other vessels: Caroline 2011; Capricornio 1999; Algoa 1994; Lee Anne 1993, 1994; Arpen IV 1991, 1992; Bruno Tesh 1989, 1990; Cometa Galleya 1988; Karl Wolf 1987; Sevastopolski Rybak 1987, 1988	1987-2011	Deepwater prawns and langoustines; various species / objectives
Tanzania	Scientific surveys by RV Dr Fridtjof Nansen	1982, 1983	Multidisciplinary incl. deep trawls
Tanzania	Scientific surveys by other vessels: Roberto 2012; RV Prof. Mesyatsev 1975, 1976, 1977	1975-1977; 2012	Deepwater crustaceans and fish
Tanzania	Exploratory deep-water trawl fisheries, incl short-term fisheries: Ocean Crest	2004	Deep-water crustaceans
Kenya	Scientific surveys by RV Dr Fridtjof Nansen	1982, 1983	Multidisciplinary incl. deep trawls
Kenya	Scientific surveys by other vessels: Roberto 2012; Ujuzi 1979-1981	1979-1981; 2012	Deepwater crustaceans and fish
Kenya	Exploratory deep-water trawl fisheries, incl short-term fisheries	No data	No data
Madagascar	Scientific surveys by RV Dr Fridtjof Nansen	2008, 2009	Multidisciplinary incl. deep trawls
Madagascar	Scientific surveys by other vessels: Caroline 2012; RV Vauban 1971-1973	1971-1973; 2011	Deepwater crustaceans and fish
Madagascar	Exploratory deep-water trawl fisheries, incl short-term fisheries: FV Domenica 2001; FV Celtic 2004; PNB-Unima 2011	2001, 2004, 2011	Deepwater crustaceans
Comoros	Scientific surveys by RV Dr Fridtjof Nansen	2009	Multidisciplinary incl. deep trawls
Mauritius	Scientific surveys by RV Dr Fridtjof Nansen	2008, 2010	Multidisciplinary incl. deep trawls

DESCRIPTION OF CRUSTACEAN DEEP-WATER TRAWLING SECTORS

INDUSTRIAL CRUSTACEAN DEEP-WATER TRAWL FISHERY (EASTERN SOUTH AFRICA)

Target species:
- *Haliporoides triarthrus*
- *Metanephrops mozambicus*
- *Palinurus delagoae*

Common bycatch species:
Retained:
- *Aristaeomorpha foliacea*
- *Aristeus* spp.
- *Chaceon macphersoni*
- *Nephropsis stewarti*
- Other crustaceans, fish and cephalopods

Discarded:
- Low-value fish, crustaceans, cephalopods, elasmobranchs

DESCRIPTION

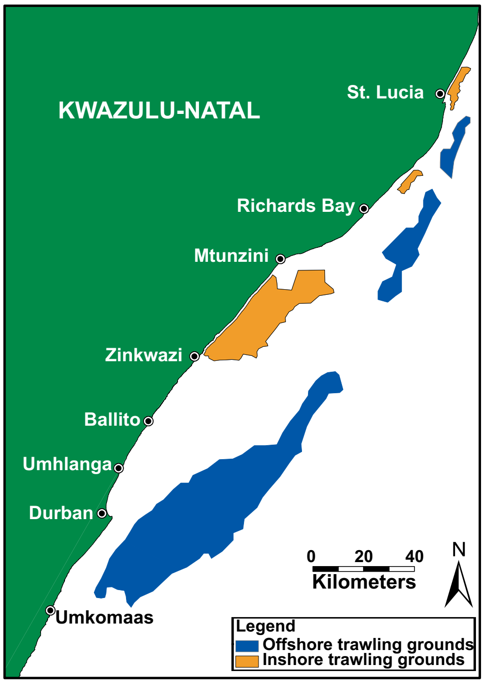
Industrial deep-water trawl fishery based in Durban.

SPATIAL EXTENT OF FISHERY

Bottom trawling for deep-water crustaceans occurs off the KwaZulu-Natal (KZN) province of South Africa from St Lucia to just south of Durban, between 28° and 30° South (in blue).

Trawl grounds range from a width of 15 km off St Lucia to 40km wide off Durban, cover an area of approximately 1,750km^2 (ORI unpublished data) and range in depth from 100 to 600m. Most trawling takes place between 300 and 500m.

Refs: de Freitas 1985; Groeneveld & Melville-Smith 1995; Fennessy & Groeneveld 1997; Groeneveld et al. *2013*



FISHING VESSELS AND GEAR

Stern trawlers with LOA of 25-35m, and 500-1,000hp are equipped with radar, sonar and GPS, carry a crew of 15-18, have storage capacity of approx. 30t and can remain at sea for 30 days. Fishing gear is a single otter trawl with footrope lengths of 25-60m. Footrope chains are attached, and nylon nets with 60 mm stretched mesh are used. Trawling takes place 24h per day, on soft muddy sediments. Trawl speed is 2-3 knots and drags last an average of 4 hours. Shore facilities are minimal as most processing takes place at sea (de-heading, grading, packing, freezing). After landing, catches are distributed to wholesalers. No bycatch reduction devices are used in the fishery.

Refs: Fennessy 2001

HISTORY OF FISHERY

Exploratory trawling in 1920 first found spiny lobster *Palinurus delagoae* off eastern South Africa; large catches of several tonnes per trawl were reported up to the 1960s. The lobster-directed trawl fishery gradually diversified to catch deep-water prawns, langoustines, red-crabs and several fish and cephalopod species. South African vessels fished in Mozambique until 1976 – when this stopped the number of vessels active in South Africa increased.

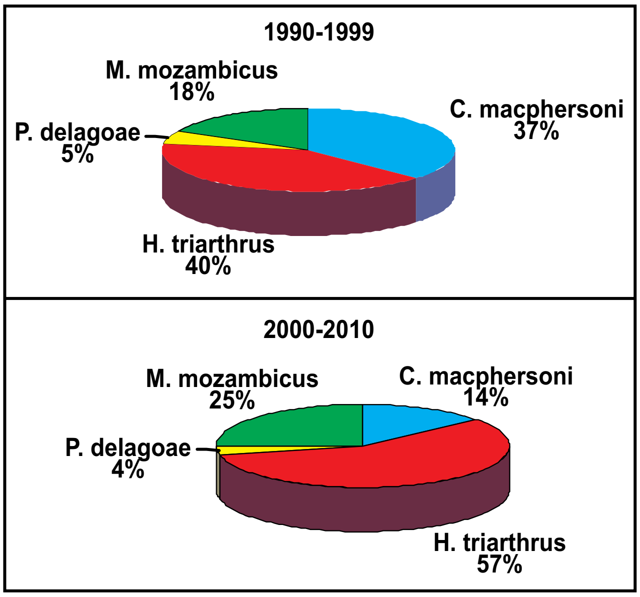
Refs: Gilchrist 1920; Berry 1972; Groeneveld & Melville-Smith 1995; Fennessy & Groeneveld 1997; Fennessy 2001

TRENDS IN CATCH, EFFORT AND CPUE

Trawling effort is distributed over depth and season according to species availability and economic value. The most valuable species mix is found at 400-500m. Catch trends by species are difficult to interpret because of targeting. Reliable data for SA are available from 1988 to date.

The number of active vessels declined from 10 in 1990 to 3-4 between 2008 and 2010. The number of days at sea declined in 2004, and has remained at approx. 450 days/year since then. Prior to 2004, approx. 700 days/year was common, except in 1994, when a major fishing company withdrew due to financial difficulties (only 293 days/year reported in 1994).

Crustacean catches range from 200 to 400 t/year (average 255 t/year). *H. triarthrus* dominated catches in 1990-1999 (40% by weight) and in 2000-2010 (57%). The importance of *C. macphersoni* declined from 37% to 14% of catches over the two decades. *M. mozambicus* increased somewhat (18% to 25%) and *P. delagoae* remained the same (5% and 4%).



Inter-annual trends in catches (see below) showed larger overall landings prior to 1994 than thereafter. *C. macphersoni* catches declined after reaching a peak in 1992: it now makes up only a small proportion of catches.

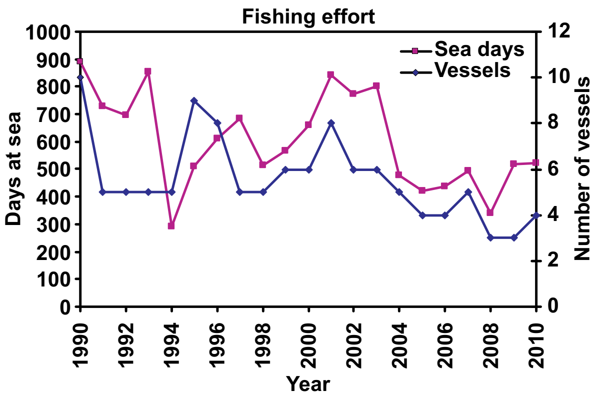
Annual catches of both *H. triarthrus* and *M. mozambicus* have remained relatively stable, despite a decline in nominal fishing effort. *P. delagoae* catches were higher than average in 1992 and 1993, and again in 2009 and 2010.

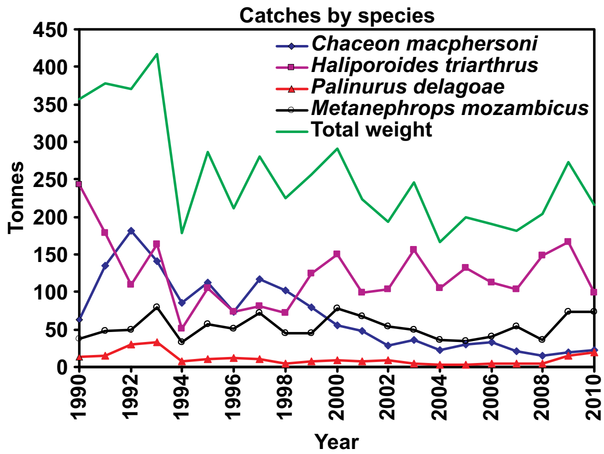
Nominal CPUE for all species combined declined gradually between 1994 and 2002, and then increased again from 2002 to 2008. The highest CPUE of the time-series was achieved in 2008 (0.6t/day), driven by a boom in *H. triarthrus* CPUE (0.44t/day).

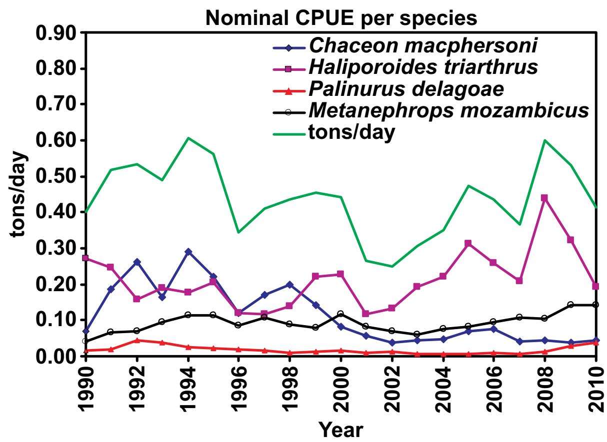
Overall, CPUE in 2009 and 2010 declined sharply, because of a reduction in *H. triarthrus* CPUE – nevertheless, nominal CPUE of *H. triarthrus* remains exceptionally high compared to other years (see 2009 value). The CPUE of *M. mozambicus* has shown a consistent increase between 2003 (0.06t/day) and 2010 (0.14t/day). *C. macphersoni* CPUE has declined since 2006 (0.07–0.04t/day), but *P. delagoae* has increased (0.01–0.04t/day).

Trends in nominal CPUE are likely affected by vessel power or efficiency, which has increased over time, and by targeting practices. Alternatively, CPUE can be affected by competition for space on fishing grounds – fewer vessels allow for more space to trawl. Nominal CPUE does therefore not necessarily directly reflect abundance.

Refs: Groeneveld & Melville Smith 1995; Fennessy & Groeneveld 1997; Robey et al. *2011, 2013a, 2013b*







MANAGEMENT CONTROLS AND REGULATIONS

The fishery is considered to be optimally exploited. Entry into the fishery is limited to South African rights holders only. Fishing permits are subject to the provisions and regulations of several laws, but most importantly the Marine Living Resources Act, 1998 (Act No. 18 of 1998).

A Total Allowable Effort (TAE) regulation limits effort to 7 permits for this deep-water fishery. These vessels are prohibited from trawling within 7nm of the high-water mark and on the Thukela Bank. Vessels must be fitted with a Vessel Monitoring System (VMS) to track movements. Mesh size on trawl nets may not be less than 50mm (centre knot to centre knot). Spotted grunter *(Pomadasys commersonii)* may not be sold as this species has been de-commercialised throughout South Africa. Fishing effort and catches (by species) must be reported in a logbook (per drag, and for each trip), and the information must be submitted to authorities. Catches are weighed at landing points, and staff of Ezemvelo KwaZulu-Natal Wildlife (the provincial conservation agency) must be informed when a trawler discharges its catch, so that it may be inspected. Catches may only be landed at the ports of Durban and Richards Bay. Vessels must accommodate fisheries observers on request.

Refs: Fennessy 2001; DAFF 2010; Anon 2011

BYCATCH AND ECOLOGICAL IMPACTS

By weight, target species make up 18% of catches; retained bycatches 12% and discarded bycatch 70%. Retained bycatch includes slipper lobster, but mainly fish (*Atrobucca nibe; Merluccius paradoxus; Chloropthalmus punctatus; Zeus faber; Helicolenus dactylopterus* and *Cheilidonichthys* spp) and cephalopods (*Veladona togata*; *Sepia officinalis*). No bycatch reduction devices are used.

Discarded bycatch comprises organisms of low commercial value, being unmarketable, inedible or too small. They are mostly dead when returned to the water. Of discards, fish make up 80%, crustaceans 10% and other species, 10%. Commonly discarded fishes include *Chaunax pictus*, various grenadiers and splitfins; discarded elasmobranchs include *Squalus megalops, S. mitsukurii, Raja* spp; discarded crustaceans include *Plesionika martia, Pleistocantha* spp. Ecological impacts of bycatches are poorly understood.

Refs: Fennessy & Groeneveld 1997; Persad 2005

INDUSTRIAL CRUSTACEAN DEEP-WATER TRAWL FISHERY (MOZAMBIQUE)

Target species:
- *Haliporoides triarthrus*
- *Aristaeomorpha foliacea*
- *Aristeus antennatus*
- *Aristeus virilis*

Common bycatch species:
<u>Retained</u>:
- *Metanephrops mozambicus*
- *Nephropsis stewarti*
- *Palinurus delagoae*
- *Chaceon macphersoni*
- Fish and cephalopods

<u>Discarded</u>:
- Low-value crustaceans, fish, elasmobranchs

DESCRIPTION

Industrial deep-water trawl fishery.

SPATIAL EXTENT OF FISHERY

Five fishing grounds are located between 17°S and 25°40'S: Sofala Bank, Bazaruto A & B, Boa Paz and Inhaca.

The fishery operates at depths of 300-700m. Fishing grounds extend over an area of > 15,000 km^2.

Refs: Sanders et al. *1988; Dias* et al. *2011*

FISHING VESSELS AND GEAR

Stern and double-rigged trawlers with an LOA of 20-35m and GRT of 150-1,000t (mostly < 500t). Freezer trawlers undertake trips of 20-40 days. Most vessels belong to foreign companies fishing under a licensing system. Vessels are equipped with radar, sonar and GPS. Otter trawls with footrope lengths of 25-60m are used; footrope chains attached. Nylon nets with 60mm stretched mesh are used. Trawling takes place 24h per day, on soft muddy sediments. Trawl speed is 2-3 knots and drags last an average of 4 hours. Most processing takes place at sea (de-heading, grading, packing and freezing).

Refs: Sanders et al. *1988; Fennessy 2001*

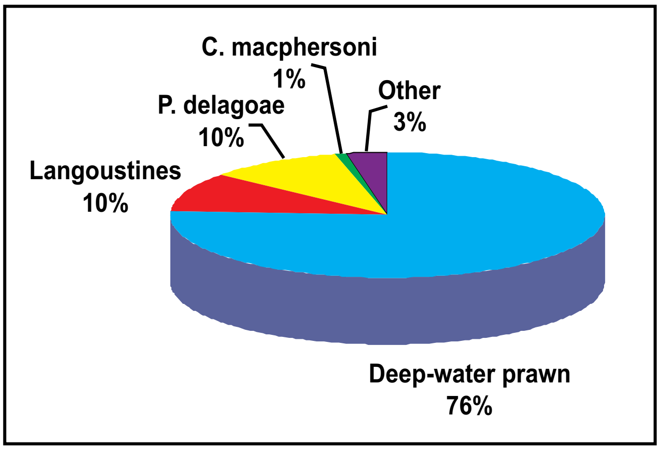
HISTORY OF FISHERY

The fishery started in 1968, but catch statistics were only available from 1978, after the declaration of the Mozambique EEZ of 200 nautical miles. Licensing of foreign vessels has included those from Spain, Germany, the USSR and South Africa. Catches were reported as 1,200–2,800t/year between 1980 and 1986. An early survey of fishing grounds was done by the RV Ernst Haeckel in 1980, including preliminary stock assessments.

Refs: Freitas & Araujo 1973; Ulltang 1980; Sanders et al. *1988*

TRENDS IN CATCH, EFFORT AND CPUE

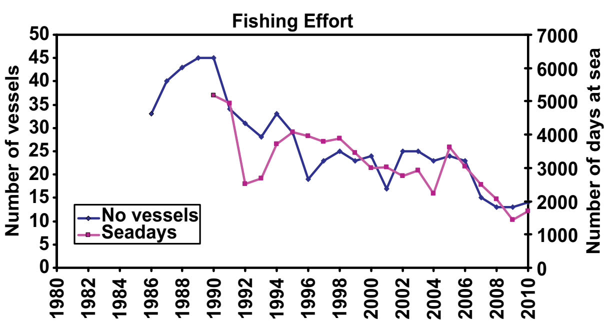
The fishery targets mainly deep-water prawns (gambas, including *H. triarthrus, A. foliacea, A. antennatus* and *A. virilis*), but langoustines (*M. mozambicus* and *Nephropsis stewarti*), spiny lobster *P. delagoae*, and deep-sea crab *C. macphersoni* are also caught and retained. Large discarded bycatch is realized – mainly fish, elasmobranchs, molluscs and crustaceans with a low commercial value.

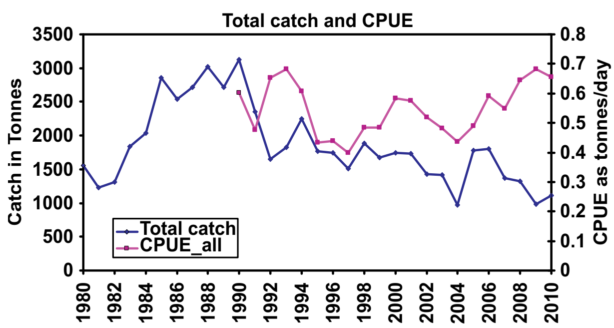


Most information and stock assessments focus on *H. triarthrus* and *A. foliacea*; far less information is available on langoustines. Fishing effort declined gradually between the mid-1980s and 2010, in terms of number of vessels and total days at sea. A maximum of 45 vessels operated in the 1980s, declining to 13 at present (see Figures below).

Total catches of deep-water prawns declined from 3,120 t in 1990 to approx 1,000 t/y in 2009 and 2010. Nominal CPUE (t/vessel day) increased from 0.43 in 2004 to 0.66 in 2010. It is unclear whether the CPUE increase is a result of stock recovery, or of an increase in fishing power and efficiency of vessels, or of reduced competition between fewer vessels.

Refs: Dias et al. *2011*





MANAGEMENT CONTROLS AND REGULATIONS

Foreign fishing vessels operating in Mozambique require a license from the government.

Fisheries statistics are collected from logbooks completed by skippers, landings statistics and trans-shipment records. Samplers at sea and in ports collect species and length composition data of catches. Research surveys are carried out (Visconde de Eza in 2007-2009; Caroline in 2011), and stock assessments of deep-water prawn are done (2005, 2007, 2011). Management recommendations are made to the Ministry on an annual basis.

Refs: Dias et al. *2011*

BYCATCH AND ECOLOGICAL IMPACTS

A large bycatch is realized – mainly fish, elasmobranchs, cephalopods and low-value crustaceans. The bycatch is either discarded overboard or retained. A recent survey by the RV Visconde de Eza reported 410 species: Fishes comprised 267 spp and made up 84% of catches by mass and 82% by numbers. Crustaceans comprised 109 species and cephalopods 35 species.

Refs: Dias et al. *2009*

DEEP-WATER TRAWL SURVEYS USING RESEARCH VESSELS

Countries:
- Mozambique
- Tanzania
- Kenya
- Madagascar
- Mauritius
- Comoros

Target species:
- Deep-water crustaceans, multi-disciplinary surveys

Bycatch species:
- n/a

DESCRIPTION

Scientific surveys using research vessels. The surveys described in this section are either targeted at deep-water crustaceans using bottom trawling, or are multi-disciplinary surveys that include some deep-water bottom trawling. The vessels used range from dedicated research vessels (such as the Norwegian RV Dr Fridtjof Nansen) to chartered commercial fishing vessels used to conduct surveys over short periods to collect information for stock assessment (for example, FV Caroline used by SWIOFP in 2011).

LIST OF SURVEYS

Surveys by RV Dr Fridtjof Nansen. These were generally of a multi-disciplinary nature including biodiversity, pelagic and demersal trawls, and acoustic and oceanographic sampling. The IMR survey reports are summarized by Saetersdal *et al.* (1999), and those completed after 1999 are available from the IMR in Bergen, Norway.

No	*Year*	*Months*	*Vessel*	*Area*	*No of trawls >100m*	*Ref*
1	1982	Aug	Dr Fridtjof Nansen	Kenya	27	IMR, 1982d
2	1982	Dec	Dr Fridtjof Nansen	Kenya	9	Nakken, 1981
3	1983	May	Dr Fridtjof Nansen	Kenya	2	Iversen, 1983
4	1982	Jun-Jul	Dr Fridtjof Nansen	Tanzania	29	Myklevoll, 1982b
5	1982	Nov-Dec	Dr Fridtjof Nansen	Tanzania	17	IMR, 1982c
6	1983	May	Dr Fridtjof Nansen	Tanzania	1	IMR, 1983a; Iversen et al. 1984
7	1977-78	Aug-Jun	Dr Fridtjof Nansen	Mozambique	42	IMR, 1977c, 1978b, 1978c and 1978d, Sætre and de Paula e Silva, 1979
8	1980	Oct-Nov	Dr Fridtjof Nansen	Mozambique	?	Brinca et al., 1981
9	1982	Sep	Dr Fridtjof Nansen	Mozambique	0	Brinca et al., 1983
10	1983	May-Jun	Dr Fridtjof Nansen	Mozambique	0	Brinca et al., 1984
11	1990	Apr-May	Dr Fridtjof Nansen	Mozambique	12	IMR, 1990b
12	1990	Aug-Sep	Dr Fridtjof Nansen	Mozambique	?	IMR, 1990d
13	1990	Nov-Dec	Dr Fridtjof Nansen	Mozambique	193	IMR, 1990f
14	2008	Oct	Dr Fridtjof Nansen	Mauritius	9	IMR, 2008a
15	2008	Aug-Sept	Dr Fridtjof Nansen	Madagascar - East	3	IMR, 2008b
16	2009	Aug-Oct	Dr Fridtjof Nansen	Madagascar - West	21	IMR, 2009
17	2009	Oct-Nov	Dr Fridtjof Nansen	Comoros	1	IMR, 2010
18	2010	Dec	Dr Fridtjof Nansen	Mauritius	1	

Surveys by other research vessels or chartered fishing boats

a) *Mozambique*:
A list of 20 important surveys targeted at deep-water crustaceans between 1980 and 2011 is given. The results of these surveys are summarized in a series of Technical Cruise Reports as cited in the table below.

No	*Year*	*Months*	*Vessel*	*Area °S*	*Partners*	*Ref*
1	2011	Nov-Dec	Caroline	21-26	SWIOFP	Everette *et al.* 2015
2	2009	Mar-Apr	Visconde de Eza	17.30-26.48	IEO, Spain	Dias *et al.* 2009; Sobrino *et al.* 2009
3	2008	Mar-Apr	Visconde de Eza	17.30-26.48	IEO, Spain	Dias *et al.* 2008
4	2007	Mar-Apr	Visconde de Eza	17.30-26.48	IEO, Spain	Sobrino *et al.* 2007a&b
5	1999	Mar-Apr	Capricornio	17.00-26.50	IPIMAR, Portugal	Dias *et al.* 1999
6	1994	Dec	Lee Anne	18-26	IIP	Rodrigues & Dengo 1995
7	1994	Jun	Algoa		IIP	
8	1993	Nov-Dec	Lee Anne	17.50-26.10	IIP	Rodrigues & Dengo 1995
9	1992	Jan-Feb	Arpen IV	Sofala Bank	IIP	Palha de Sousa 1992
10	1991	Jan	Arpen IV	Sofala Bank	IIP	Dengo & Caramelo 1992
11	1990	Dec	Bruno Tesh	19.27-26.45	GDR	
12	1989	Nov-Dec	Bruno Tesh	16.00-26.30	GDR	
13	1988	Oct-Nov	Ernst Haeckel	21.00-26.30	GDR	Pacule 1989, Dengo 1989, Relatorio de cruzeiro 10&24
14	1988	Mar-Apr	Cometa Galleya	Boa Paz	USSR	Relatorio de cruzeiro 16 (Sousa 1990)
15	1987	Oct	Sevastopolsky Rybak	16-26.30	USSR	Relatorio de cruzeiro 26
16	1987	Feb-Mar	Karl Wolf	17-26.30	GDR	
17	1988	Feb-Mar	Sevastopolsky Rybak	19.27-26.45	USSR	Pacule 1990
18	1982	Jan-Feb	Ernst Haeckel	21-26.30	GDR	Brinca *et al.* 1983
19	1981	Jan-Feb	Ernst Haeckel	21-26.30	GDR	Brinca *et al.* 1983
20	1980	Aug-Sep	Ernst Haeckel	21-26.30	GDR	Brinca *et al.* 1983

b) Tanzania:

- A SWIOFP deep-water trawl survey targeted at langoustines and prawns was undertaken in February 2012 by FV Roberto in two areas: Dar es Salaam (180km^2) and NW Mafia (<220 km^2). The target depth range was 100-500m.
- The R/V Professor Mesyatsev undertook trawl surveys off Tanzania in Dec 1975 – June 1976/July 1977 (Birkett 1978; Burczynski 1976, VNIRO 1978).

Deep-water shrimp (*Heterocarpus* sp) were caught during these surveys although catch rates were generally low. Lobsters were identified as *Linuparus somniosus*, while langoustines, *Metanephrops andamanicus* were regularly caught at depths of 250-320m at the southern end of the Zanzibar channel by the Prof. Mesyatsev. The FV Roberto caught only small quantities of crustaceans in 2012.

c) Kenya:

- A SWIOFP deep-water trawl survey targeted at crustaceans was undertaken in February/March 2012 by FV Roberto in three areas: Malindi-Ngomeni area, Kilifi area, and north of Chale Island. The target depth range was 100-500m.
- Trawl surveys were done with F/V Ujuzi between 1979 and 1981, backed by the FAO/UNDP (1982).

Deep-water shrimp (mainly *Heterocarpus woodmansoni*) were caught by the F/V Ujuzi at approx. 366m depth offshore of Ungwana Bay. Deep-water lobster *Puerulus angulatus* and *Metanephrops andamanicus* were also caught by F/V Ujuzi. Estimates exist of biomass and trawlable areas (Sparre and Venema 1988; FAO/UNEP 1982).

d) Madagascar:

- A SWIOFP deep-water trawl survey targeted at crustaceans was undertaken in November and December 2011 by F/V Caroline in three areas: Tulear, Morombe and Maintirano. The target depth range was 200-600m.
- Deep-water trawl surveys were undertaken by the R/V Vauban between 1971 and 1973 along stretches of the Madagascar coastline, under the sponsorship of ORSTOM (see Crosnier and Jouannic 1973).
- Deep-water trawl survey carried out by FAO/UNDP (Anon 1974).

Although the continental shelf is mostly steep, and very irregular and therefore unsuitable for trawling, limited trawling areas with prawns catches were found by FAO/UNDP Project MAG/68/515. Crosnier & Jouannic (1973) found many species in deep water but identified only the following as having potential commercial importance due to their size and abundance: knife prawn (identified as *Hymenopenaeus sibogae,* but probably *Haliporoides triarthrus*), deep-water shrimps *Aristaeomorpha foliaceae*, two species of *Aristeus, Plesiopenaeus edwardsianus,* langoustines *Metanephrops mozambicus*, deep-water crab *Chaceon macphersoni* and several species of lobster: *Justitia* spp, *Puerulus* spp and *Palinurus* spp.

Refs: Crosnier & Jouannic 1973; Anon 1974; Sparre & Venema 1988; FAO/UNEP 1982; Birkett 1978; Burczynski 1976; VNIRO 1978;Iversen et al. *1984; see Tables above for RV Dr. Fridtjof Nansen and Mozambique survey references; Saetersdal* et al. *1999; Everett* et al. *2015.*

SAMPLING GEAR

All vessels used bottom trawl nets. Footrope lengths, mesh size, net opening and configuration and trawl speeds are described in the respective survey reports.

SURVEY OUTPUTS

Survey reports and several publications describe findings on species composition, distribution patterns, abundance of target species, biomass estimates, as well as biological parameters (size & sex composition) and bottom-type or habitats.

Many surveys, and particularly those done by the FV Dr Fridtjof Nansen programme, have succeeded in collecting large quantities of good quality data on biological resources and the environment. These data are available from both the Nansen and SWIOFP programmes.

The SWIOFP trawl surveys undertaken in 2011 and 2012 showed that deep-water crustaceans were less abundant in Kenya and Tanzania than further south, with limited commercial appeal. Crustacean catch composition in Mozambique was strikingly similar to commercial landings in eastern South Africa, supporting a distinct sub-region for fisheries management, but differed markedly across the Mozambique Channel. New deep-water trawl fisheries will have to contend with significant teleost bycatch.

EXPLORATORY DEEP-WATER TRAWL FISHERIES, INCLUDING SHORT-TERM FISHERIES

Countries:
- Tanzania
- Madagascar
- Kenya

Target species:
- Deep-water crustaceans

Bycatch species:
- n/a

DESCRIPTION

Exploratory trawl fisheries are occasional deep-water trawl fishing for crustaceans for commercial purposes within the SWIOFP region, mainly in Madagascar, Tanzania and Kenya. They are usually of short duration, and little information exists on their catches.

SAMPLING GEAR

All vessels used bottom trawl nets. Footrope lengths, mesh size, net opening and configuration and trawl speeds are generally unknown.

TRENDS IN CATCHES, EFFORT AND CPUE

- Fishing effort and catch data (commercial pack categories by species) are available for three vessels operating off western Madagascar: FV Domenico (Jun-Sep in 2001), FV Celtic (Sep-Nov 2004) and PNB-Unima (2011). A small trawl fishery of a few vessels operates on deep-water fishing grounds off western Madagascar at present.
- Some fishing effort and catch data (commercial pack categories – mainly langoustine) are available for the South African vessel FV Ocean Crest operating in Tanzania in May-Jun 2004.
- Virtually no information is available on deep-water trawling off Kenya, although a local fishing company representative (Alesandro Basta; Ittica) stated that "economical trawling off Kenya takes place at depths ranging from 150–350 m".

OUTCOMES

Deep-water trawl fishing in Madagascar and Tanzania takes place sporadically, presumably because trawl grounds are limited and difficult to trawl, and profits are marginal compared to shallow-water prawn resources.

PRIORITY SPECIES

HALIPOROIDES TRIARTHRUS (STEBBING, 1914)

Common names:
- Knife prawn
- Pink prawn

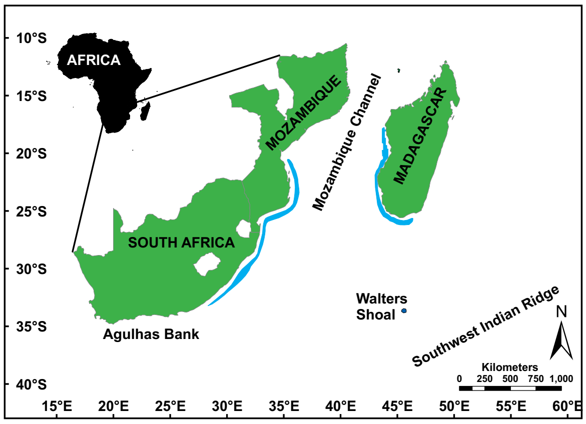
Fisheries:
- Target species in deep-water crustacean trawl fisheries in South Africa and Mozambique.

SWIOFP Countries:
- South Africa
- Mozambique
- Madagascar
- Tanzania (possibly)

DISTRIBUTION AND HABITAT

SE African coast; approx 20° S (Mozambique) to 30° S (South Africa). Also SW Madagascar. Depth range is 180-650m. Soft muddy bottom, near edge of continental slope – sticky mud largely composed of foraminiferous remains.

Refs: Holthuis 1980, Berry et al. *1975, de Freitas 1985*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

Reproductively active females are scarce on fishing grounds, except at Bazaruto, which may be a spawning area with high proportions of mature females. Females mature at 29-50mm CL. Ovarian activity has been observed throughout the year, peaking in July to September in Mozambique and October to November in South Africa. Four ovarian developmental stages are: Stage 1=Inactive or immature ovaries; Stage 2=Active; Stage 3=Ripe; Stage 4=Spent. Transition between stages is gradual, and sometimes difficult to classify. Ovary stages can be seen macroscopically through the abdomen (purple ovary visible through shell).

Refs: Berry et al. *1975; Brinca* et al. *1983; Robey* et al. *2013a*

LARVAL DISTRIBUTION AND RECRUITMENT

Small specimens (recruits) are abundant in catches in August and September, and in January and February in Mozambique, and in December and February in South Africa. Most recruitment in Mozambique occurs at Bazaruto B and Inhaca.

Refs: Berry et al. *1975; Brinca* et al. *1983; Robey* et al. *2013a*

MOULTING AND GROWTH

Von Bertalanffy growth parameters L_∞ and K for Mozambique were 53mm CL and $0.42y^{-1}$ for both sexes combined. In South Africa the parameters were 35.2mm and $1.27\ y^{-1}$ for males, and 40.6mm and $1.06y^{-1}$ for females. Males grew faster than females, but females reached a larger asymptotic length.

Refs: Dias et al. *2011; Robey* et al. *2013a*

MAXIMUM SIZE

60mm CL in females; 50mm CL in males. Can reach a total length of 150mm.

Refs: Berry et al. *1975; Holthuis 1980; Brinca* et al. *1983; de Freitas 1985; Robey* et al. *2013a*

NATURAL MORTALITY

Likely life span of 2-3 years. Estimates of M in Mozambique were 0.34/y (1998-2004) and 0.64/y (1986-1990).

Refs: Holthuis 1980; Berry et al. *1975; de Freitas 1985; Dias & Caramelo 2005.*

LENGTH-WEIGHT

Various relationships described (CL, total weight and length, male, female and sexes combined.)

Refs: Berry et al. *1975; Ivanov & Krylov 1980; Brinca* et al. *1983; de Freitas 1985; Torstensen 1989; Robey* et al. *2013a*

POPULATION SIZE STRUCTURE

Females become larger than males. Several cohorts are represented by size frequency modes. In Mozambique larger individuals occur at Bazaruto A (those with CL<20mm absent) compared to Bazaruto B where the size distribution is heterogeneous (several cohorts, incl. very small individuals). Off South Africa, month influenced CL, with larger individuals caught in March and November, and smaller ones in December and February. Females were larger, and CL fluctuated only marginally across a narrow depth gradient (400–500m) for which samples were available.

Refs: Berry et al. *1975; Brinca* et al. *1983; Robey* et al. *2013a*

SEX RATIO

Depth dependent sex ratio – 50:50 at < 450m deep; females dominate > 450m. Some seasonal fluctuation occurs.

Refs: Berry et al. *1975; Torstenson 1989; Robey* et al. *2013a*

MIGRATIONS

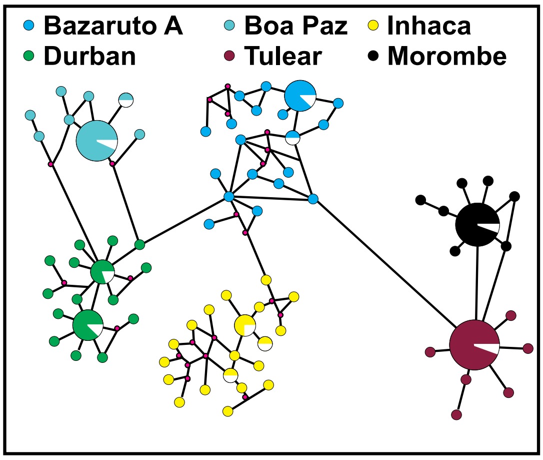
Likely, but not shown conclusively. Reproductively active females may move off fishing grounds. Possible counter-current migrations to redress downstream larval dispersal in Mozambique. Structured population in Mozambique suggests that ontogenic migrations may occur.

Refs: Berry et al. *1975; de Freitas 1985; Dias* et al. *2011*

GENETIC STOCK STRUCTURE

Highly structured populations based on COI (see figure), 16S and ANT genes. The finding of distinct metapopulations (or genetic stock units) over short geographic distances suggests that there is no single stock that is shared by South Africa, Mozambique and Madagascar. *H. triarthrus vniroi* in Madagascar is geographically and genetically distinct from *H. triarthrus triarthrus* along the African shelf, providing strong support for raising it to specific rank. This striking result is in concordance with the morphological and life history information; both these indicate high variability, which can be interpreted as characteristics of structured stocks.

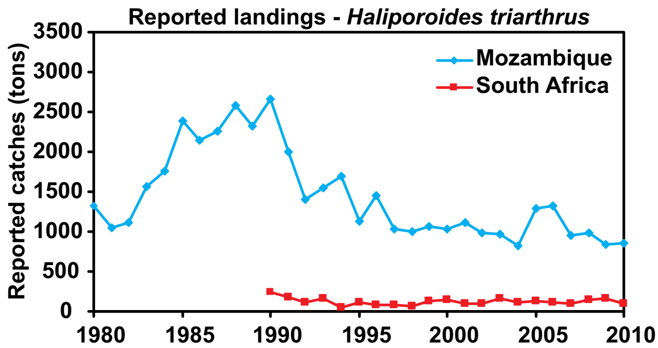
Refs: Zacarias 2013



STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

Annual landings in Mozambique declined from 2,600t in 1990 to 1,400t in 1992. South African catches ranged between 50 and 250t/y.

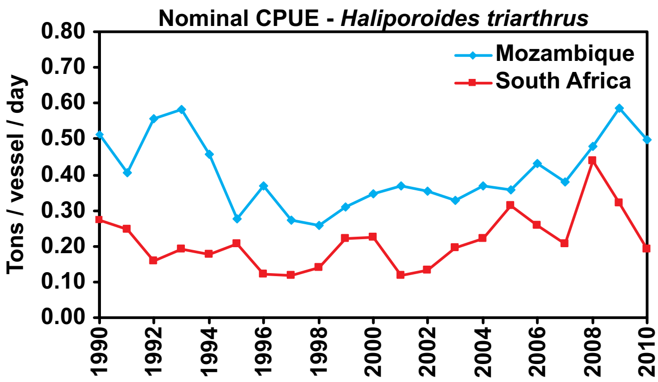


<u>Mozambique</u>: Regular assessments done – 2005, 2007, 2011. The most recent assessment indicates that deep-water prawns are under-exploited relative to MSY levels. Biomass: B_{CUR}/B_{MSY}=164%; Fishing mortality: F_{CUR}/F_{MSY}=39%. A TAC increase to 2,500t/yr has been recommended (2010 catches were 1,114t). The nominal CPUE has gradually increased since 1998, supporting the recommendation.

Surveys by the RV Vizconde de Eza have provided the following biomass estimates:

- 2007: 2050t; 39% at Inhaca; 26% at Bazaruto A
- 2008: 1637t; 41% at Inhaca; 23% at Bazaruto A
- 2009: 3101t; 48% at Inhaca; 29% at Bazaruto A

Refs: Sobrino et al. *2007; Dias* et al. *2008, 2009, 2011*



<u>South Africa</u>: No assessments yet, but a standardized CPUE trend (1988-2010) has been developed. CPUE lower than in Mozambique in all years, but a gradual increase (2001-2008) was followed by a sharp decline. The effects of increased vessel power and fewer active vessels on the CPUE trend is unknown. Data from South Africa and Mozambique originate from different vessels and gears – thus trends are indicative and cannot be directly compared.

Refs: Robey et al. *2013a*

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

Mozambique: MSY used as reference point. In 2010, biomass was 43% above BMSY. Management objectives are to increase catches and effort.

South Africa: In the absence of formal assessments, the management objective is precautionary – i.e. fishing effort is restricted to a few vessels to maintain status quo.

Refs: Dias et al. *2011; Robey* et al. *2013a*

DATABASES

DATA COLLECTION

Mozambique: Reporting of landings and effort; fisheries observers collect detailed fisheries and biological data at sea and at landing sites; scientific surveys undertaken to determine distribution, abundance and stock status.

South Africa: Drag sheets completed by skippers on board for each trawl (estimated catches); catches weighed at landing sites; fisheries observers at sea sample bycatches and collect biological data (species & quantities).

Refs: Robey et al. *2011; 2013a; Dias* et al. *1999, 2011*

KNOWN DATABASES

Mozambique:
- Production data (1986-2010)
- Logbook data – daily records (1994-2010)
- Biological sampling by IIP (1994-2010)
- Scientific surveys (2007-2009)

South Africa:
- Government database of rights holders, vessels, quotas, catches
- Prawn system with drag and landings data (1988-date)
- Ad hoc databases - biological data (1970s, 1990s, 2011)

METADATA

- ZAF-D007: KZN Crustacean trawl fisheries database
- ZAF-D008: KZN Crustacean trawl biological data
- MOZ-D2: Industrial register
- MOZ-D201: MOZ deep-water shrimp 1980-1990
- MOZ-D202: MOZ deep-water shrimp 1991-2008
- MOZ-D203: MOZ deep-water shrimp biological sampling 1980-2008

ARISTAEOMORPHA FOLIACEA (RISSO, 1827)

Common names:
– Giant red shrimp

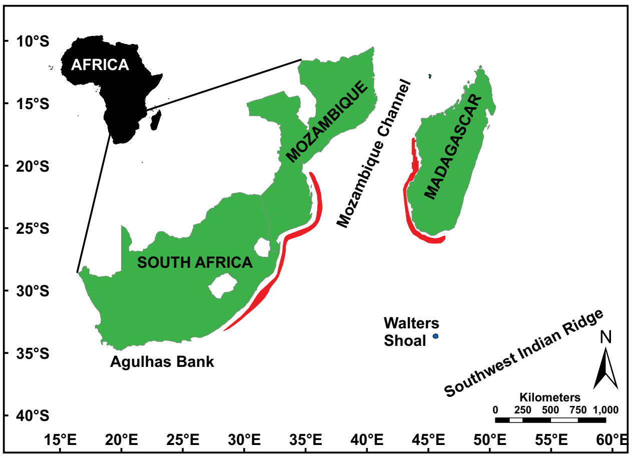
Fisheries:
– Target species in deep-water crustacean trawl fishery in Mozambique.
– Bycatch in South Africa.

SWIOFP Countries:
– Mozambique
– South Africa
– Madagascar

DISTRIBUTION AND HABITAT

Wide geographic distribution – Mediterranean Sea; E and W Atlantic; Indian Ocean and W Pacific from Japan to Australia, New Zealand and the Fiji Islands. Depth distribution ranges from 123-1,047m; max. abundance from 400-800 m in most areas. Soft muddy bottoms.

Refs: Pérez Farfante & Kensley 1997; Politou et al. *2004*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

No data for SWIO.
Mediterranean: Data from several sites. Females mate from 26.9mm CL, and mature from 29.8mm. Spawning takes place in June to-August (summer).

Refs: Politou et al. *2004; Kapiris & Thesalou-Legaki 2001*

LARVAL DISTRIBUTION & RECRUITMENT

No data for SWIO.
Recruitment at 600m depth in the Mediterranean.

Refs: Sarda et al. *2001*

MOULTING AND GROWTH

No data for SWIO.
Many estimates exist for Mediterranean populations, where females become larger than males, summarized in Politou *et al.* (2004), for example:

Refs: Politou et al. *2004*

Parameter	*Females (range)*	*Males (range)*
CL_∞ (mm)	62-73	41-60
K (y^{-1})	0.37-0.67	0.40-0.96
T0(y)	-0.11	-0.42

MAXIMUM SIZE

Males 170mm TL; Females 225mm TL

Refs: Holthuis 1980

NATURAL MORTALITY

No data for SWIO.

LENGTH-WEIGHT

Various relationships described for Western Indian Ocean populations (CL, total weight and total length; male, female and sexes combined).

Refs: *Ivanov & Krylov 1980*

POPULATION SIZE STRUCTURE

Female *A. foliacea* in Mozambique reach a maximum CL of 60mm, with 3 size modes at 24-26mm, 36-38mm and 48-50mm, respectively. Males have modes at 28-30mm and 38-40mm CL. Surveys showed that most small juveniles (70%) occurred at Inhaca, with largest individuals occurring at Sofala Bank and Bazaruto A.

Refs: *Dias* et al. *2009*

SEX RATIO

Sex ratios of catches made by Visconde de Eza in 2009 were skewed towards females: 4:1 at Inhaca and 2:1 at Bazaruto A. In 2008 it was 3:1 at Inhaca and 2:1 at Boa Paz.

Refs: *Dias* et al. *2008, 2009*

MIGRATIONS

No data for SWIO, but the skewed sex ratio and size gradient along the coast suggests that migrations may occur.

GENETIC STOCK STRUCTURE

No data for SWIO.

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

South Africa: Annual landings ranged between 1.4t and 8.1t (1995-2010). Catches have declined since 2000 – the smallest catches were reported in 2008 (2.4t), 2009 (1.9t) and 2010 (1.4t).

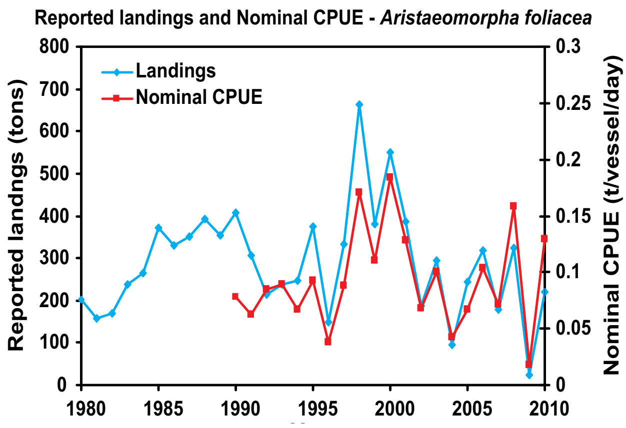
Mozambique: Annual landings and CPUE fluctuated widely, but are closely linked.

Surveys by the RV Vizconde de Eza have provided the following biomass estimates:
- 2007: 896 t; 46% at Inhaca, 22% at Boa Paz
- 2008: 152 t; 47% at Inhaca, 30% at Sofala Bank
- 2009; 295 t; 66% at Inhaca, 16% at Sofala Bank

Estimates also fluctuate widely between years.

Assessments were done in 2005, 2007, 2011. The most recent assessment indicates an underexploited stock (B_{CUR}/B_{MSY}=168% [was 137% in 2007]); Fishing mortality is estimated as F_{CUR}/F_{MSY}=5% (25% in 2007).

Refs: Dias et al. *2009, 2011*



REFERENCE POINTS OR MANAGEMENT OBJECTIVES

MSY is used as reference point in Mozambique. At present biomass is 68% above BMSY. The 2011 management objective was to increase effort and catches.

Refs: Dias et al. *2011*

DATABASES

DATA COLLECTION

<u>*Mozambique*</u>: Reporting of landings and effort; fisheries observers collect detailed fisheries and biological data at sea and at landing sites; scientific surveys undertaken to determine distribution, abundance and stock status.

<u>*South Africa*</u>: Drag sheets completed by skippers on board for each trawl (estimated catches); catches weighed at landing sites; fisheries observers at sea sample bycatches (species & quantities) and collect biological data.

Refs: *Dias* et al. *1999, 2011; Robey* et al. 2013a

KNOWN DATABASES

<u>*Mozambique*</u>:
- Production data (1986-2010)
- Logbook data – daily records (1994-2010)
- Biological sampling by IIP (1994-2010)
- Scientific surveys (2007-2009)

<u>*South Africa*</u>:
- Government database of rights holders, vessels, quotas, catches
- Prawn system with drag and landings data (1988-date)
- Ad hoc databases – biological data (1970s, 1990s, 2010-2012)

METADATA

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- MOZ-D2: Industrial register
- MOZ-D201: MOZ deep-water shrimp 1980-1990
- MOZ-D202: MOZ deep-water shrimp 1991-2008
- MOZ-D203: MOZ deep-water shrimp biological sampling 1980-2008

ARISTEUS ANTENNATUS (RISSO, 1827)

Common names:
– Blue and red shrimp

Fisheries:
– Target species in deep-water crustacean trawl fishery in Mozambique.
– Bycatch in South Africa.

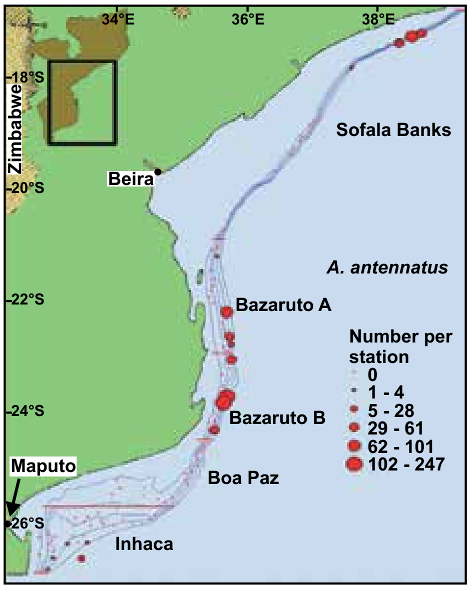
SWIOFP Countries:
– Mozambique
– South Africa
– Madagascar

DISTRIBUTION AND HABITAT

Eastern Atlantic from Portugal to the Cape Verde Islands; entire Mediterranean; SWIO. Depth range is 200-1,440m.

In Mozambique it is caught at 450-700m, possibly deeper. Soft muddy substratum. The figure shows relative abundance by area based on the 2009 RV Visconde de Eza survey.

Refs: Sobrino et al. *2009; Dias* et al. *2009*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

Mozambique trawl surveys by R/V Visconde de Eza (2007-2009) showed that 32% of females were mature in March and April, and that 34% carried a spermatophore. Most mature females were impregnated (smallest= 18mm CL). Most mature females were caught at 550-675m depth. Male size at maturity was 20mm CL (% spermatic mass in coxae) or 22mm (% petasma joint).

Refs: *Sobrino* et al. *2007, 2009; Dias* et al. *2008, 2009*

LARVAL DISTRIBUTION & RECRUITMENT

Small individuals at Sofala Bank (min. CL=12mm), suggest a recruitment hotspot there.

Refs: *Dias* et al. *2009*

MOULTING AND GROWTH

Few soft-shelled individuals were caught in March and April. No growth parameters have been estimated.

Refs: Sobrino et al. *2009; Dias* et al. *2009*

MAXIMUM SIZE

Max CL (female) = 72mm; male = 64mm. Max TL = 220mm.

Refs: *Sobrino* et al. *2009; Dias* et al. *2009*

NATURAL MORTALITY

No data for SWIO.

LENGTH-WEIGHT

CL to whole mass relationship is $WM = 0.0017*CL^{2.5567}$

Refs: Dias et al. *2009*

POPULATION SIZE STRUCTURE

Mozambique: Size range 12-72mm CL; male avg = 25.6mm; female avg = 35.7mm. Modes were at 14-34mm and 42-62mm. All large specimens were concentrated in the north, near Sofala. Mean size increased with depth from 400-600m, decreasing thereafter to 700m.

Refs: *Sobrino* et al. *2009; Dias* et al. *2009*

SEX RATIO

Mozambique: Overall sex ratio favoured females (71.8%). In small size classes, the sex ratio was near 50:50, but females dominated large size classes.

Refs: Sobrino et al. *2009; Dias* et al. *2009*

MIGRATIONS

No data for SWIO. Given the gradients in size frequency and sex ratios across depth and area, movements are likely.

GENETIC STOCK STRUCTURE

No data for SWIO.

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

Biomass estimates from the RV Visconde de Eza surveys were 37t in 2007, 31t in 2008 and 44t in 2009. Biomass was concentrated on Sofala Bank: 57%, 87% and 86%, respectively, for the 3 years.

Refs: Sobrino *et al.* 2007; Dias *et al.* 2008, 2009

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

Not defined. Species considered as part of the deep-water prawn target group of the Mozambican fishery.

DATABASES

DATA COLLECTION

Mozambique: Reporting of landings and effort; fisheries observers collect detailed fisheries and biological data at sea and at landing sites; scientific surveys undertaken to determine distribution, abundance and stock status.

South Africa: Catches reported in grouped deep-water prawns category.

Refs: Dias et al. *1999, 2011; Groeneveld & Melville-Smith 1995*

KNOWN DATABASES

Mozambique:
- Production data (1986-2010)
- Logbook data – daily records (1994-2010)
- Biological sampling by IIP (1994-2010)
- Scientific surveys (2007-2009)

South Africa:
- No data at species level

METADATA

- MOZ-D201: MOZ deep-water shrimp 1980-1990
- MOZ-D202: MOZ deep-water shrimp 1991-2008
- MOZ-D203: MOZ deep-water shrimp biological sampling 1980-2008

ARISTEUS VIRILIS (BATE, 1881)

Common name:
- Stout red shrimp

Fisheries:
- Target species in deep-water crustacean trawl fishery in Mozambique;
- Bycatch in South Africa.

SWIOFP Countries:
- Mozambique
- South Africa
- Madagascar

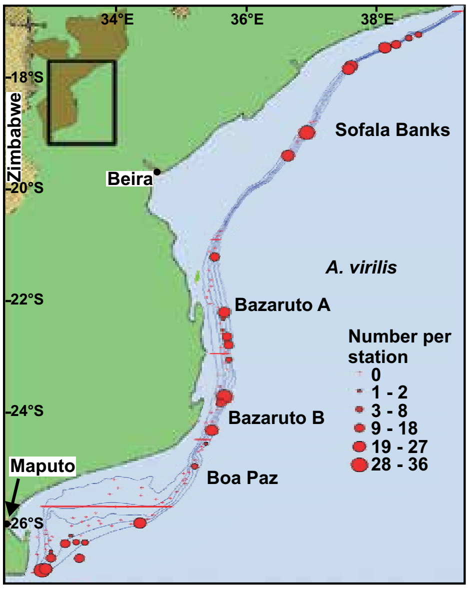
DISTRIBUTION AND HABITAT

Widespread in the Indo-West Pacific. In SWIO it occurs along the East African coast and Madagascar; South to KZN in South Africa and north to Zanzibar and the Andaman Islands.

In Mozambique it is caught at 450-700m, possibly deeper. More abundant in the northern Sofala Bank area, but also caught at Boa Paz, Bazaruto and Inhaca. Prefers a soft muddy substratum.

The figure shows relative abundance by area based on the RV Visconde de Eza survey in 2009.

Refs: Holthuis 1980; Sobrino et al. *2009; Dias* et al. *2009; WoRMS*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

Survey data (2007-2009) show that 12.5% of females were mature in Mar /Apr, and that 47.3% carried a spermatophore. Mature females > 28mm CL were all impregnated. Most mature females were caught at 550-575m depth. Males reached maturity at 26mm CL (% spermatic mass in coxae) or 27mm (% petasma joint).

Refs: *Sobrino* et al. *2007, 2009; Dias* et al. *2008, 2009*

LARVAL DISTRIBUTION & RECRUITMENT

Most recruits were observed at Inhaca, but not elsewhere.

Refs: Dias et al. *2009*

MOULTING AND GROWTH

Some soft-shelled individuals were observed in trawls in Mar /Apr in Mozambique, but no growth parameters have been estimated for SWIO.

Refs: *Sobrino* et al. *2009*

MAXIMUM SIZE

Max CL (female) = 80mm at Sofala Bank

Refs: *Sobrino* et al. *2009; Dias* et al. *2009*

NATURAL MORTALITY

No data for SWIO.

LENGTH-WEIGHT

CL to Whole Mass relationship: $WM=0.0049*CL^{2.3186}$

Refs: *Dias* et al. *2009*

POPULATION SIZE STRUCTURE

Size ranged from 20 to 73mm CL in 2007, with means of 31 and 39mm for males and females, respectively. Both sexes had a single mode. The average CL remained constant over the depth range sampled. In 2009 males had a size mode at 32-34mm CL at all fishing grounds, and females had modes at 29-30mm and 40-44mm at most fishing grounds. Indeterminate sex (i.e. recruits) occurred only at Inhaca with a mode at 14-18mm CL.

Refs: *Sobrino* et al. *2009; Dias* et al. *2009*

SEX RATIO

Sex ratios in Mozambique were heavily weighted towards females especially in large size classes. Overall sex ratio favoured females (65.7%; 2007 survey). Parity in small prawns.

Refs: *Sobrino* et al. *2009; Dias* et al. *2009*

MIGRATIONS

No data for SWIO – possibly reproductive movements.

GENETIC STOCK STRUCTURE

No data for SWIO.

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

Biomass estimates from the RV Visconde de Eza surveys were 95t in 2007, 49t in 2008 and 94t in 2009. The bulk of the biomass occurred at Inhaca: 57%, 41% and 61% respectively for the 3 years, and also at Sofala Bank (18-33%).

Refs: *Sobrino* et al. *2007; Dias* et al. *2008, 2009*

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

Not defined. Species considered as part of the deep-water prawn target group of the Mozambican fishery.

DATABASES

DATA COLLECTION

Mozambique: Reporting of landings and effort; fisheries observers collect detailed fisheries and biological data at sea and at landing sites; scientific surveys undertaken to determine distribution, abundance and stock status.

South Africa: Catches reported in grouped deep-water prawns category.

Refs: Dias et al. *1999, 2011*

KNOWN DATABASES

Mozambique:
- Production data (1986-2010)
- Logbook data – daily records (1994-2010)
- Biological sampling by IIP (1994-2010)
- Scientific surveys (2007-2009)

South Africa:
- No data at species level

METADATA

- MOZ-D201: MOZ deep-water shrimp 1980-1990
- MOZ-D202: MOZ deep-water shrimp 1991-2008
- MOZ-D203: MOZ deep-water shrimp biological sampling 1980-2008

METANEPHROPS MOZAMBICUS (MACPHERSON, 1990)

Common name:
- Langoustine
- African lobster

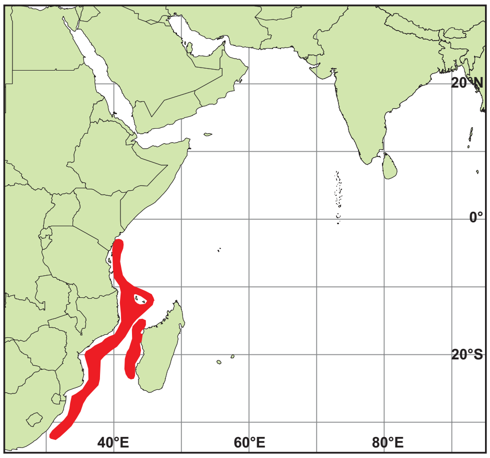
Fisheries:
- Target catch in deep-water crustacean trawl fishery in South Africa;
- Retained bycatch in Mozambique.

SWIOFP Countries:
- South Africa
- Mozambique
- Madagascar
- Tanzania

DISTRIBUTION AND HABITAT

Eastern Africa from Kenya to KwaZulu-Natal, South Africa and western Madagascar. Depth ranges from 200–750m. Occurs close to edge of continental shelf; sticky muddy substratum; burrows. Known as *M. andamanicus* prior to 1990.

Refs: *Holthuis 1991; Berry 1968, 1969*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

Mozambique: More than 80% of mature females bore eggs in September to March, declining to 34-63% in March and April.

South Africa: The smallest female with external eggs measured 34mm CL, and 50% of females matured at 48-49mm. Females with freshly spawned eggs were most abundant in August, and the incidence of egg-bearing remained high until March, whereafter it declined. Eggs about to hatch occurred mainly in May. Females produce a single brood per year, and spawning to hatching takes 9-10 months. Fecundity ranged from 400-1,600 eggs per clutch, increased with increasing CL and decreased over time, as eggs ripened. Egg are large (2-3.6mm diameter) and their size increase while they ripen. Four developmental egg stages are illustrated.

Refs: *Berry 1969; Dias* et al. *2009; Robey* et al. *2013b; Robey & Groeneveld 2014*

LARVAL DISTRIBUTION AND RECRUITMENT

Larvae hatch at an advanced stage of development, with characteristics suitable for a benthic, rather than a natatory phase. Larval dispersal presumably occurs over a short period of hours or days, with larvae settling close to adult habitats.

Refs: *Berry 1969; Robey & Groeneveld 2014*

MOULTING AND GROWTH

Immature langoustines might moult several times per year, but mature animals moult only once annually. Mature males moult mainly in December to March; females moult between May and July. Growth parameter estimates are 65.5 mm CL (L_∞) and 0.7 y-1 (K) for sexes combined in South African waters.

Refs: Berry 1969; Robey et al. *2013b*

MAXIMUM SIZE

Can attain 88 mm CL (male) and 83 mm (female): equivalent to 200 mm total length. Maximum CL of 73 mm measured in a subsequent study.

Refs: Holthuis 1991; Robey et al. *2013b*

NATURAL MORTALITY

In South Africa, predators include teleost *Helicolenus dactylopterus*, dogshark *Cephaloscyllium* sp., octopus *Veladona* sp. Copepod parasites can cause extensive damage to gills.

Refs: *Berry 1969*

LENGTH-WEIGHT

South Africa: Various relationships described between CL, tail weight and total weight, for males, females and sexes combined.

Mozambique: Whole mass= $0.006*CL^{2.988}$ for both sexes combined.

Refs: *Berry 1969; Ivanov & Krylov 1980; Dias 2009; Robey* et al. *2013b*

POPULATION SIZE STRUCTURE

South Africa: Size of langoustines caught by trawlers ranged from 17 to 73mm CL, and mean CL decreased with increasing depth. Multiple cohorts (modes) were visible in trawl data and longevity was estimated to be 3-4 years. The mean monthly CL remained stable over a year's sampling.

Mozambique: Size ranged from 14 to 78mm CL, and multiple cohorts were visible in trawl data. Smallest individuals occurred at Sofala Bank.

Refs: *Dias* et al. *2009; Robey* et al. *2013b*

SEX RATIO

South Africa: Parity in all months except November, when males dominated. Males more frequent in sizes > 60 mm CL.
Mozambique: Parity at most sizes. Data restricted to Mar/Apr.

Refs: *Dias* et al. *2009; Robey* et al. *2013b*

MIGRATIONS

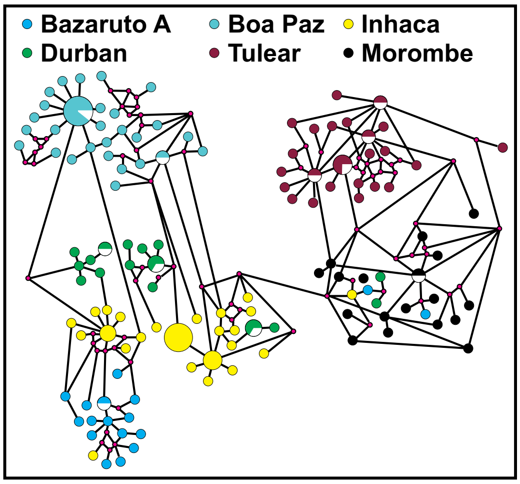
The mean CL, size frequency distribution and sex ratios in South Africa remained constant every month over several parts of fishing grounds sampled, suggesting a stable non-migratory population.

Refs: *Berry 1969*

GENETIC STOCK STRUCTURE

Highly structured populations based on COI (see figure), 16S and ANT genes. The finding of distinct metapopulations (or genetic stock units) over short geographic distances suggests that there is no single stock that is shared by South Africa, Mozambique and Madagascar. A very short (hours to days) drifting larval phase that settles close to the original adult populations, and an absence of extensive benthic migrations can give rise to the observed genetic structure. *M. mozambicus* larvae hatch in an advanced developmental stage, and are adapted to a benthic, rather than a natatory existence – thus supporting the genetic information.

Refs: Zacarias 2013; Robey & Groeneveld 2014



STOCK ASSESSMENTS AND REFERENCE POINTS

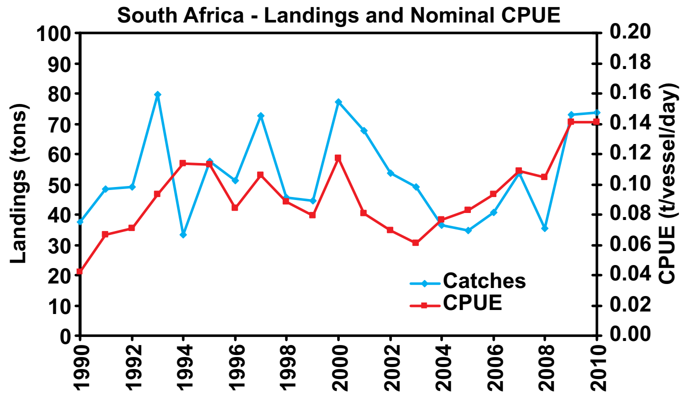
ASSESSMENTS AND STOCK STATUS

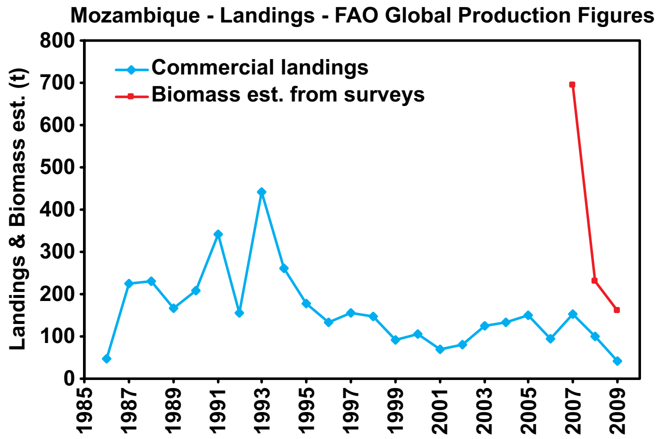
No formal stock assessments have been done in Mozambique or South Africa. Biomass estimates for Mozambique are available from surveys done by the RV Vizconde de Eza in 2007-2009.

South Africa: Nominal CPUE in South Africa has increased continually since 2003 to the highest level on record, and catches have doubled since 2005. Stock assumed to be healthy, although increased vessel power or targeting may have contributed to increasing CPUE and catches.

Mozambique: Reported landings (FAO global production figures) have declined continually since 1993, with some respite between 2001 and 2007. It is unclear how langoustine landing and catch rates are affected when deep-water prawn is the main target of the fishery. Declines in catches are cause for concern. The apparent decline in abundance is confirmed by biomass estimates from Visconde de Eza surveys, which also shows biomass to be concentrated at Boa Paz, i.e. 694t in 2007 (79% at Boa Paz); 230t in 2008 (57% at Boa Paz) and 160t in 2009 (44% at Boa Paz).

Refs: FAO 2011; Dias et al. *2008, 2009; Sobrino* et al. *2007*





REFERENCE POINTS OR MANAGEMENT OBJECTIVES

No formal reference points or stated management objectives in South Africa or Mozambique. Management objective in South Africa is precautionary.

DATABASES

DATA COLLECTION

Mozambique: Reporting of landings and effort (as bycatch); Fisheries observers collect data at sea and landing sites. Scientific surveys in 2007-2009 by Visconde de Eza. Older surveys also done i.e. RV Capricornio in 1999.

South Africa: Drag sheets are completed by skippers on board for each trawl; Catches are weighed at landing sites. Students collect biological data of *M. mozambicus* at sea.

Refs: Dias et al. *1999, 2011; Robey* et al. *2011*

KNOWN DATABASES

Mozambique:
– Production data (1986-2010)
– Logbook data – daily records (1994-2010)
– Biological sampling by IIP (1994-2010)
– Scientific surveys (2007-2009)

South Africa:
– Government database of rights holders, vessels, quotas, catches
– Prawn system with drag and landings data (1988-date)
– Ad hoc databases - biological data (1970s, 1990s, 2011)

METADATA

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– MOZ-D202: MOZ deep-water shrimp 1991-2008
– MOZ-D203: MOZ deep-water shrimp biological sampling 1980-2008

NEPHROPSIS STEWARTI (WOOD-MASON, 1872)

Common names:
- Langoustine
- Indian Ocean lobsterette
- Langoustine indienne
- White/blind langoustine

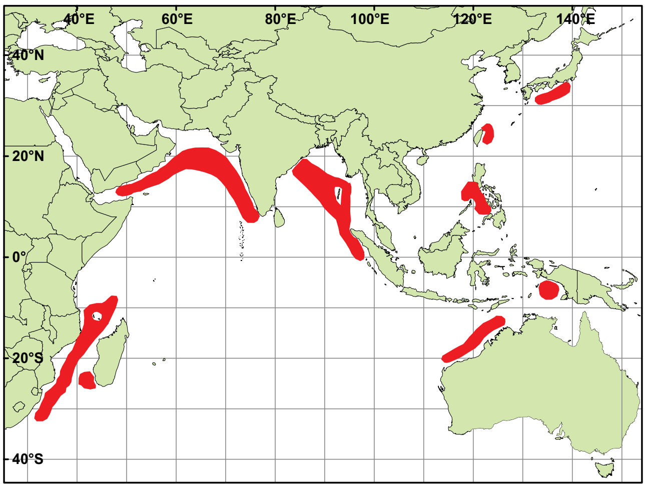
Fisheries:
- Bycatch in deep-water crustacean trawl fisheries in South Africa and Mozambique.

SWIOFP Countries:
- Mozambique
- South Africa
- Madagascar (possibly)
- Tanzania

DISTRIBUTION AND HABITAT

Indo-West Pacific from Gulf of Aden & East Africa to Japan, Taiwan, Philippines, Indonesia and W. Australia. Depth range: 170-1,060m; usually 500-750m. Soft muddy substrates. In Mozambique it occurs mainly at Boa Paz and Bazaruto A.

Refs: *Holthuis 1991; Dias* et al. *2009*



BIOLOGY, POPULATION DYNAMICS AND STOCK

REPRODUCTIVE BIOLOGY

Ovigerous females CL = 42-70mm. 50% of females mature at 37.4mm CL in Mozambique. Approx. 50% of females mature in Mar-Apr; of these 6.5%, 22.5% and 14.3% carried eggs between 2007 and 2009.

Refs: *Holthuis 1991; Dias* et al. *2009*

LARVAL DISTRIBUTION & RECRUITMENT

Small individuals with indeterminate sex occurred at Sofala Bank and Bazaruto A.

Refs: *Dias* et al. *2009*

MOULTING AND GROWTH

No data for SWIO.

MAXIMUM SIZE

TL of 150mm; Max CL of males = 71mm, females = 70mm.

Ref: Holthuis 1991

NATURAL MORTALITY

No data for SWIO.

LENGTH-WEIGHT

Whole mass = $0.0006 * CL^{2.9874}$

Refs: Dias et al. *2009*

POPULATION SIZE STRUCTURE

Size range in catches: males, 22-71mm CL; females 14-70mm. In Mozambique size range is 14-57mm. Variable size structure with 2-3 modes – one of these for small individuals and a major mode for adults at approx. 40-52mm CL.

Refs: Holthuis 1991; Dias et al *2009*

SEX RATIO

M:F = 0.7:1. Variations in sex ratios by depth stratum and area.

Refs: D*ias* et al. *2009*

MIGRATIONS

No data for SWIO. Gradients in size structure and sex ratios suggest that movements take place.

GENETIC STOCK STRUCTURE

No data for SWIO.

STOCK ASSESSMENTS AND REFERENCE POINTS

Assessments and stock status: No data.

Reference points and management objectives: No data.

DATABASES

Data collection: No data.

Known databases: No data.

Metadata: No data.

PALINURUS DELAGOAE (BARNARD, 1926)

Common names:
- Natal deep-water spiny lobster (SA)
- Lagosta de profundidade (Mozambique)

Fisheries:
- Target species in deep-water crustacean trawl fisheries in South Africa and Mozambique.
- Also a target species of occasional long-line trap-fisheries in both countries.

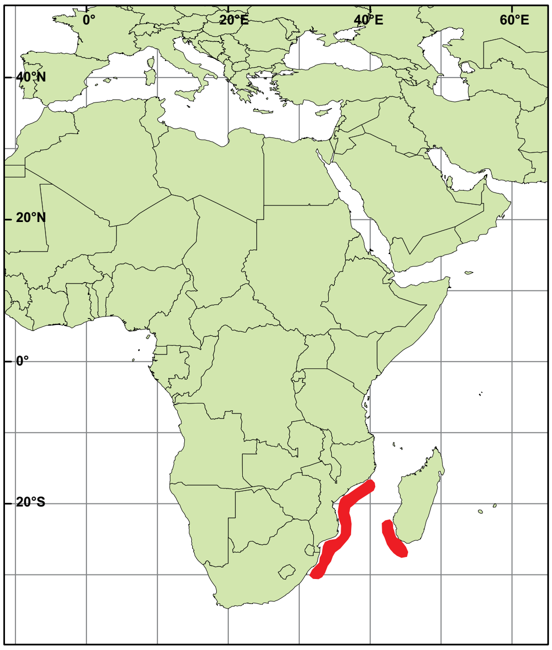
SWIOFP Countries:
- South Africa
- Mozambique
- Madagascar (possibly)

DISTRIBUTION AND HABITAT

From 17°S (Mozambique) to 32°S (eastern South Africa), depth range 150-600m.

Rocky areas and a substratum consisting of mud with a high organic content and varying quantities of sand and coral fragments. Status of *Palinurus* spp. off S. Madagascar unsure – possibly *Palinurus barbarae.*

Refs: Berry 1971; Holthuis 1991; Groeneveld et al. *2006*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

South Africa: 50% of females mature at 67.3mm CL (setal method) or 71.2mm CL (ovigerous method).
Mozambique: 50% of females mature at 64.8mm CL (gonad method) or 69.3mm CL (ovigerous method).

Mating occurs between hard-shelled individuals. A gelatinous spermatophoric mass transferred from the male to the sternal plate of female. Fertilization is external, during oviposition. Single annual brood. Freshly spawned eggs are observed in September, eggs about to hatch in April, and hatched eggs in May to July. Incubation takes 5-6 months. The ovarian cycle confirms the reproductive cycle: 90% of females have inactive ovaries in April, and most ripe ovaries occur in November and December. Large aggregations of egg-bearing females have been caught in trawl nets.

Females with CL>140mm may carry >300 000 eggs/brood. Fecundity increases linearly with increasing CL, and is described by the equation: Fecundity = 3205.3*CL – 204501. Egg-loss during incubation is estimated at 10-16%.

Refs: Berry 1969, 1972, 1973; Berry & Heydorn 1970; Brinca & Palha de Sousa 1983; Palha de Sousa 1998; Groeneveld 2000; Groeneveld et al. *2005*

LARVAL DISTRIBUTION AND RECRUITMENT

Larvae pelagic for 4+ mo. Widely dispersed by Mozambique channel eddies and upper Agulhas Current. Pueruli likely settle outside 100-600 m fished depth range. A recruitment hotspot has been identified near Durban (southern or downstream extreme of the species distribution).

Refs: *Berry 1974; Gopal* et al. *2006; Groeneveld* et al. *2012*

MOULTING AND GROWTH

Adults moult once per year, between August and October. A minor moult peak in April is probably continued moulting by sub-adults, which moult more often. Adults grow slowly; annual increments decrease with increasing CL; females grow slower than males after becoming mature.

CL increments, and growth parameters $L\infty$ and K from tag-recapture data are:
South Africa: CL_{incr} = -0.0691*CL+8.94; $L\infty$ = 161mm CL, K = 0.07 $year^{-1}$
Mozambique: Females: $L\infty$ = 170mm, K = 0.3 $year^{-1}$; Males: $L\infty$ = 182mm, K = 0.3 $year^{-1}$

Refs: Berry 1973; Brinca & Palha de Sousa 1983 ; Palha de Sousa 1992, 1998; Groeneveld 2000

MAXIMUM SIZE

Observed max CL > 180mm, compared to length-based Powell-Wetherall estimates of 160-163mm CL. Low value of K reflects slow growth towards $L\infty$, - consistent with slow-growing and long-lived life strategy.

Refs : Groeneveld 2000

NATURAL MORTALITY

M estimates are 0.09-0.15 y^{-1}. Predators in South Africa include dogsharks *Dalatius licha* and *Cephaloscyllium sufflans*.

Refs: Berry 1973; Groeneveld 2000

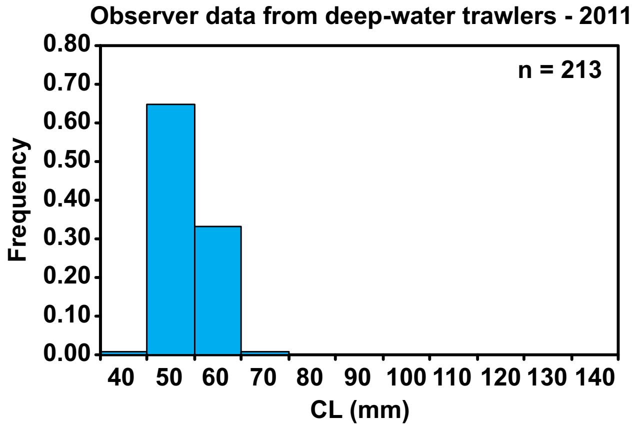
LENGTH-WEIGHT

Various relationships described: CL, whole mass, tail mass, males, females and both sexes.

Refs: Groeneveld & Goosen 1996, Dias et al. *2009*

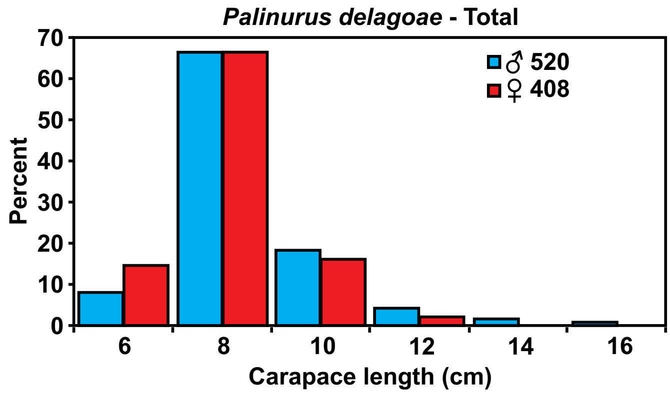
POPULATION SIZE STRUCTURE

South Africa: Length distribution of trawl catch (1994-1997) was unimodal comprising mainly small lobsters with a CL of 65-70mm. Observer data from 2011 similarly show that trawls catch only juvenile and small mature lobsters (mainly 50-70mm CL), with no adults of 80-170 mm.



Mozambique: The size structure differs across fishing grounds, with mainly small individuals caught at Inhaca. Data from Vizconde de Eza survey in 2009 are shown:

Refs: Berry 1973; Groeneveld 2000; Dias et al. *2009*



SEX RATIO

Males dominate size classes > 125mm CL. Large concentrations of egg-bearing females were reported from trawl catches before the 1980s.

Refs: Berry 1972, 1973; Koyama 1971; Kondritskiy 1976

MIGRATIONS

Three distinct migratory life-history strategies have been shown from tagging and size composition data: an ontogenetic inshore movements by juveniles, alongshore movements by pre-adults; and inshore-offshore movements for reproduction.

Refs: Koyama 1971; Berry 1972, 1973; Kondritskiy 1976; Cockcroft et al. *1995; Groeneveld 2002*

GENETIC STOCK STRUCTURE

Mitochondrial DNA (control region) show a shallow genetic partitioning between S Mozambique and E South Africa. The break supports earlier morphological studies suggesting two populations off SE Africa – var. *natalensis* from South Africa and var. *delagoae* from Mozambique. The break appears to be near the interface of the Mozambique Channel eddies and upper Agulhas Current.

Refs: Berry & Plante 1973; Gopal et al. *2006*

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

South Africa: A length-based yield model suggested a sustainable yield of 60t per year in the mid-1990s (trap and trawl fishery combined). Combined catches in 1994 and 1995 were >60t, followed by a collapse of the resource. Some recoveries in trawl catches were reported in 2008 and 2009.

Mozambique: No biomass estimates have been made from trawl data. Visconde de Eza catch rates by depth showed highest catch rates in 200-400m depth, followed by 400-500m, and by area highest catch rates were at Bazaruto B, Boa Paz and Inhaca in 2008, and in Bazaruto A and B in 2009.

Refs: Groeneveld 2000; Dias et al. *2008, 2009*

FISHING MORTALITY

No data.

REFERENCE POINTS / MANAGEMENT OBJECTIVES

Although a target species, it is secondary to prawns and langoustines in the deep-water trawl fishery, mainly because lobster densities are generally low. No formal reference points or management objectives have been stated.

DATABASES

DATA COLLECTION

Catch and effort of the South African trawl fishery have been monitored since 1988. Catch records include date, depth, position and breakdown of trawl catches per species and commercial weight categories. Fisheries observers occasionally collect biological data at sea.

Refs: Groeneveld & Melville-Smith 1995; Groeneveld et al. *2013; Robey* et al. *2011*

KNOWN DATABASES

South Africa:
- Government database with details of rights holders, vessels, quotas and reported catches;
- Prawn database (1988-date). Includes lobster catches (kg) per drag; data available in 3 commercial weight categories: <400g/lobster; 401-1,000g/lobster; and >1,000g/lobster.
- Historical trawl samples exist with size composition / biological data – early 1970s and mid-1990s. New biological data collected in 2010-2011.
- MS Access database with Catch and Effort data and all biological data for the 2004-2007 experimental trap fishery (Geo-referenced, Observer-based).

Mozambique:
- Voluntary logbook data collected from various trawling vessels.
- Databases available for Visconde de Eza surveys in 2007-2009.

METADATA

- ZAF-D007: KZN Crustacean trawl fisheries database
- ZAF-D008: KZN Crustacean trawl biological data
- MOZ-D2: Industrial register
- MOZ-D201: MOZ deep-water shrimp 1980-1990
- MOZ-D202: MOZ deep-water shrimp 1991-2008
- MOZ-D203: MOZ deep-water shrimp biological sampling 1980-2008

CHACEON MACPHERSONI (MANNING AND HOLTHUIS, 1981)

Common name:
- Deep-sea red crab
- East Coast red crab
- Deep-sea crab
- Caranguejo de profundidade

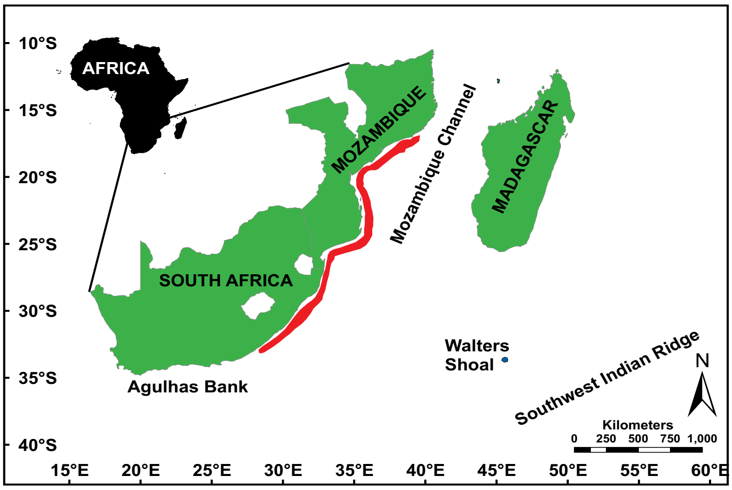
Fisheries:
- Caught as a retained bycatch in deep-water trawl fisheries in South Africa and Mozambique.
- Also targeted by a long-line trap fishery in Mozambique

SWIOFP Countries:
- South Africa
- Mozambique
- Madagascar
- Tanzania (possibly)
- Kenya (possibly)

DISTRIBUTION AND HABITAT

Southwest Indian Ocean and South Africa. Depths of 200 to >1,000m. Most abundant at 500-800 m. Occurs on soft and hard substrata.

Refs: Manning & Holthuis 1988; Paula e Silva 1984; Dias et al. *2009*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

South Africa: The L_{50} (or 50% maturity) was 118mm CW for males and 82mm for females. Fewer than 6.1% of females caught in trawls carries eggs, irrespective of month of capture or CW.

Mozambique: Some egg-bearing females were captured during all months of fishing. The smallest females with eggs had CW of 80-85mm.

Refs: Paula e Silva 1984; Groeneveld et al. *2013*

LARVAL DISTRIBUTION & RECRUITMENT

Unclear, but recruitment of small crabs to fishing grounds has been observed in February and March, and August to October in Mozambique.

Refs: Paula e Silva 1984

MOULTING AND GROWTH

No data.

MAXIMUM SIZE

Males become much larger than females. Largest male had a CW of 164mm, and largest female 140mm (recent data).

Refs: Groeneveld *et al.* 2013

NATURAL MORTALITY

No data.

LENGTH-WEIGHT

South Africa: Length-weight relationships recently calculated as:

- Male: $WW = 0.00008*CW^{3.2765}$; n=261 over a size range of 78-164 mm; $r^2 = 0.91$
- Female: $WW = 0.0011*CW^{2.7057}$; n = 261 over a size range of 68-118mm; $r^2 = 0.79$
- All: $WW = 0.00009*CW^{3.2474}$, n=522; $r^2 = 0.92$

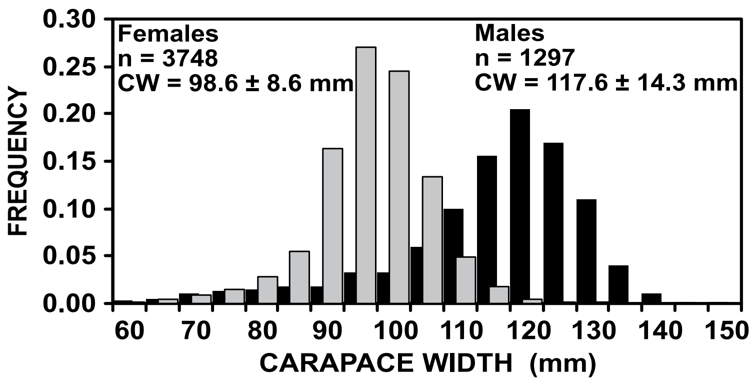
Where WW is whole weight and CW is Carapace Width.

Refs: Groeneveld et al. *2013*

POPULATION SIZE STRUCTURE

Separate modes existed for females and males. Size and sex structure suggest incomplete segregation by sex. The mean size of crabs remained constant over depth (100-600 m) and did not differ by month. No size data are available beyond 600m depth.

Refs: Paula e Silva 1984; Groeneveld et al. *2013*



SEX RATIO

South Africa: Skewed towards females over the whole depth range sampled and during all months tested.

Mozambique: Females were four times more abundant than males in depths of <400m, but equal numbers of males and females occurred at depths >400m. No data for deeper strata.

Refs: Paula e Silva 1984; ORI unpublished data

MIGRATIONS

Unknown. Assumed to move between depths and alongshore, as in other *Chaceon* spp.

GENETIC STOCK STRUCTURE

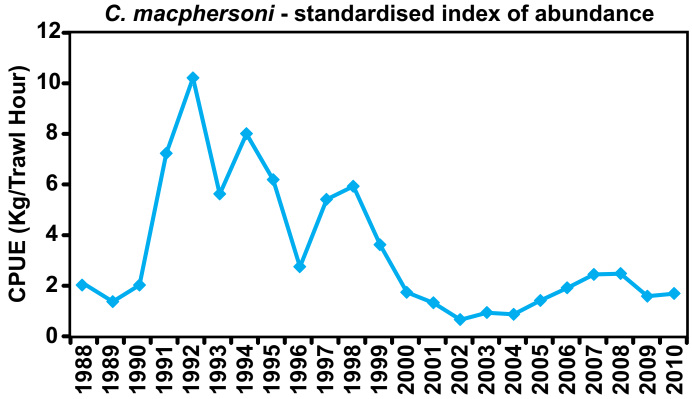
No data.

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

Reduced catches in deep-water trawl fishery suggest that stock has declined. A standardized abundance index based on trawl data (1988-2010) showed a long-term decline, with some recovery after 2002 (see below). Abundance on trawl grounds increases by depth up to 500 m, and availability is highest in November to February. Stock status is overexploited.

Refs: *Groeneveld and Melville-Smith 1995; ORI unpublished data; Groeneveld* et al. *2013*



DATABASES

DATA COLLECTION

South African trawl fishery monitored since 1988. Catch records include date, depth, position and breakdown of trawl catches per species. Fisheries observers collect biological data at sea during fishing operations.

KNOWN DATABASES

South Africa:

- Governmental database with details of rights holders, vessels, quotas and reported catches;
- Prawn database (1988-date): Includes red crab catches (kg) per drag. Historic trawl samples exist with size composition/biological data from mid 1990s. New biological data collected 2010-2011.
- MS Access database with Catch and Effort data and all biological data for the 2004-2007 experimental trap fishery (Geo-referenced, Observer-based).

Mozambique:

- Catch and fishing effort data reported in logbooks.
- Biological data and biomass estimates made by Visconde de Eza surveys in 2007-2009.

Refs: *Dias* et al *2008, 2009; Groeneveld* et al. *2013*

METADATA

- ZAF-D003: KZN deep-water trapping survey 2004-2007
- ZAF-D007: KZN Crustacean trawl fisheries database
- ZAF-D008: KZN Crustacean trawl biological data
- MOZ-D2: Industrial register
- MOZ-D201: MOZ deep-water shrimp 1980-1990
- MOZ-D202: MOZ deep-water shrimp 1991-2008
- MOZ-D203: MOZ deep-water shrimp biological sampling 1980-2008

Metadata

The full set of databases on the SWIOFP StatBase is presented in Chapter 1. Several of these long-term databases specifically focus on deep-water crustacean trawl fisheries in South Africa and Mozambique. Consultative workshops and enquiries to fishing companies and fisheries researchers showed that several smaller short-term databases exist – for deep-water trawling off Madagascar in 2001 and 2004, and off Tanzania in 2004. Data collected by the RV Dr Fridtjof Nansen during several surveys in Kenya, Tanzania, Madagascar and Mozambique since the early 1980s are available from the IMR in Bergen, Norway. Few of the Nansen surveys were specifically targeted at deep-water crustaceans, but when deep-water trawls were made, crustaceans in catches were identified and quantified.

The following databases include long-term fisheries, survey databases, and additional data from exploratory fisheries:

- KZN prawn trawl database; 1988-date (South Africa)
- KZN prawn trawl biological sampling data; 1995-1997 (South Africa)
- Madagascar deep-water prawn trawl data; 2001 and 2004
- Tanzania deep-water prawn trawl data; 2004
- Mozambique Industrial Register
- Mozambique deep-water shrimp fisheries database (1980-2008)
- Mozambique deep-water shrimp biological sampling database (1980-2008)
- Mozambique deep-water shrimp Research Ship surveys (1980-2008) (other than Nansen)
- Mozambique deep-water shrimp wet-leasing vessel surveys (1980-2008)
- Research surveys using deep bottom trawls conducted by the R/V Dr Fridtjof Nansen in the SWIO area (1982-2010)
- Kenya deep-water bottom trawl surveys (other than Nansen)
- Tanzania deep-water bottom trawl surveys (other than Nansen)
- Madagascar deep-water bottom trawl surveys (other than Nansen)

Metadata to describe the databases were compiled in terms of the Memorandum of Understanding between SWIOFP and the participant countries, and provided in Annex 1. Descriptors were standardized according to those used for StatBase as described in Chapter 1.

Regional synthesis

1. Only two long-term deep-water trawl fisheries for crustaceans operate in the SWIO region – these are off Mozambique (13-45 vessels; 1,000–3,000t of crustaceans/year) and off eastern South Africa (2-8 active vessels; 200-400 t/year). Several other deep-water trawl fisheries operate occasionally off western Madagascar, Tanzania and Kenya – these generally consist of one or two vessels that operate for short periods before returning to other fishing sectors.
2. The trawl fisheries are multispecies in nature, with the composition of catches depending on the depth and bottom-type trawled. The species composition of targeted crustaceans in the Mozambique and South African fisheries are similar – although the relative quantities vary.
3. The main target species in both fisheries is pink (or knife) prawn *Haliporoides triarthrus* – this species is endemic to the SWIO region where it is restricted to the coasts of South Africa, Mozambique, SW Madagascar, and possibly Tanzania, at depths of 180-650m.
4. Other crustaceans that are targeted include red prawns *Aristaeomorpha foliacea*, *Aristeus antennatus*, *Aristeus virilis*, langoustines *Metanephrops mozambicus*, spiny lobster *Palinurus delagoae*, and deep-sea crab *Chaceon macphersoni*. Small quantities of langoustine *Nephropsis stewarti*, slipper lobster *Scyllarides elisabethae* and several other penaeid and carid prawn spp. are also caught as a retained bycatch, but are not specifically targeted.
5. Langoustine *M. mozambicus* is relatively more important in the South African fishery, whereas deep-water prawns (*H. triarthrus, A. foliacea, A. antennatus* and *A. virilis*) are more important in Mozambique.
6. Both fisheries realize large bycatches, mainly fish (many spp.), elasmobranchs, cephalopods and crustaceans of low value. Bycatch is either discarded overboard or retained, depending on its commercial value.
7. Fishing effort (number of vessels and days at sea) show a long-term decline in the Mozambique fishery, up to 2010. In the South African fishery, a decline in fishing effort is notable after 2001 – although effort increased again in 2009-2010. Improvements in vessel power over time have not been taken into account in the effort trends.
8. Total catches of deep-water prawns in Mozambique have declined since 1990, but CPUE has increased since 2004 – it is unclear whether the increase in nominal CPUE is a result of stock recovery, or an increase in fishing power of vessels, or reduced competition for trawling areas with fewer vessels competing. Total catches in the South African fishery has remained relatively constant since 1994, with increasing nominal CPUE between 2002 and 2010. As in Mozambique, the reason for the increase in CPUE is unclear.
9. Numerous surveys of deep-water trawl grounds have been undertaken in Mozambique using research vessels and wet-leased trawlers. Most of these surveys were for stock assessment and fisheries development purposes, and information from the surveys are incorporated into fisheries management decisions.

10. Far fewer deep-water trawl surveys have been undertaken in Madagascar, Tanzania and Kenya, and these surveys were mainly of an exploratory nature. These surveys include those done by the RV Dr Fridtjof Nansen (16 surveys between 1982 and 2009) which are generally multi-disciplinary and include fisheries research for biomass estimates, biodiversity issues, and oceanographic aspects.
11. The data from the Nansen surveys are held by the IMR in Norway, and are available to SWIOFP and countries where surveys took place. The data are of an exceptional quality, and need to be explored more fully.
12. Data from the RV Visconde de Eza surveys in Mozambique (2007-2009) are of a high quality – these data belong to the IEO (Spain) and the IIP. These data need to be further explored.
13. Long-term databases of the deep-water crustacean trawl fisheries in Mozambique (1986-date) and South Africa (1988-date) describe trends in fishing effort and catches by species or species group. Data are based on skipper logbooks, landing weights, and information gathered by fisheries observers, and it includes biological information on target spp. The databases are of a high quality and are under the custodianship of the fisheries departments (DAFF and IIP) of the South African and Mozambique governments. The South African data have recently been analysed to produce standardized abundance indices (1988-2010) for deep-water prawns (Robey *et al.* 2013a), langoustines (Robey *et al.* 2013b), deep-sea crab (Groeneveld *et al.* 2013) and spiny lobsters (Groeneveld *et al.* 2013); the findings from these need to be incorporated into fisheries management.
14. Data describing the short-term (occasional) deep-water trawl fisheries in Tanzania and Madagascar are either very basic, or could not be located, or do not exist. No data could be located for the deep-water trawl fishery in Kenya.
15. The IIP in Mozambique undertakes a stock assessment of deep-water prawn resources every two to three years, based on the long-term database and survey information, and the results are used in management decisions at Fisheries Ministry level. No stock assessments have been undertaken by DAFF in South Africa, and the fishery is managed according to a *status quo* effort limitation on the number of rights holders and fisheries permits.
16. The two deep-water crustacean trawl fisheries in Mozambique and South Africa are controlled according to national management strategies. Even though some stocks may have a transboundary distribution, and many other issues regarding the sustainable use of marine resources are shared among countries, these need to be crystalized before regional management strategies can be considered.
17. Studies on the population genetic structure of deep-water prawns and langoustines were supported by SWIOFP, and showed highly structured populations in both species, based on COI, 16S and ANT genes. The finding of distinct metapopulations (or genetic stock units) over short geographic distances suggests that there is no single stock that is shared by South Africa, Mozambique and Madagascar. Strongly structured populations can result from a short drifting larval phase (hours to days), with post-larvae that settle close to original adult populations, and an absence of extensive benthic migrations. A shift in fisheries management strategy, from local to regional, can therefore not be supported on the grounds of shared or transboundary stocks of prawns or langoustines.
18. The SWIOFP project generated a Crustaceans data gap-analysis, an extensive *Endnote* bibliography of published literature, internal- and survey reports, a meta-database on the SWIOFP GeoNetwork System and catch and effort summarisations on StatBase covering selected fisheries and a detailed Retrospective Analysis (this document). This information, together with surveys at sea using chartered fishing vessels and observer data collected under SWIOFP in 2011 and 2012 is a large step forward towards the development of management plans (regional or national), however important information on stock identity and basic biology still needs to be obtained, to provide a framework for planning.

Recommendations

Recommendations are summarized below, by country and for the region as a whole, and specific issues are highlighted. Key findings of this study are that: (a) considerable quantities of data collected by research vessels presently exist for the SWIOFP region, spanning from the 1970s to date – much of this has not been fully explored; and (b) considerably more information will be required to justify a shift in fisheries management strategy, from national to sub-regional or regional management plans.

The recommendations shown below reflect these two key findings, and highlight the following activities: (a) collection of new information; (b) further analysis and stock assessments based on existing (historical) information; and (c) the use of the outputs in management and governance at national and regional levels.

SWIOFP Country	***Fishery / Species / Issue***	***Narrative and Recommendation***
All countries	All species that are likely to be shared by two or more countries in the region, incl. *H. triarthrus* and *M. mozambicus.*	Species with a transboundary distribution may benefit from regional or sub-regional management strategies that encompass its entire distribution and all life-history phases. ***Recommendation 1***: Population genetic studies to be undertaken for key transboundary species such as *H. triarthrus* and *M. mozambicus* to assist in decisions on whether fisheries should be managed at national or regional levels. Results of these studies to be incorporated in decision making. ***Recommendation 2***: Collect biological information of key deep-water species *H. triarthrus* and *M. mozambicus* and determine basic biological and population characteristics required for development of models to predict sustainable levels of fishing. ***Recommendation 3***: South Africa and Mozambique to be considered a sub-regional unit as opposed to Madagascar and countries further to the north based on a unique suite of species (possibly subtropical), and similar fully developed trawl fisheries. *Comment*: Population genetic studies have been completed for *H. triarthrus* and *M. mozambicus*, and have shown highly structured populations or distinct stocks (Zacarias 2013). Biological and population studies have been completed for the two species to determine basic parameters important for assessments and fisheries management (Robey *et al.* 2013a, 2013b; Robey & Groeneveld 2014).
All countries	Existing databases from past and recent research surveys	Research ships (i.e. RV Dr. Fridtjof Nansen; RV Visconde de Eza; others) have conducted surveys in the waters of several SWIOFP countries (Mozambique, Madagascar, Tanzania, Kenya) over the past 4 decades. Databases from these past surveys need to be more fully explored. SWIOFP completed 4 deep-water trawl surveys in 2011 and 2012 in the waters of Mozambique, Madagascar, Tanzania and Kenya. ***Recommendation 4***: Explore historical databases in depth to provide further insights into species distribution, biodiversity, biology and fisheries potential, and that the results be consolidated; ***Recommendation 5***: Recent data from SWIOFP deep-water trawl surveys to be analysed at local and regional levels. *Comment*: Deep-water trawl survey data have been analysed and recommendations made to SWIOFC. Detailed analysis of the composition and abundance of deep-water crustaceans has been published by Everett *et al.* (2015).

SWIOFP Country	*Fishery / Species / Issue*	*Narrative and Recommendation*
All countries	Species identity and identification	A large number of species are caught by deep-water trawls, and in several cases species identity remains unclear. For example, it is unclear whether *M. mozambicus* extends to Tanzania and Kenya, or whether these northern populations are *M. andamanicus*. Species identification by observers and research surveys are inconsistent. ***Recommendation 6***: Standardize species identification across the region by developing species identification keys to be compiled in a guidebook for use by all observers. Continued observer training (or regular refreshment courses) in species identification and sampling methods is recommended.
South Africa	Industrial deep-water crustacean trawl fishery	The fishery is considered to be optimally exploited. Managed by a TAE (7 permits) allocated to South African rights holders. ***Recommendation 7***: Maintain status quo over the short term. Consider sub-regional collaboration with Mozambique over the medium and longer terms – but this must be based on strong evidence (genetic and biological) that stocks and conservation issues are shared.
South Africa	Long-term trends in CPUE of *H. triarthrus* and *M. mozambicus*	Nominal CPUE trends presently available for the two key species do not take the influence of factors such as changes in vessel power, seasonality, depth and area of fishing, and targeting into account. Thus it remains unclear whether changes in CPUE are as a result of abundance fluctuations, or changes in fishing strategy. ***Recommendation 8***: Standardize nominal CPUE from logbook data to provide abundance indices over time, and assess the influence of increased fishing power and other factors on trends seen on South African fishing grounds. *Comment*: Standardized abundance indices are now available for *H. triarthrus* (Robey *et al.* 2013a) and *M. mozambicus* (Robey *et al.* 2013b)
Mozambique	Industrial deep-water crustacean trawl fishery	Regular stock assessments of deep-water prawn are done (2005, 2007, 2011) and management recommendations are made to the Fisheries Ministry. ***Recommendation 9***: Maintain *status quo* over the short term in Mozambique
Mozambique	Long-term trends in the CPUE of deep-water prawns	Fishing effort and total catches declined gradually between the mid-1980s and 2010, but nominal CPUE increased from 2004 to 2010. It is unclear whether the increase in nominal CPUE is a result of stock recovery, or an increase in fishing power of vessels. ***Recommendation 10***: Assess changes in the fishing power of vessels, and the influences thereof on the CPUE trends and the production model used in Mozambique

SWIOFP Country	*Fishery / Species / Issue*	*Narrative and Recommendation*
Madagascar	Industrial deep-water crustacean trawl fishery (occasional)	Little is known about the occasional deep-water trawl fishery for crustaceans along the western coast of Madagascar. ***Recommendation 11***: Conduct an in-depth analysis of data collected during the SWIOFP deep-water trawling survey undertaken in Madagascar in Nov / Dec 2011. ***Recommendation 12***: Initiate the use of logbooks and deploy SWIOFP observers onto deep-water trawlers to assist in characterizing the Madagascar fishery. Define the fishing grounds, measure fishing effort and catches, determine the species composition of catches.
Kenya and Tanzania	Deep-water trawl fisheries for crustaceans	Very little is known about occasional deep-water trawling for crustaceans in these two countries. ***Recommendation 13***: Conduct an in-depth analysis of data collected during the SWIOFP deep-water trawling surveys undertaken in Tanzania and Kenya in 2012. *Comment*: Deep-water trawl survey data have been analysed and recommendations made to SWIOFC. Detailed analysis of the composition and abundance of deep-water crustaceans has been published by Everett *et al*. (2015).

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Annex:

Metadata tables: South Africa deep-water trawl fishery; Madagascar deep-water trawl fishery; Tanzania deep-water trawl fishery; and Mozambique deep-water trawl fishery

Metadata table: South Africa deep-water trawl fishery; Madagascar deep-water trawl fishery; Tanzania deep -water trawl fishery				
Database Identifier	ZAF-D007	ZAF-D008	MAD-D001	TAN-D001
Dataset name	KZN Crustacean trawl fisheries database	KZN Crustacean trawl biological data	MAD deep-water trawl fishery, 2001 & 2004	TAN deep-water trawl fishery, 2004
Country or regional body	ZAF-South Africa	ZAF-South Africa	MAD-Madagascar	TAN - Tanzania
Responsible agency	DAFF	ORI	Le Ministère de l"Agriculture de l"Elevage et de la Pêche (MAEP)	TAFIRI
Source of information	Fishing logbook	Industrial fisheries: Sampling	Fishing logbook	Fishing logbook
Juridictional scale	National	National	National	National
Nature of the data	Effort Catch Species composition	Size composition Biological data Morphometry	Effort Catch Species composition	Effort Catch Species composition
Gear type	Bottom trawl	Bottom trawl	Bottom trawl	Bottom trawl
Target species	Deepwater crustaceans	Deepwater crustaceans	Deepwater crustaceans	Deepwater crustaceans
Biological data	Species composition	Biological data Size composition Morphometry, including weight		
Physical data	Depth & area	Depth & area	Depth & area	Depth & area
Type of dataset	Raw data	Raw data	Raw data	Raw data
Status of data	Data checked and published	Data checked and published	Data unchecked	Data unchecked
Data medium	Paper and digitized	Paper and digitized	Digitized	Paper
Digital medium	Hard disk	Hard disk	Hard disk	
Operating system	Unix	Windows XP	Windows	
Data base software	Oracle	Access	Excel	
Digital format		Access		
Temporal coverage	1988/01/01 - current	1995-1997	2001 & 2004	2004
Temporal resolution	Hour	Hour	Day	Hour
Spatial coverage Couverture spatiale	Territorial sea	Territorial sea	Territorial sea	Territorial sea
Spatial resolution	Fishing spot	Fishing spot	Fishing spot	Fishing spot
Spatial extent	27-31°S; 31-33°E	27-31°S; 31-33°E	Tulear; Morombe, Maintiramo	06-08°S; 39-40°E
Locality	DAFF	ORI		TAFIRI
Language	English	English	English / French	English
Comments	Extensive long-term database; data available per trawl, and as trip landings; retained demersal fish bycatch available.	Discontinuous biological samples for several species collected in ad hoc way.	Limited database	Very limited database

Metadata table: Mozambique deep-water trawl fishery					
Database Identifier	MOZ-D2	MOZ-D201	MOZ-D203	MOZ-S201	MOZ-S202
Dataset name	Industrial register	MOZ deep-water shrimp 1980-2008	MOZ deep-water shrimp biological sampling1980-2008	MOZ deep-water shrimp Research Ship (1980-2008)	MOZ deep-water shrimp Wet leasing (1980-2008)
Country or regional body	MOZ-Mozambique	MOZ-Mozambique	MOZ-Mozambique	MOZ-Mozambique	MOZ-Mozambique
Responsible agency	IIP	IIP	IIP	IIP	IIP
Source of information	Industrial fisheries: Sampling	Fishing logbook	Industrial fisheries: Sampling	Research ship	Wet-leased commercial vessel
Juridictional scale	National	National	National	National	National
Nature of the data			Size composition Biological data Morphometry	Size composition Biological data Morphometry	Size composition Biological data Morphometry
Gear type		Bottom trawl	Bottom trawl	Bottom trawl	Bottom trawl
Target species		Deepwater crustaceans	Deepwater crustaceans	Deepwater crustaceans	Deepwater crustaceans
Biological data			Biological data Size composition Morphometry, including weight	Biological data Size composition Morphometry, including weight	Biological data Size composition Morphometry, including weight
Physical data		Depth & area	Depth & area	Depth & area	Depth & area
Type of dataset	Processed data	Processed data	Processed data	Processed data	Processed data
Status of data	Data checked and published	Data checked and published	Data checked and published	Data checked and published	Data checked and published
Data medium					
Digital medium					
Operating system					
Data base software					
Digital format					
Temporal coverage		1980-1990; 1991-2008	1980 - 2008	1980-1982, 1987-1988, 1990, 1999, 2007-2008	1987,1989, 1990,1991,1993,1994
Temporal resolution		Hour	Hour	Hour	Hour
Spatial coverage Couverture spatiale		Territorial sea	Territorial sea	Territorial sea	Territorial sea
Spatial resolution		Fishing spot	Fishing spot	Fishing spot	Fishing spot
Spatial extent		16-26°S; 32-36°E	16-26°S; 32-36°E	16-26°S; 32-36°E	16-26°S; 32-36°E
Locality		IIP	IIP	IIP	IIP
Language	Portuguese	Portuguese	Portuguese	Portuguese	Portuguese
Comments	Fisheries register	1980-1990 datacurrently inacessible because it was stored in outdated magnetic tapes	On board and port sampling of several spp.	On board sampling by researchers	On board sampling by researchers

4.
CRUSTACEAN DEEP-WATER TRAP FISHERIES

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4. CRUSTACEAN DEEP-WATER TRAP FISHERIES

A retrospective analysis of their status in the Southwest Indian Ocean

Johan Groeneveld[1]

Abstract

Deep-water trap fisheries in the Southwest Indian Ocean (SWIO) catch spiny lobsters (*Palinurus* spp.), slipper lobsters *Scylarides elisabethae* and deep-sea crabs *Chaceon macphersoni*. A trap fishery for *P. gilchristi* off southern South Africa has been active since 1974, and produces 700-1,000t of lobster per year for export. Fishing effort, catch and biological data support stock assessments, and a robust management strategy with good enforcement. Two trap fisheries for *P. delagoae* (eastern South Africa and Mozambique) are less stable. In eastern South Africa, experimental fishing depleted spiny and slipper lobster stocks between 1994 and 1997. Stocks recovered after a 6-year layoff from fishing, but renewed fishing in 2004 to 2007 reversed partially restored catch rates. The Mozambican industrial trap fishery by Japanese and local vessels reported annual landings of up to 400 t/year between 1980 and 1999, when fishing ceased because of low catch rates. Trapping for deep-sea crabs and spiny lobsters have recently (2009) resumed. Soviet and Ukrainian vessels explored the seamounts south of Madagascar and on the SW Indian Ridge during the 1980s and 1990s, reporting modest spiny lobster catches. Trap surveys off SE Madagascar captured unidentified *Palinurus* lobsters. Trapping for deep-sea crab (possibly *Chaceon* spp.) in Kenya ceased in 2010, when the vessel was hijacked. Trapping for deep water shrimps *Heterocarpus laevigatus, H. ensiver* and *Pleisionika longirostris* was explored in Mauritius, Seychelles and La Réunion during the mid-1980s. The biology, life history and fisheries of *P. gilchristi* and *P. delagoae* are well-documented, but less is known about most other species. SWIOFP collected historical catch, effort and species composition information to assess fisheries potential of deep-water crustaceans, and determine whether stocks are distinct, or shared regionally. This chapter summarizes historical information by fishery and species, highlights remaining gaps, and makes recommendations for future research and management.

Introduction and objectives

Deep-water trap fisheries for spiny lobsters and crabs rely on large ocean-going fishing vessels that deploy hundreds of baited traps along anchored bottom-set longlines. They target high-value species, which are often slow-growing, and hence vulnerable to over-exploitation. Four distinct deep-water trap fishing sectors are known from the SWIO:

1. Industrial trap fishery for Palinurus gilchristi ***(southern South Africa):*** A sustainable and well-managed fishery active since 1974. Restricted to local fishing companies, and targets endemic spiny lobster *P. gilchristi* at depths of 50-200m. Fishing takes place on the Agulhas Bank and further eastwards, landing 700-1,000 t/lobster per year for export markets.

2. Experimental trap fishery for Palinurus delagoae ***(eastern South Africa):*** Traps to catch spiny lobster *P. delagoae*, slipper lobster *Scyllarides elisabethae* and deep-sea crab *Chaceon macphersoni* set at 150 to 450m depth along the KwaZulu-Natal coastline in 1994 to 1997 (3 vessels) and 2004 to 2007 (1 vessel). Catch rates declined steeply during both periods, leading to suspension of the fishery. All three species have an apparent transboundary distribution in the SWIO.

3. Industrial trap fishery for P. delagoae ***(Mozambique):*** Active between 1980 and 1999. Operated by two Japanese longliners under license from the government, and by two smaller local Marpesca vessels in later years. Bycatches were *S. elisabethae* and *C. macphersoni*. Fishing was suspended after 1999 because of low catch rates. Surveys to assess stock recovery have been undertaken in 2005 (*FV Cape Flower*) and 2010 (*FV Rio Saiňas*).

4. Exploratory trapping for spiny lobsters, crabs and deep-water shrimps in other SWIOFP countries and on seamounts: Trapping expeditions for spiny lobsters off Madagascar undertaken during the 1980s. Small trap fisheries for

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deep-sea crabs (*Chaceon* spp.) active in Mozambique (2009 to date) and Kenya up to 2010, when the vessel was hijacked. Exploratory trapping undertaken for deep water shrimps *Heterocarpus* spp. and *Pleisionika longirostris* off Mauritius, Seychelles and La Réunion during the mid-1980s. Exploratory trapping on seamounts at Walters Shoals and the Southwest Indian Ridge undertaken by Soviet and Ukrainian vessels (1970s-2000) and later by EU and South African vessels. Catches included spiny lobsters *Palinurus barbarae* and *Jasus paulensis*.

A growing number of peer-reviewed publications on deep-water trap fisheries in the SWIO are available in the literature, including on the fisheries and biology of lobster and crab species in South Africa and Mozambique (Groeneveld *et al*. 2006a, 2012a, 2013a, 2013b), the genetic population structure (Tolley *et al.* 2005; Gopal *et al.* 2006; Groeneveld *et al.* 2012b), and catches made on seamounts (Groeneveld *et al.* 2006b). Very little published information is available from Madagascar, Tanzania and Kenya. References to all accessible published information and internal reports are available on the SWIOFP *Endnote* collection. Several long-term databases exist under the custodianship of the South African and Mozambican governments. A meta-database of selected fisheries is stored on GeoNetwork and effort and catch summarisations of these fisheries are available on SWIOFP StatBase.

This Retrospective Analysis aims to identify and collate all the available information on deep-water trap fisheries and their target species in the SWIO region to provide specialist advice to support and underpin a regional approach towards sustainable management of this valuable resource.

GEOGRAPHICAL SCOPE

The larger SWIOFP geographic study area is described in Chapter 1, and includes the continental shelf areas of all SWIOFP countries. In addition, neighbouring areas also addressed in this chapter include the Agulhas Bank and seamounts of the South Madagascar Ridge (Walters Shoals) and the Southwest Indian Ridge.

MATERIALS AND METHODS

Consultative Workshops were used to gather information on all available literature and reports, using *Endnote* as a starting point, and to identify relevant databases in each country, using StatBase as a starting point. The information was contextualized with the assistance of local scientists and data managers.

The location and extent of fishing grounds were mapped using GIS Software wherever the information was available and of good quality. Spatial distribution maps of the abundance of selected species were developed where data allowed.

Spatial and temporal trends in fishing effort, catches, and catch rates were extracted from historical data. Fishing area, depth and gear-type were taken into account where possible. Basic biological parameters describing average size, sex ratios, size at sexual maturity, growth and mortality rates, fecundity and reproductive activity were tabulated for priority species.

The fishing sectors and priority crustacean species selected for this study are shown in the fisheries by species matrix below. Priority species were as specified in the SWIOFP data gap-analysis for crustaceans (Groeneveld *et al*. 2010).

Main target species per sector	*Palinurus gilchrist*	*Palinurus delagoae*	*Palinurus barbarae*	*Scyllarides elisabethae*	*Chaceon macphersoni*	*Heterocarpus spp*
Sector 1: Industrial trap fishery for *Palinurus gilchristi* (South Africa, south coast)	■					
Sector 2: Experimental trap fishery for *Palinurus delagoae* (South Africa, east coast)		■		■	■	
Sector 3: Industrial trap fishery for *Palinurus delagoae* (Mozambique)		■		■	■	
Sector 4: Exploratoryw trapping for spiny lobsters, crabs and deep-water shrimps (SWIOFP countries; high-seas)			■		■	■

Results

COUNTRY SUMMARY

The country summary tabulated below shows all the deep-water trap fisheries for crustaceans that could be located in the SWIO region, including active fisheries, past surveys, exploratory and recent commercial fisheries. Only one fishery (for *Palinurus gilchristi* off South Africa) has remained active over the long term (since 1974) – this fishery has a history of management intervention, including regular stock assessments and a successful government fisheries strategy based on effort and catch limitations. At the other end of the scale are fisheries operated by licensed foreign vessels, with limited government control (e.g. Mozambique and Kenya).

Summary of all the deep-water trap fisheries for crustaceans that could be located in the SWIO region.
Target species shown in bold. Long-term fishery in blue.

SWIOFP Country	Fishery	Time period	Species
South Africa	Industrial trap fishery	1974-date	***Palinurus gilchristi***
South Africa	Experimental trap fishery	1994-1997 2004-2007	***Palinurus delagoae*** ***Scyllarides elisabethae*** ***Chaceon macphersoni***
Mozambique	Industrial trap fishery	1980-1999	***Palinurus delagoae*** *Scyllarides elisabethae* *Chaceon macphersoni*
Mozambique	Experimental trap fishery (crabs)	2009-date	***Chaceon macphersoni*** *Palinurus delagoae*
Kenya	Occasional commercial trap fishery (crabs)	Unknown, ending 2010	*Chaceon* sp *Heterocarpus* spp
Madagascar	Scientific surveys by RV Dr Fridtjof Nansen	1969, 1987	***Palinurus* sp.** *Chaceon*
Mauritius	Exploratory trapping for deep-water shrimps	1984-1986	***Heterocarpus laevigatus*** *Heterocarpus ensifer* *Pleisionika longirostris*
Seychelles	Exploratory trapping for deep-water shrimps	1985	***Heterocarpus laevigatus*** ***Heterocarpus ensifer*** ***Pleisionika longirostris***
La Réunion	Exploratory trapping for deep-water shrimps	1981-Unknown	***Heterocarpus laevigatus*** ***Heterocarpus ensifer***
International waters	Exploratory pot fishing for crustaceans by int. vessels (Soviet, Ukraine, EU, South Africa and others) on ridges of the SWIO	1980-date; Occasional and often unreported	*Palinurus barbarae* *Jasus paulensis*

DESCRIPTION OF CRUSTACEAN DEEP-WATER TRAPPING SECTORS

INDUSTRIAL LONGLINE TRAP FISHERY (SOUTHERN SOUTH AFRICA)

Countries:
– South Africa, south coast

Target species:
– *Palinurus gilchristi*

Bycatch species:
– *Octopus magnificus*

DESCRIPTION

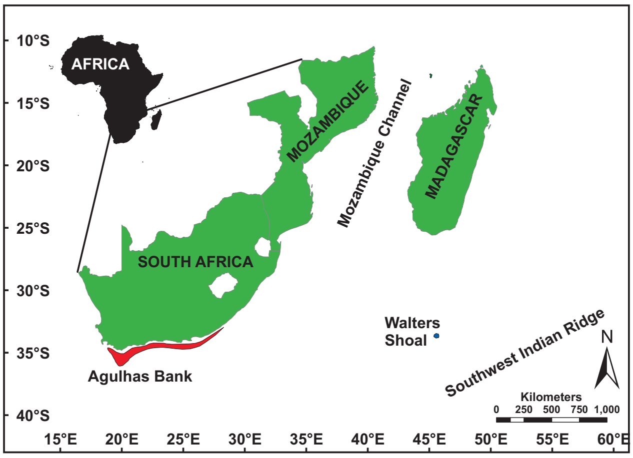
Industrial deep-water trap fishery. Active since 1974. Sustainably managed and stable sector of South African fishing industry.

Refs: Groeneveld et al. *2006a, 2013a*

SPATIAL EXTENT OF FISHERY

Commercial fishing grounds for *Palinurus gilchristi* along the southern coast of South Africa, between Cape Point (19˚ E) and East London (28˚ E). Traps are set on rocky patches between 50 and 200m deep.

Refs: Groeneveld et al. *2006a, 2013a*



FISHING VESSELS AND GEAR

Vessels: Large ocean-going vessels (30–60m length) can remain at sea for up to 35 days. Vessels have storage space for 2,000+ traps, a powerful line-hauler to retrieve traps, a chute to set traps, modern navigational equipment, accommodation for 25+ crew, on-board factory, blast freezer, and /or seawater tanks for live lobster transport. Nine vessels active in 2011.

Gear: Strings of 100-200 plastic top-entry traps tied to bottom longlines anchored at each end, and baited with hake heads. Soak-times range from 24-96 hours (average is 48 hours). Vessels set and haul 8-15 longlines per vessel per day, often working with two complete sets (i.e. one set for alternate days).

Refs: Pollock & Augustyn 1982; Groeneveld et al. *2006a, 2013a*

HISTORY OF FISHERY

Exploitation by local and foreign vessels began in 1974, but foreign vessels withdrew in 1976 when *P. gilchristi* was recognized as endemic to the South African continental shelf.

Effort increased between 1974 and 1979/80, then dissipated when vessels moved to other fisheries after catch rates collapsed in 1980s. Gradual effort increase between 1984 and 2001. Number of vessels reduced by 30% (to 9 vessels) in 2001, when a rogue fishing company (Hout Bay Fishing) was closed down. Fishing effort stable since 2001, when a Total Allowable Effort (TAE, sea-days) was implemented. No gear saturation observed at high effort levels.

Catch and catch rates can be subdivided into 5 periods: 1974-1979/80, catches increase rapidly to above sustainable levels – collapse of the resource; 1980/81-1983/84, small catches made, – resource recovers; 1984/85-1999/2000, gradual increase in catches as result of large unreported catches – catch rates decline by 5-10% /yr; 2000/01-2005/06, – smaller catches of <1000 t/yr result in increase in catch rates; Post-2006 – catches stable.

Refs: Pollock & Augustyn 1982; Groeneveld 2003; Groeneveld et al. *2006a, 2013a; Anon 2010*

MANAGEMENT CONTROLS AND REGULATIONS

Limited entry fishery for South African fisheries rights-holders (quotas) and vessels; Fishery operates year-round (1st October to 30th September); No minimum legal size (MLS); Egg-bearing females to be released; Total Allowable Catch (TAC) set for the fishery each year, based on an assessment and Operational Management Plan (OMP); Total Allowable Effort (TAE) imposed as number of fishing days, based on quota and vessel efficiency; days at sea monitored using VMS; Authorities at landing sites weigh all catches; Gear restricted to longlines & plastic top-entry traps; Export permits required.

Refs: Groeneveld et al. *2006a, 2013a; Anon 2010*

BYCATCH AND ECOLOGICAL IMPACTS

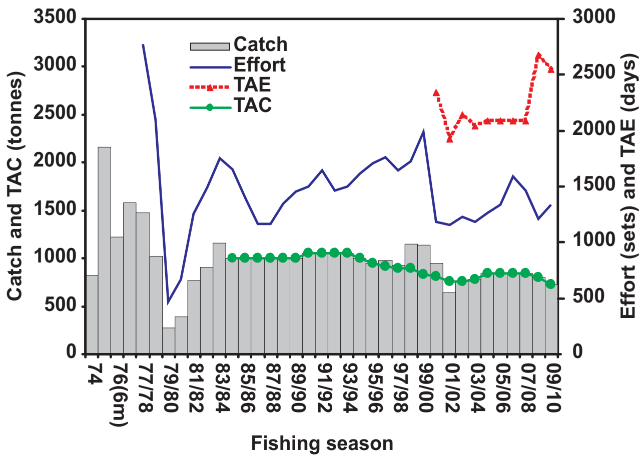
Approximately 100t/yr of *Octopus magnificus* is caught and sold. Other bycatches are negligible; no ghost fishing; ecological impact considered minimal.

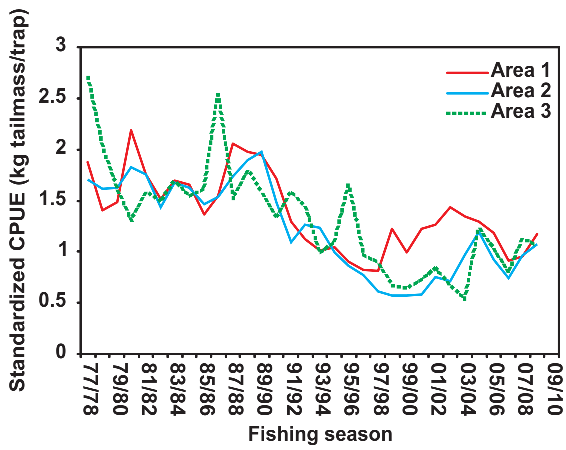
Refs: Groeneveld et al. *2006c*

TRENDS IN CATCH, EFFORT AND CPUE

Long-term trends in the commercial trap-fishery for *P. gilchristi*: (below left) Catch and effort (including TAC and TAE levels); and (below right) standardized CPUE trends (kg tailmass/trap) for three fishing areas – Area 1 = East of 25°E; Area 2 = Central South Coast; Area 3 = Agulhas Bank. The effects of gear-saturation on the abundance index was tested, but was not significant.

Refs: Groeneveld et al. *2003, 2006a, 2013a, Anon. 2010*





EXPERIMENTAL LONGLINE TRAP FISHERY (EASTERN SOUTH AFRICA)

Countries:
- South Africa (KwaZulu-Natal coast)

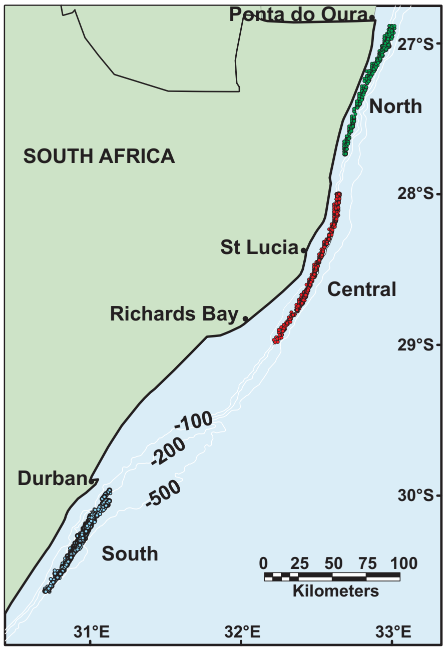
Target species:
- *Palinurus delagoae*
- *Scyllarides elisabethae*
- *Chaceon macphersoni*

Bycatch species:
- Small quantities of other crustaceans, which are discarded

DESCRIPTION

Experimental deep-water trap fishery targeting spiny and slipper lobsters, and deep-sea crabs. Operational in 1994-1997 and in 2004-2007. Presently inactive.

Refs: Groeneveld 2000; Groeneveld et al. *2012a, 2013a*



SPATIAL EXTENT OF FISHERY

KwaZulu-Natal coast of South Africa; from the Mozambique border (26˚54 S) southwards to Port St Johns (32˚ S). Shelf is steep and narrow, and fishing takes place within a few miles from the shore, in 3 areas – North, Central and South. Traps set on rocky and hard substrates, at 75-462m depth.

Refs: Groeneveld & Cockcroft 1997

FISHING VESSELS AND GEAR

Longline trap fishing vessels used, storage space for 2,000+ traps, powerful line-hauler to retrieve traps, chute used to set traps, modern navigational equipment, accommodation for a crew of 25+. Vessels equipped with on-board factory, blast freezer, and /or seawater tanks for transport of live lobster. In 2004-2007, the FV Cape Flower, 50 m length, 1,200t GRT was used. Three vessels were used in 1994-1997.

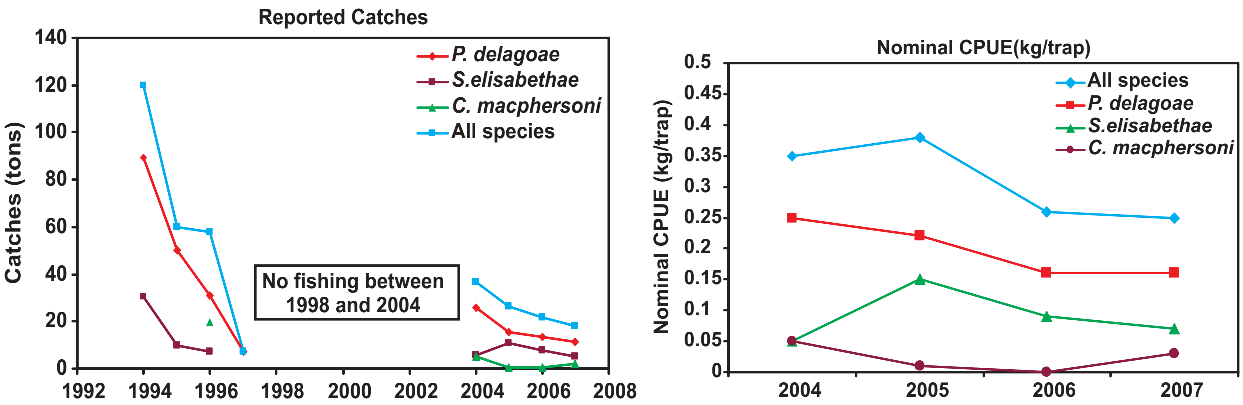
Strings of 100-200 plastic top-entry traps, tied to bottom longlines anchored at each end, and baited with hake heads. Soak-times range from 24-96 hours (average is 48 hours). Vessels set and haul 8-15 longlines per vessel per day, often working with 2 complete sets (i.e. alternate days).

Refs: Kirkman & Groeneveld 2005a, 2006; Groeneveld 2000, 2012a

HISTORY OF THE FISHERY

Experimental trap fishery carried out between 1994-1997 (4 years) and again between 2004-2007 (4 years). In each case the fishery was discontinued because of sharp declines in catches and catch rates. Although focussed on spiny lobster, slipper lobster and deep-sea crab are considered as an additional targeted catch, and not as bycatch. Target species selected by setting traps in different areas or depths, based on perceived abundance and value.

Initial catches in 1994 were 89.5t of *P. delagoae* and ~ 30t of slipper lobster *Scyllarides elisabethae*. Spiny lobster catches declined to 50t in 1995, 30.5t in 1996, and 7.8t in 1997, and the fishery was discontinued. Total catches in 2004-2007 were 66.5t of spiny lobsters, 29.1t of slipper lobsters and 7.6t of deep-sea crabs. On a year-by-year basis, catches declined continually from 36.7t caught in 2004 to 18.3t in 2007 (–50.2%). By species, spiny lobster catches declined most over 4 y (–56%).



Trends in total landings (left) and catch rates (right) of spiny and slipper lobsters, and deep-sea crabs. Spiny lobster catches declined most, by 75% between 1994 and 1997, and by 42% between 2004 and 2007. Declines in slipper lobster catch rates were also observed. Deep-sea crabs were targeted less often, and catch rates fluctuated.

Refs: Groeneveld & Cockcroft 1997; Groeneveld 2000; Groeneveld et al. *1995, 2006a, 2012a; Kirkman & Groeneveld 2005a, 2006*

MANAGEMENT CONTROLS AND REGULATIONS

A tightly controlled experimental fishery with restricted entry and pre-determined research grid to be fished to provide research data and samples;
Full time scientific observer on-board while at sea;
No minimum legal size (MLS);
Egg-bearing females to be released;
Gear restricted to longlines & plastic top-entry traps;
Authorities at landing sites weighed all catches; Export permits required.

BYCATCH AND ECOLOGICAL IMPACTS

Spider crabs are sometimes caught in numbers, but are discarded. Other bycatches (i.e. fish) are negligible, and no ghost fishing is reported.

Given the fishing method (trapping), the physical damage caused by the gear to the seafloor is considered minimal. Some gear may be lost at sea (plastic traps, ropes)

Refs: Groeneveld et al. *1995, 2012a, 2013a*

INDUSTRIAL LONGLINE TRAP FISHERY (MOZAMBIQUE)

Countries:
– Mozambique

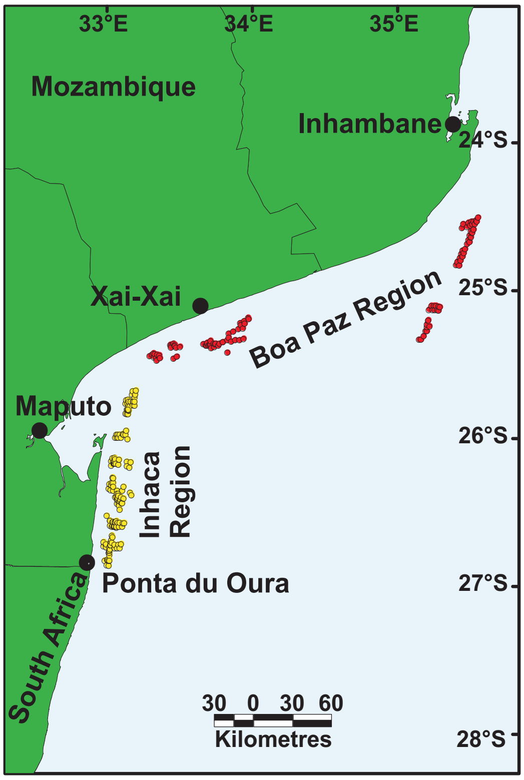
Target species:
– *Palinurus delagoae*

Bycatch species:
– *Scyllarides elisabethae, Chaceon macphersoni*

DESCRIPTION

Industrial deep-water trap fishery targeting spiny lobster and landing unknown bycatch quantities of slipper lobster and deep-sea crab. Comprised 2 Japanese longliners under license to Mozambique government, and 2 smaller local vessels during later years. Fishery closed since 1999. Two experimental surveys undertaken in 2005 and 2010 to assess stock recovery. Fishery resumed after 2011, but little information available.

Refs: Palha de Sousa 1998, 2001



SPATIAL EXTENT OF FISHERY

Fishing grounds extend from 22˚S (Bazaruto A) to the South African border at 27˚S. Four statistical fishing areas (from North to South) are Bazaruto A and B, Boa Paz and Inhaca. Most fishing occurs between 200 and 400m depth. Commercial fishery concentrated on areas of high density between Inhaca and Bazaruto A.

Refs: Palha de Sousa 1992, 1998, 2001

FISHING VESSELS AND GEAR

1980-1984: Ryo Shimaru (Japanese fishing vessel)
1986-1999: Rigel 3 and Rigel 4 (Japanese fishing vessels).

In 1993 and 1994, 2 smaller Marpesca vessels (FV Ze To and FV Stella Maris) joined the fishery working with different types of traps.

<u>Gear</u>: Japanese used conical bee-hive traps; metal-frame covered with netting and a single plastic tunnel entrance at top. Trap dimensions were 77.5×113 cm (H×Diam). Marpesca used rectangular steel-frame traps (70×26×45 cm) with a single plastic tunnel entrance at the top.

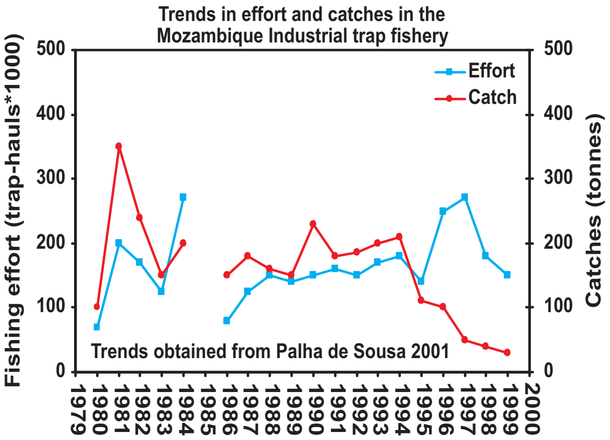
Refs: Palha de Sousa 1998, 2001

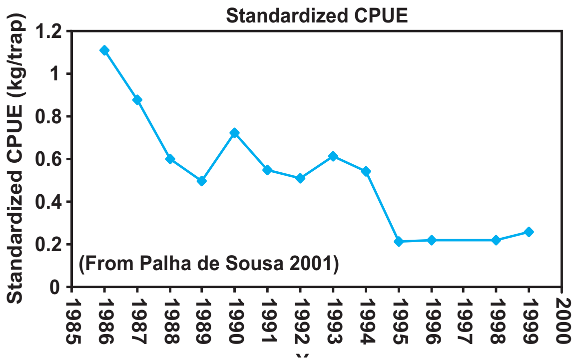
HISTORY OF FISHERY

Inception of commercial fishery in 1980, growth and decline in effort and catches well documented up to 1999.

Fishing effort (Traps*1000) increased in 1980-1984 but fishing stopped in 1985. Fishing resumed in 1986; effort increased gradually up to 1994. In 1994-1998 effort increased when 2 Marpesca vessels joined the fishery.

> 300t of lobsters caught in 1981. Catches declined to 100-200t in the following 2 years. Approx 200t/yr landed in 1986-1994, but effort increased. Catches declined in 1994-1998.





CPUE declined >50% in 1980-1984, but increased after the 1985 stoppage. CPUE decreased in 1986-1998 because of high effort and a decline in stock abundance. Fishery closed in 1999.

Experimental trapping over short periods (1 month) to assess recovery of the stock was undertaken by the *FV Cape Flower* in 2005, and again by the *FV Rio Saiňas* in 2010. Present status of trap fishery unknown.

Refs: Palha de Sousa 1998, 2001; Kirkman et al. *2005b; Dias 2011*

MANAGEMENT CONTROLS AND REGULATIONS

Licensing of Japanese vessels in 1984-1999. Closure of the trap fishery based on declines in catches / CPUE and subsequent surveys to monitor stock recovery. Although proposals exist regarding limitations on effort, size and breeding conditions, these have not been enacted.

Refs: Palha de Sousa 2001

BYCATCH AND ECOLOGICAL IMPACTS

Retained bycatches are slipper lobster (*Scyllarides elisabethae*) and deep-sea red crab (*Chaceon macphersoni*). Other bycatches (i.e. fish) are negligible. No ghost fishing reported. Given the fishing method (trapping), the physical damage caused by the gear to the seafloor is considered minimal. Impact of removal of large crustaceans on trophic functioning unknown.

Refs: Kirkman et al. *2005b*

EXPLORATORY TRAPPING FOR SPINY LOBSTERS, CRABS AND DEEP-WATER SHRIMPS (SWIOFP COUNTRIES AND HIGH-SEAS SEAMOUNTS)

Countries:
- Kenya
- Mozambique
- Madagascar
- Mauritius
- Seychelles
- La Réunion (France)
- South Madagascar Ridge (Walters Shoals)
- South West Indian Ridge

Target species:
- *Palinurus delagoae*
- *Palinurus barbarae*
- *Jasus paulensis*
- *Chaceon macphersoni,*
- *Chaceon* spp.
- *Heterocarpus laevigatus*
- *Heterocarpus ensifer*
- *Pleisionika longirostris*

Bycatch species:
- Unknown

DESCRIPTION

1. Exploratory pot fishing for lobsters by international vessels (Soviet, Ukrainian, EU, South African and others) on the deep-water ridges of the SW Indian Ocean.
2. Occasional historic surveys off Madagascar.
3. Trap-fishery for crabs (*Chaceon* spp.) off northern Kenya.
4. Trap-fishery for crabs (*Chaceon macphersoni*) off Mozambique (2009-2010).
5. Exploratory trapping for deep-water shrimps (*Heterocarpus* spp) off Mauritius.
6. Exploratory trapping for deep-water shrimps (*Heterocarpus* spp) off Seychelles.
7. Exploratory trapping for deep-water shrimps (*Heterocarpus* spp) off La Réunion.

1. EXPLORATORY POT FISHING FOR LOBSTERS BY INTERNATIONAL VESSELS (SOVIET, UKRAINIAN, EU, SOUTH AFRICAN AND OTHERS) ON THE DEEP WATER RIDGES OF THE SOUTH WEST INDIAN OCEAN

Target species: Spiny lobsters *Palinurus barbarae* and *Jasus paulensis* (both spp. shown in picture)

Spatial extent: Seamounts and Ridges of SWIO, mainly Madagascar Ridge and SW Indian Ridge. Walters Shoals at 33°9-16'S; 44°49-56'E. Seamounts 102, 105, 150, 251, 358, 360, 422, 415, 215, 350, 335, 336 on the SW Indian Ridge (see Romanov 2003). Seamounts listed by minimum depth in meters. Catches made from approximately 100 to 500m depth.

Fishing vessels and gear: Soviet and Ukrainian research and fishing vessels, mainly stern trawlers, converted for trawl, line, longline and pot-fishing. LOA 54-103m; GRT 600-5,000t. Lobster pots of various shapes and sizes used, set individually or strings of a few dozen pots – because tops and slopes of seamounts have rough and sharply cut surfaces. South African longline trapping vessel "*FV Palinurus*". Spanish fishing vessel "*FV Iannis*". Unreported fishing (2000-2011). SA vessel used plastic- and beehive traps.

History of fishery: Records of Soviet and Ukrainian exploratory fishing and research with pots in the SWIO for spiny lobster span from 1980-1986. Reported trips by Spanish vessel FV *Iannis* took place in 2004 and 2005. SA vessel *FV Palinurus* undertook trips in 2010 and 2011. IUU fishing occurs.

Management controls and regulations: Fisheries on seamounts operate in international waters – therefore they should adhere to UNCLOS regulations. SA vessel required a permit. Few controls enforced. Catch made by SA vessel weighed at off-loading.

Bycatch and ecological impacts: Catches on seamounts described. Potential ecological impacts because of isolation and unique seamount habitats.

Refs: Romanov 2003; Groeneveld et al. *2006; 2012b*

2. OCCASIONAL HISTORICAL SURVEYS OFF MADAGASCAR

Target species: Spiny lobsters *Palinurus* spp.

Spatial extent: Small numbers of *Palinurus* spp. were found south of 25˚S in southern Madagascar (near Fort Dauphin) in 100-360m depth, on areas difficult to exploit. The area name is Banc d'Etoile, comprising about 5,000 km^2 between 100 and 1,000m depth.

Fishing vessels and gear: Trap surveys done by *FV La Barbade* (1969) and *FV Nosy Be 6* (1987).

History of fishery: Catch rates were low: *La Barbade* (1969) 10 days, 568 traps , 33 *Palinurus* lobsters; *Nosy Be 6* (1987) 4 days, 393 traps, 66 lobsters.

Management controls and regulations: Unknown for Madagascar surveys.

Bycatch and ecological impacts: No data for Madagascar surveys.

Refs: Roullot 1988

3. TRAP FISHERY FOR CRABS (*CHACEON* SPP) OFF NORTHERN KENYA

Target species: Unknown crab, probably *Chaceon* spp. Picture shows *Chaceon macphersoni.*

Spatial extent: Fishing grounds for crabs in Kenya are at 01˚S -03˚S; 40˚E -42˚E.

Fishing vessels and gear: The *FV Golden Wave* was active until it was hijacked in 2010.

History of fishery: No data on Kenyan fishery.

Management controls and regulations: No data.

Bycatch and ecological impacts: Kenyan crab trap-fishery also lands small quantities of deep-water prawns.

Refs: Pers. comm. Collins Ndoro, Fisheries Department, Mombasa

4. TRAP FISHERY FOR CRABS (*CHACEON MACPHERSONI*) OFF MOZAMBIQUE (2009-2010)

Target species: Deep-sea crab *Chaceon macphersoni*

Spatial extent: The crab fishery operated mostly near Sofala Bank at depths of 400-500m.

Fishing vessels and gear: Two crab trap-vessels were active – *FV Rio Saiňas* and *FV Crisfer.*

History of fishery: Trap-fishery started in 2009. Reported crab catches were 51t in 2009 and 168t in 2010. Anecdotal information suggests that the fishery expanded after 2011 and that it also catches *P. delagoae*.

Management controls and regulations: A monitored experimental fishery – recommended that it becomes a commercial fishery.

Bycatch and ecological impacts: Fishery also lands spiny lobster *Palinurus delagoae* when it operates south of Sofala Bank.

Refs: Anon. 2011

5. EXPLORATORY TRAPPING FOR DEEP-WATER SHRIMPS (*HETEROCARPUS* SPP) OFF MAURITIUS (1980S)

Target species: Most of the catches were of *Heterocarpus laevigatus* (shown alongside). Small quantities of *Heterocarpus ensifer* were taken in depths of 350 to 500m.

Spatial extent: Areas with suitable depths (600 to 1,000 m) identified as about 40 km^2 around Mauritius (Island) and about 2,000 km^2 on the more distant grounds immediately to the north. No consideration yet given to the possible exploitation of more distant grounds, such as the Nazareth and Saya de Malha Banks.

Fishing vessels and gear: Intermittently from 1984 through 1986, two privately owned vessels were engaged in commercial feasibility fishing along the west coast of Mauritius. These were the *FV Umbrina* (24m length) and a smaller "big game" fishing boat. Subsequently the *Umbrina* explored more distant grounds immediately to the north of the island. Gear were traps attached to long lines. The larger boat used one line with 45 traps; the smaller boat used two lines with 10 traps each.

History of fishery: Catches were approx. 5 tonnes whole weight from 2 boats per year during mid 1980s. Catch rates exceeded 2 kg/trap.day in productive areas. Presently neither vessel is engaged in the fishery.

Management controls and regulations: Not applicable.

Bycatch and ecological impacts: Not applicable.

Refs: Roullot & Soondron 1986; Pellegrini 1986; Samboo & Mauree 1988

6. EXPLORATORY TRAPPING FOR DEEP-WATER SHRIMPS (*HETEROCARPUS* SPP) OFF SEYCHELLES (1980S)

Target species: Deep water shrimps *Pleisionika longirostris* (200-300m depth); *Heterocarpus ensifer* (250-450m) *Heterocarpus laevigatus* (350-700m); Deep-sea crabs *Chaceon* sp. (300-1,000m).

Spatial extent: The Seychelles Plateau is quite shallow, and deep water crustaceans are found along the edge of the plateau. Deep water areas (200-600m depth), have been estimated as 2,600 km^2 for the Mahé Plateau and as 1,000 km^2 for the Amirantes Plateau.

Fishing vessels and gear: Experimental trap fishing by the Seychelles Fishing Authority along the edge of the Mahé Plateau during 1985 caught promising quantities of carids. Following this, a 14m commercial vessel carried out several trials using a variety of experimental traps. Conical traps were used for deep-sea crabs.

History of fishery: Catch rates of 600 g/trap set were obtained for the most successful trap type set at 380 to 500m depth. The best traps were rectangular (40 x 80 x 95cm), covered with jute sacking. For deep-sea crabs, conical traps had catch rates of 1,200g/trap at 500-700m depth. No long-term fishery initiated.

Management controls and regulations: Not applicable.

Bycatch and ecological impacts: Not applicable.

Refs: Lablache et al. *1988*

7. EXPLORATORY TRAPPING FOR DEEP-WATER SHRIMPS (*HETEROCARPUS* SPP) OFF LA RÉUNION (1980S)

Target species: The species of principal interest are *Heterocarpus laevigatus* (most common at 600-1,000m depth) and *H. ensifer* (350-600m).

Spatial extent: All around Réunion Island in depths of 100 to 1,000m, particularly on sandy substrates containing organic detritus.

Fishing vessels and gear: Few commercial boats operated since 1981, but seldom more than one at a time. Traps attached to longlines.

History of fishery: The catch from commercial fishing is unknown. During experimental fishing in 1981, catch rates were about 1 kg/trap.day at 750 to 850m depth, and 400 g/trap.day at 450 to 550m. No estimates of potential yield exist. Some conclusions about the biology of the important species and catch rates were obtained during experimental fishing.

Management controls and regulations: Not applicable.

Bycatch and ecological impacts: Not applicable.

Refs: Kopp & Hebert 1981; Biais 1988

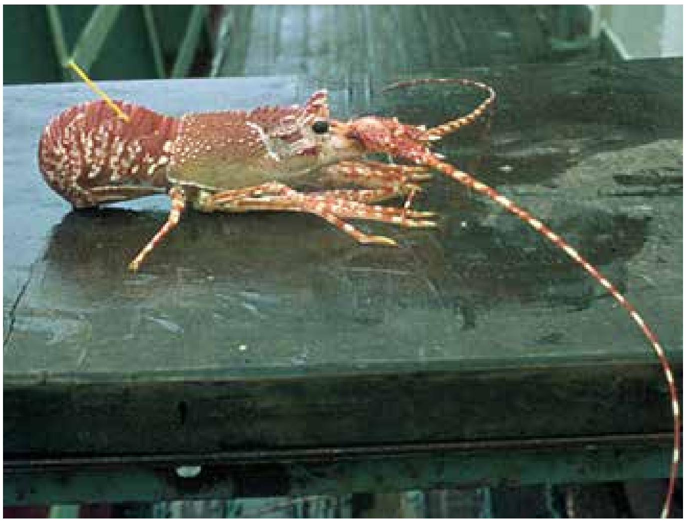
PRIORITY SPECIES

PALINURUS GILCHRISTI (STEBBING, 1900)

Common name:
– South Coast rock (spiny) lobster;

Target fisheries:
– Industrial longline trap fishery

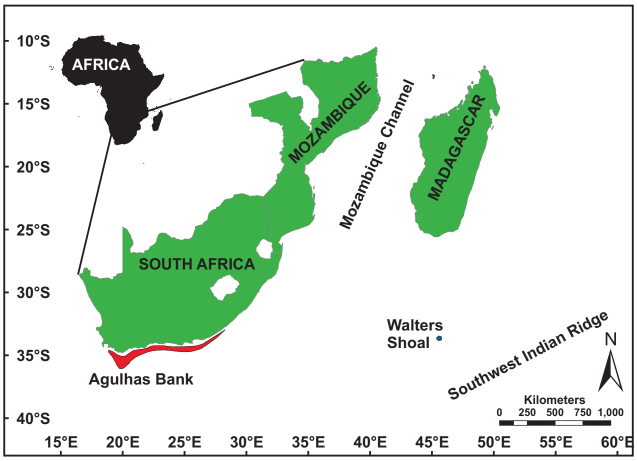
SWIOFP Countries:
– South Africa



DISTRIBUTION AND HABITAT

Endemic to South Africa; Cape Point (19˚E) to East London (28˚E); Agulhas Bank up to 250 km offshore. Close inshore near East London, where shelf is steep and narrow. Rocky substrata at depths of 50-200m.

Refs: Pollock & Augustyn 1982; Holthuis 1991; Groeneveld 2006a, 2013a



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

Size at maturity varies geographically. Port Alfred females mature at 59-62mm CL. Algoa Bay to Agulhas Bank females mature at 64-71mm CL

Mating occurs between hard-shelled individuals. Gelatinous spermatophoric mass transferred from male to sternal plate of female. Fertilization external, during oviposition. Most ovaries ripen in June; spawning in July-August. Egg-bearing highest in July-October (60-85%), declining in November. Incubation takes 4-6 months. Most ovaries spent or inactive in October-November. Large females may spawn twice/yr, in fall and spring. Egg-bearing females are present in all months.

Max. number of eggs/brood = 200,000. Fecundity increase with increasing CL. Fecundity lower at Port Alfred than at Algoa Bay to Agulhas Bank. No of eggs/female are:
Eggs = 2043*CL – 90 439 (Port Alfred); Eggs = 3086*CL – 166 819 (Algoa-Agulhas)
Egg-loss during incubation est. 14-17%. Small females contributed 93% to egg-production at Port Alfred; larger females 84% at Algoa Bay to Agulhas Bank.

Refs: Berry 1969; Berry & Heydorn 1970; Groeneveld & Melville-Smith 1994; Groeneveld & Rossouw 1995; Groeneveld 2005

LARVAL DISTRIBUTION AND RECRUITMENT OF PUERULI

Phyllosoma larvae are pelagic for 4+ months and are presumably widely dispersed by the Agulhas Current. Puerulus settlement hotspot identified at Cape Agulhas – the downstream (western-most) extreme of species distribution. Small juveniles (CL< 55mm) scarce in other areas.

Refs: Berry 1974; Groeneveld & Branch 2002

MOULTING AND GROWTH

Size-dependent moult season in summer, when bottom temperature is cooler because of a seasonal thermocline. Grows slowly, annual growth increments decrease with increasing CL; females grow slower than males after reaching maturity. Moult increments smaller at Port Alfred (1.5mm/yr for a male of 70mm CL) than at Algoa Bay to Agulhas Bank (3.5 mm/yr). Regressions of annual growth increments at size are:

- G = 4.854-0.0512*CL (Port Alfred males)
- G = 5.832-0.0763*CL (Port Alfred females)
- G = 9.786-0.088*CL (Algoa B-Agulhas B males)
- G = 11.61-0.1208*CL (Algoa B-Agulhas B females)

Moult frequencies decrease with increasing size.

Recent growth curves accounting for tag-induced retardation suggest that *P. gilchristi* grows substantially faster than previously thought, when no corrections were made.

Refs: Groeneveld 1997; Groeneveld & Branch 2001; Santos & Groeneveld 2015

MAXIMUM SIZE

Max. observed CL is 110mm (males) and 97mm (females) at Port Alfred, and 130mm (both sexes) at Algoa Bay to Agulhas Bank.

Refs: Groeneveld 1997

NATURAL MORTALITY

Estimate of M = 0.1 y^{-1}.
Octopus magnificus enter traps and prey on captured lobsters.
Highest predation on larvae, during juvenile stages and during moulting.

Refs: Groeneveld et al. *2006c, 2013a*

LENGTH-WEIGHT

Many relationships described (CL, whole mass, tail mass, males, females and both sexes combined). Conversion factor used to convert catches from whole to tail mass is 0.450.

Refs: Groeneveld & Goosen 1996

POPULATION SIZE STRUCTURE

Trap-caught lobsters range from 50–130mm CL. Lobsters >125mm scarce. Average CL increases from W to E. Small immature lobsters (mean = 62mm) at Cape Agulhas; at W Agulhas Bank (mean = 71.3mm) a mixture of immature and small mature lobsters occur; at E Agulhas Bank (mean = 75.8mm) bimodal distribution suggests that small mature lobsters (mode = 65mm) coexist with mature lobsters (mode = 77mm). Size distributions at remaining 2 sites are unimodal – mean CL = 76.5mm at and 70.7mm at Port Alfred.

Refs: Groeneveld & Branch 2002

SEX RATIO

Sex ratios vary with season. Generally 1:1, or males outnumber females except Port Alfred.

Refs: Pollock & Augustyn 1982; Groeneveld & Branch 2002

MIGRATIONS

Juveniles migrate against flow-direction of Agulhas Current.

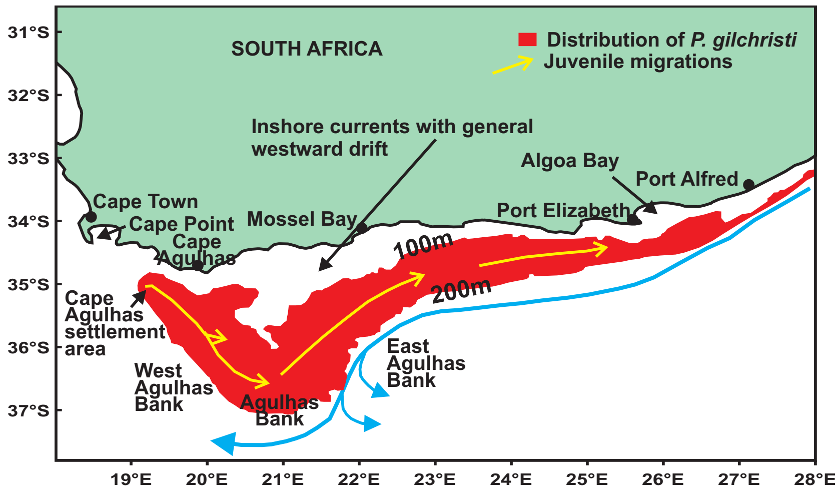
97% of tagged juveniles at Cape Agulhas migrated SE offshore to outer Agulhas Bank (mean =154 km), or E to Algoa Bay (461 km). Furthest straight-line distance = 790 km. Fastest 5% of migrants moved at 0.43- 0.78 km d^{-1}.

Cape Agulhas migrants reach outer Agulhas Bank within 1-2 yrs, and Algoa Bay within 3. No return migration observed. Port Alfred population is non-migratory. Increase in size composition and mean size from west to east supports information on migrations from tagging.

Migration pattern assumed to have evolved to maintain the distribution of *P. gilchristi* in the region of the strong unidirectional Agulhas Current regime. Pelagic phyllosoma larvae dispersed downstream – migrations redress the shift by going upstream.

Advection-diffusion models for quantifying migrations for use in spatial fisheries management have recently been developed for *P. gilchristi*.

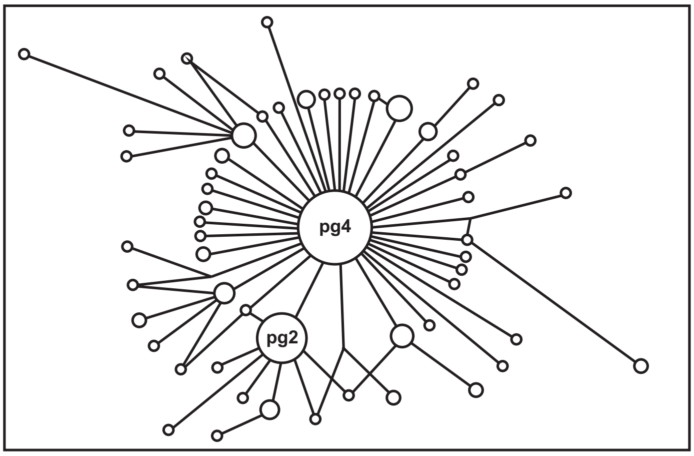
Refs: Groeneveld & Branch 2002; Santos et al. *2014*



GENETIC STOCK STRUCTURE

Mitochondrial DNA analysis (control region) showed a panmictic population due to a high amount of gene flow during larval stage and juvenile migrations. Figure shows star-shaped haplotype network.

Refs: Tolley et al. *2005*



STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

An Operational Management Plan (OMP) implemented since 2008. It is a pre-agreed formula which uses resource monitoring data (e.g. total catch, catch-rate data [or CPUE], and catch length composition) to provide a TAC recommendation. Output tuned to achieve medium term goals through trading-off of high catches with low risks of resource depletion, and small year-to-year changes (i.e. stability). Present stock status considered stable with recent estimates of exploitable biomass at 37% of pristine. Some declines shown over past decade. MSY estimated as 797 – 977t whole mass (359-440t tail mass).

Refs: Anon. 2010; DAFF 2010

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

The management objective is to increase spawning biomass by 20% (in median terms) over 20 years from 2006 to 2026. TAC cannot change > 5% between years.

Refs: Anon. 2010; DAFF 2010

DATABASES

DATA COLLECTION

Logbooks – catch, effort, geographical position; Catches weighed at off-loading;
Observers collect size composition and other biological data; Occasional tagging for growth, migrations.

Refs: DAFF 2010

KNOWN DATABASES

Government data of rights holders, vessels, quotas, catches; Catch and Effort data (logbooks); Size composition database (observer data); Tag-recapture database.

METADATA (SEE ANNEX)

- ZAF-D001: South coast rock lobster commercial catch & effort, sampling and tagging data
- ZAF-D002: South coast rock lobster – Observer data

PALINURUS DELAGOAE (BARNARD, 1926)

Common names:
- Natal deep-water spiny lobster (SA)
- Lagosta de profundidae (Mozambique)

Target fisheries:
- Experimental longline trap fishery, KwaZulu-Natal
- Industrial trap fishery, Mozambique
- Deep-water crustacean trawl fishery (SA)
- Deep-water crustacean trawl fishery (Moz)

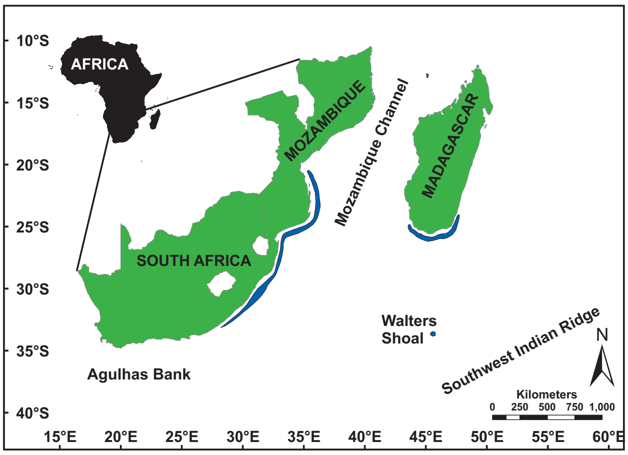
SWIOFP Countries:
- South Africa
- Mozambique

DISTRIBUTION AND HABITAT

From 17°S (Mozambique) to 32°S (eastern South Africa), depth range 150-600 m.

Rocky areas and a substratum consisting of mud with a high organic content and varying quantities of sand and coral fragments.
Palinurus spp. off S Madagascar unsure.

Refs: Berry 1971; Holthuis 1991



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

South Africa: 50% of females mature at 67.3 mm CL (setal method) or 71.2 mm CL (ovigerous method).

Mozambique: 50% of females mature at 64.8mm CL (gonad method) or 69.3 mm CL (ovigerous method).

Mating between hard-shelled individuals. Gelatinous spermatophoric mass transferred to sternal plate of female. Fertilization external, during oviposition. Single annual brood. Freshly spawned eggs in Sep, eggs about to hatch in April, hatched eggs in May-July. Incubation 5-6 months. Ovarian cycle confirms egg-bearing periodicity: 90% of females have inactive ovaries in April; November-December has highest incidence of ripe ovaries. Large aggregations of egg-bearing females observed. Females with CL>140mm may carry >300 000 eggs/brood. Fecundity increases linearly with increasing CL. Eggs slightly larger than in *P. gilchristi*.

Eggs = 3205.3*CL – 204501 (SA) ; Egg-loss during incubation est. 10-16%.

Refs: Berry 1969, 1972, 1973; Berry & Heydorn 1970; Brinca & Palha de Sousa 1983; Palha de Sousa 1998; Groeneveld 2000; Groeneveld et al. *2005*

LARVAL DISTRIBUTION AND RECRUITMENT

Larvae pelagic for 4+ mo. Widely dispersed by Mozambique channel eddies and upper Agulhas Current. Pueruli likely settle outside 100-600m fished depth range.

Refs: Berry 1974; Gopal et al. *2006*

MOULTING AND GROWTH

Adults moult once per year: August to October in South Africa and in Mozambique. A minor peak in April is probably continued moulting by sub-adults, which moult more often.

Adults grow slowly; annual increments decrease with increasing CL; females grow slower than males after becoming mature.

<u>South Africa</u>: CL increments from tag-recapture data described by:
$A = -0.0691*CL+8.94$; $CL_{inf} = 161$mm, $K = 0.07$ year^{-1}

<u>Mozambique</u>: Females – $CL_{inf} = 170$mm, $K = 0.3$ year^{-1}; Males – $CL_{inf} = 182$mm, $K = 0.3$/yr

Refs : Berry 1973; Brinca & Palha de Sousa 1983; Palha de Sousa 1992, 1998; Groeneveld 2000

MAXIMUM SIZE

Observed max CL > 180 mm, compared to length-based Powell-Wetherall estimates of 160-163mm CL. Low value of K reflects slow growth towards CL_{inf} – consistent with slow-growing and long-lived life strategy.

Refs : Groeneveld 2000

LENGTH-WEIGHT

Various relationships described: CL, whole mass, tail mass, males, females and both sexes.

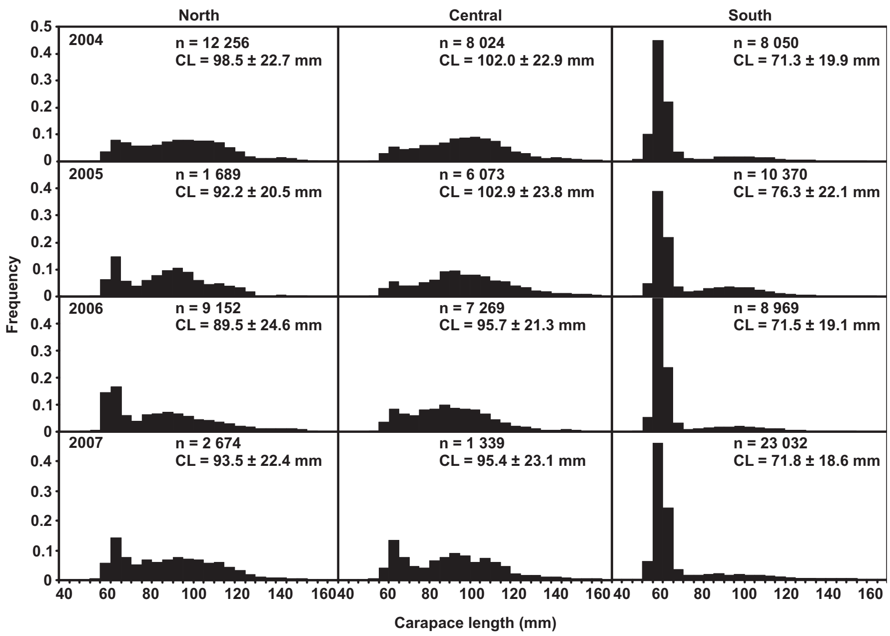
Refs: Groeneveld & Goosen 1996

POPULATION SIZE STRUCTURE

<u>South Africa</u>: CL range from 50-185mm; marked absence of juveniles <50mm in traps. Depth and latitude strongly influence size composition. Mean CL increases as depth decreases from 400-150m. By latitude, mean CL small south of Durban, larger along KZN North Coast, but variable. Size distributions often bimodal, showing recruitment cohorts and adult population. Trap fishing reduced mean CL off SA in 1994-1997 and in 2004-2007. Size distribution per year (2004-2007) and area (South, Central and North) shown opposite.

<u>Mozambique</u>: Size frequency unimodal on all fishing grounds. Smaller lobster caught at Inhaca and Bazaruto B. Larger lobsters caught at Boa Paz and Bazaruto A. Larger lobsters more frequent in shallower depth strata.

Refs: Cockcroft et al. *1995; Groeneveld & Cockcroft 1997; Palha de Sousa 1998; Groeneveld* et al. *2012a*



SEX RATIO

Males dominate size classes > 125 mm CL. Sex ratios during the non-reproductive season (May-September) evenly spread across depth. Males = 54% (112-200m), 46% (20-275m), 51% (276-325m), 51% (326-375m) and 50% (376-425m). In Mozambique sex ratios vary over time, but females appear to be more vulnerable to traps.

Refs: Palha de Sousa 1998; Groeneveld 2000, 2012a

NATURAL MORTALITY

M estimates are 0.09-0.15y^{-1} Predators include dogsharks *Dalatius licha* and *Cephaloscyllium sufflans.*

Refs: Berry 1973

MIGRATIONS

Highly migratory. Three distinct migratory life-history strategies: ontogenetic inshore movements by juveniles, alongshore movements by pre-reproductive lobsters, and inshore-offshore movements related to reproduction.

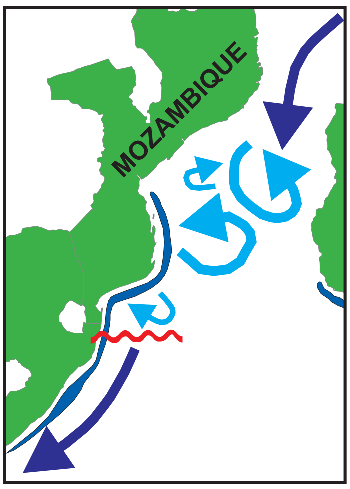
1. Size composition shows that juveniles inhabit 400-600m depth range and gradually move shallower as they grow larger to recruit to the adult population at 150-350m.
2. Pre-reproductive lobsters tagged at southern range limit migrated up to 495km NE alongshore, counter to Agulhas Current between Durban and S Mozambique.
3. Egg-bearing females concentrate in dense aggregations in shallower strata (150-275m) in summer; move deeper (>300m) in autumn and winter after eggs have hatched.

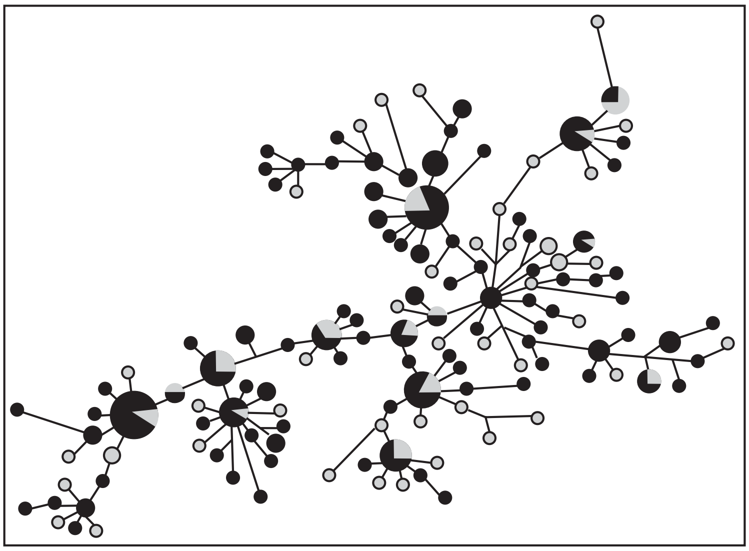
Refs: Koyama 1971; Berry 1972; Kondritskiy 1976; Cockcroft et al. *1995; Groeneveld 2002*

GENETIC STOCK STRUCTURE

Mitochondrial DNA (control region) show a shallow genetic partitioning between S Mozambique and E South Africa. The break supports earlier morphological studies suggesting 2 populations off SE Africa – var. *natalensis* from South Africa and var. *delagoae* from Mozambique. The break is along the interface of the Mozambique Channel eddies and upper Agulhas Current.

Refs: Berry & Plante 1973 ; Gopal et al. *2006*





STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

South Africa: Length-based cohort analyses based on 1994-1997 data showed that F was highest on immature and small mature lobsters. The equilibrium biomass prediction was 800t (32% of unexploited), and a Thompson and Bell model suggested a sustainable yield of 60t per year (trap and trawl fishery combined). Catches in 1994 and 1995 were > 60t, suggesting over-fishing. Catch rates improved between 1997 and 2004, when no trapping was allowed, but declined rapidly when fishing resumed. SA stock depleted.

Mozambique: Stock assessment in 1992 estimated growth and mortality parameters. Length converted catch curve showed three levels of total mortality (year^{-1}): Z=2.9 for smaller sizes; Z=1.4 for intermediate; and Z=0.6 for large lobsters. Yield-per-recruit analysis showed that an increase of 50% in long-term yield would be possible by increasing size at first capture from 60 to 100 mm CL.

Refs: Groeneveld 2000; Palha de Sousa 1992, 1998, 2001; Groeneveld et al. *2012a*

FISHING MORTALITY

South Africa: F highest in small size classes (60-69 mm CL).
Mozambique: VPA showed that F was highest in small size classes (60-90 mm CL).
Z ranges between 0.21 and 0.45/year.

Refs: Palha de Sousa 1992, 1998; Groeneveld 2000

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

South Africa: Fishery closed pending assessment & management decisions.
Mozambique: Fishery closed. Surveys to assess stock recovery undertaken in 2005 and 2010.

Refs: Palha de Sousa 2001; Kirkman 2005b; Dias 2011

DATABASES

DATA COLLECTION

Fisheries observers collect fisheries & biological data on-board during fishing, or during port sampling when vessels docked.

KNOWN DATABASES

South Africa: Governmental database with details of rights holders, vessels, quotas and reported catches; MS Access database with Catch and Effort data and all biological data for the 2004-2007 experimental fishery (Geo-referenced, Observer-based); Tag-recapture database (DAFF); Catch, effort and biological data from 1994-1997 (DAFF).

Mozambique: Several databases exist. Port sampling data from 1987-1992. Onboard sampling data of catch, effort, size composition for 1980-1984 and again 1993-1998. Access database for 2005 survey by FV *Cape Flower*. Database for 2010 survey by FV *Rio Saiñas*. 1980-1999 – Voluntary logbook data collected from various vessels.

METADATA (SEE ANNEX)

- ZAF-D003: KZN deep-water trapping survey 2004-2007
- ZAF-D004: KZN deep-water trapping survey 1993-1997
- MOZ-D303: Mozambique observer samples 1980-2000
- MOZ-999 : Deep-water trapping survey 2005
- MOZ-998 : Deep-water trapping survey 2010

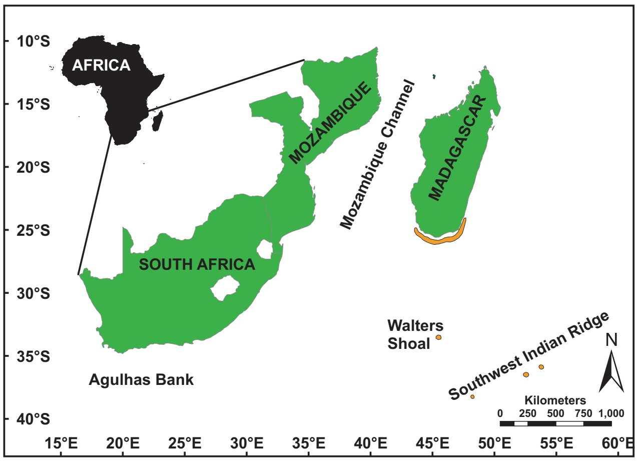
PALINURUS BARBARAE (GROENEVELD *ET AL.* 2006)

Common name:
– Deep-water spiny lobster

Target fisheries:
– Exploratory trapping for spiny lobsters and crabs on high-seas seamounts on South Madagascar Ridge (Walters Shoals) and SW Indian Ridge.

SWIOFP Countries:
– High seas

DISTRIBUTION AND HABITAT



Seamounts and Ridges of the SWIO, mainly Madagascar Ridge and SW Indian Ridge. Walters Shoals (33˚9-16' S; 44˚ 49-56' E) on the Madagascar Ridge. Seamounts 102, 105, 150, 251, 358, 360, 422, 415, 215, 350, 335, 336 on the SW Indian Ridge (see Romanov 2003). Possibly shelf and slope of S Madagascar.

Refs: Groeneveld et al. *2006b; Romanov 2003*

BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

MAXIMUM SIZE

Observed maximum CL = 186 mm; > 3kg
Max Total length = 540 mm; = 4.2 kg

Refs : Groeneveld et al. *2006b; Romanov 2003*

GENETIC STOCK STRUCTURE

Mitochondrial DNA analyses (using 16S and COI markers) showed that lobsters at Walters Shoals and at Seamount 150 (SW Indian Ridge) cluster as a distinct taxon (*P. barbarae*) with no gene flow with *P. delagoae* in South Africa and Mozambique.

Refs: Gopal et al. *2006; Groeneveld* et al. *2007; Matthee (pers. com.)*

SCYLLARIDES ELISABETHAE (ORTMANN, 1894)

Common names:
- Cape slipper lobster
- Shovelnose lobster
- Cava-cava

Target fisheries:
(Caught as target or bycatch)
- Experimental longline trap fishery, KwaZulu-Natal
- Industrial trap fishery for deep-water lobsters, Mozambique
- Deep-water crustacean trawl fishery (SA)
- Deep-water crustacean trawl fishery (Mozambique)

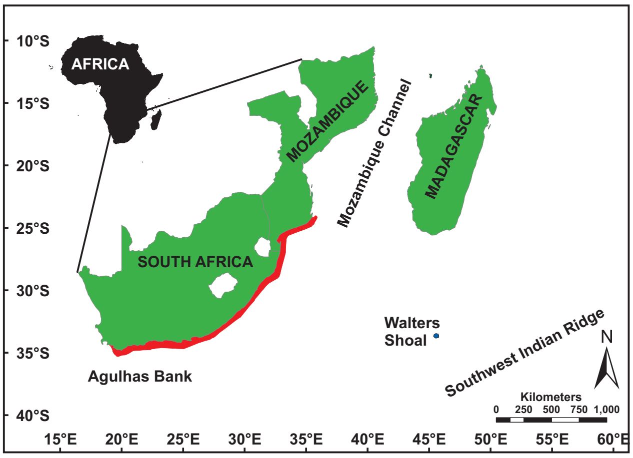
SWIOFP Countries:
- South Africa
- Mozambique

DISTRIBUTION AND HABITAT

Indo-West Pacific region: only known from SE Africa (from Inhambane, Mozambique to Cape Agulhas, South Africa; about 24-35˚S).

Depth range reported from 37m to 450m. Trap catches increased with increasing depth from 200 to 400m. Fine sediments – mud or fine sand. Rocky substrates and reefs.

Refs: Holthuis 1991; Groeneveld et al. *2012a*



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

No females with eggs reported from 2004-2007 experimental fishery off eastern South Africa. No immature females reported from trap catches.

Refs: Groeneveld et al. *2012a*

LARVAL DISTRIBUTION & RECRUITMENT

Larvae captured off eastern SA and described.

Refs: Berry 1974

MAXIMUM SIZE

Observed maximum CL = 111mm, Max. weight approx. 600g.

Refs: Groeneveld et al. *1995, 2012a*

LENGTH-WEIGHT

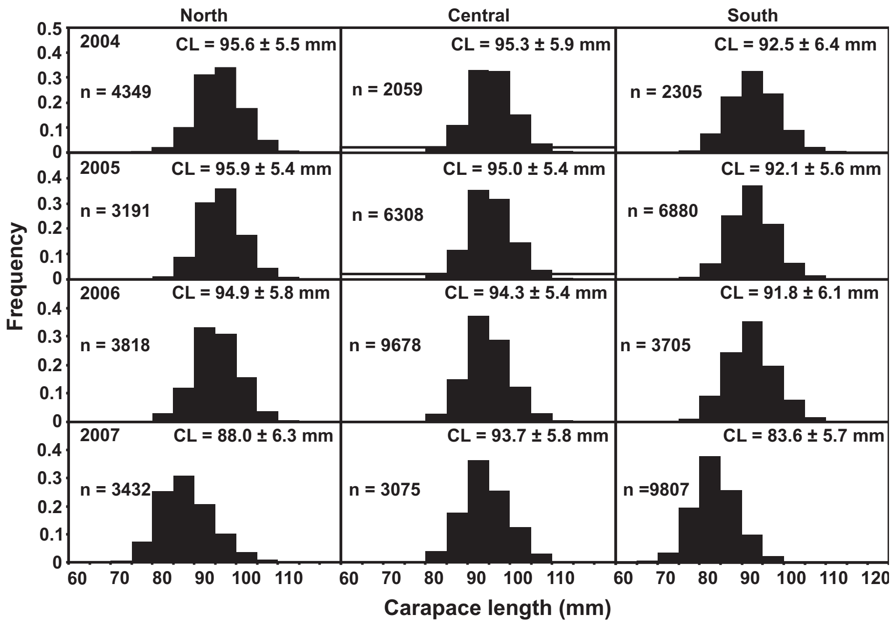
Various relationships described - CL, whole mass, tail mass, males, females and both sexes

Refs: Groeneveld & Goosen 1996

POPULATION SIZE STRUCTURE

Trap catches off South Africa show narrow unimodal size range (75-110mm CL). Small individuals with CL <75mm absent – juveniles & small adults possibly absent from adult habitats. Average CL similar irrespective of depth sampled between 150 and 450m. Females larger than males. Decline in average CL observed over four years of fishing. Lobsters in southern areas smaller than elsewhere.

Refs: Groeneveld et al. *1995; 2012a*



SEX RATIO

No difference in numbers of males and females caught in traps in two of three sampled areas off KZN, but males dominated in one area.

Refs: Groeneveld et al. *2012a*

STOCK ASSESSMENTS AND REFERENCE POINTS

Assessments and stock status

Relative abundance on eastern SA trap-fishing grounds determined based on stratified trapping survey in 1994. Some declines in trap catch rates between 2004 and 2007.

Refs: Groeneveld et al. *1995, 2012a*

DATABASES

DATA COLLECTION

South African government database with details of rights holders, vessels, quotas and reported catches. MS Access database with Catch and Effort data and all biological data for the 2004-2007 experimental fishery (Geo-referenced, Observer-based).

KNOWN DATABASES

Catch, effort, size composition and sex ratio data for KZN experimental trap-fishery for 1994-1997 and 2004-2007.

METADATA (SEE ANNEX)

- ZAF-D003: KZN deep-water trapping survey 2004-2007
- MOZ-999: Mozambique deep-water trapping survey 2005

CHACEON MACPHERSONI (MANNING AND HOLTHUIS, 1981)

Common name:
– Deep-sea crab

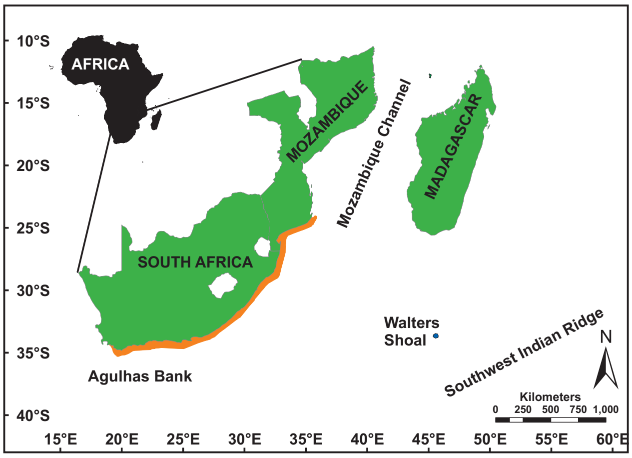
Target fisheries:
(Caught as target or bycatch)
– Experimental longline trap fishery, KwaZulu-Natal
– Industrial trap fishery for lobsters (Mozambique)
– Deep-water crustacean trawl fishery (SA)
– Deep-water crustacean trawl fishery (Mozambique)
– New deep-water trap fishery (Mozambique)

SWIOFP Countries:
– South Africa
– Mozambique
– Kenya

DISTRIBUTION AND HABITAT

South Africa – from Cape Columbine on the west coast, south and east coasts, to central Mozambique. Also found in S Madagascar. Depths of 200 to >1,000m. Most abundant at 500-800m. Mainly on soft substrata.

Refs: Manning & Holthuis 1988, 1989; Paula e Silva 1984



BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

Males attain sexual maturity at 112-124mm CW (L_{50} = 118mm); females at 76-88mm (L_{50} = 82mm).
Egg-bearing season unclear; 8.1% of females caught in traps carried eggs.
Smallest egg-bearing female measured 83mm; 4.2% of egg-bearers had a CW < 90mm.

Refs: Paula e Silva 1984; Groeneveld et al. *2013b*

LARVAL DISTRIBUTION & RECRUITMENT

Unclear, but recruitment of small crabs to fishing grounds seen in Feb-Mar and Aug-Oct in Mozambique.

Refs: Paula e Silva 1984

MAXIMUM SIZE

Males larger than females. Max. CW of 151mm. Max weight approx 1 kg.

Refs: Paula e Silva 1984

LENGTH-WEIGHT

South Africa: Length-weight relationships recently calculated as:

- Male: $WW = 0.00008*CW^{3.2765}$; n=261 over a size range of 78-164 mm; $r^2 = 0.91$
- Female: $WW = 0.0011*CW^{2.7057}$; n = 261 over a size range of 68-118mm; $r^2 = 0.79$
- All: $WW = 0.00009*CW^{3.2474}$, n=522; $r^2 = 0.92$

Where WW is whole weight and CW is Carapace Width.

Mozambique:

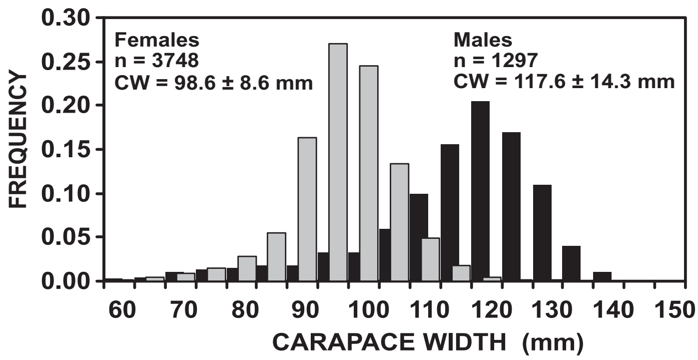
- $TW = 0.0001*CW^{3.1577}$ (TW = Total Weight)

Refs: Paula e Silva 1984; Groeneveld et al. *2013b*

POPULATION SIZE STRUCTURE

Separate modes existed for females and males. Size and sex structure suggest incomplete segregation by sex. The mean size of crabs remained constant over depth (100-600 m) and did not differ by month. No size data are available beyond 600m depth.

Refs: Paula e Silva 1984; Groeneveld et al. *2013b*



SEX RATIO

South Africa: Skewed towards females over the whole depth range sampled and during all months tested.

Mozambique: Females 4 times more abundant than males in depths of <400m, but parity at depths > 400m. No data existed for deeper strata.

Refs: Paula e Silva 1984; Groeneveld et al. *2013b*

MIGRATIONS

Unknown. Assumed to move between depths and alongshore, as in other *Chaceon* spp.

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENTS AND STOCK STATUS

No assessment based on trapping. Reduced catches in deep-water trawl fishery suggest that stock has declined.

Refs: Groeneveld & Melville-Smith 1995; Groeneveld et al. *2013b*

DATABASES

DATA COLLECTION

None for trapping after 2007. As bycatch in trawl fishery by observers.

KNOWN DATABASES

South African government database with details of rights holders, vessels, quotas and reported catches. MS Access database with Catch and Effort data and all biological data for the 2004-2007 experimental trap fishery (Geo-referenced, Observer-based).

METADATA (SEE ANNEX)

- ZAF-D003: KZN deep-water trapping survey 2004-2007
- MOZ-999: Mozambique deep-water trapping survey 2005

HETEROCARPUS LAEVIGATUS (SPENCE BATE, 1888); *HETEROCARPUS ENSIFER* (A. MILNE EDWARDS, 1881); *PLESIONIKA LONGIROSTRIS* (BORRADAILE, 1900)

Heterocarpus ensifer

Common name:
- Deep-water shrimp
- Pandalid shrimp
- Carid shrimp
- Smooth nylon shrimp
- Armed nylon shrimp

Target fisheries:
(Exploratory fisheries)
- Exploratory trapping in Mauritius
- Exploratory trapping in Seychelles
- Exploratory trapping in La Réunion

SWIOFP Countries:
- Mauritius
- Seychelles
- La Réunion

DISTRIBUTION AND HABITAT

H. laevigatus inhabits benthic deep-water habitats (450-900m) throughout the tropical Pacific; Arabian Sea, Canary Islands, Cape Verde, French Polynesia, Hawaii, Indo-Pacific, Indo-West Pacific, Kenya, Madagascar, Madeira, Malaysia, Mauritania, Mozambique, New Caledonia, New Zealand, Réunion, Somalia, South Africa, Tanzania, West Atlantic.

H. ensifer has wide distribution at low latitudes, including the SWIO. Adults recorded from sandy/muddy substrates at 88 -885m depth, but most abundant between 300 and 600m depth.

P. longirostris is a junior synonym of *Plesionika edwardsii* (Brandt, 1851), which occurs in the Atlantic, Mediterranean and Indo-Pacific (La Réunion). Generally found shallower than *Heterocarpus* spp.

Refs: Chan & Yu 1991; Tuset et al. *2009; http://eol.org/pages/342614/overview*

BIOLOGY, POPULATION DYNAMICS AND STOCK IDENTIFICATION

REPRODUCTIVE BIOLOGY

H. laevigatus: Females mature at 40mm CL, ovigerous individuals found year-round, main reproductive season in Aug to Feb in the Hawaiian Pacific (no data for Indian Ocean).

H. ensifer: Females mature at 22.4–25.7mm CL (NE Atlantic), ovigerous females present during all months but mass spawning occurs in spring and summer.

P. longirostris: No data from La Réunion Island or Seychelles

Refs: Dailey & Ralston 1986; Tuset et al. *2009*

MOULTING AND GROWTH

H. laevigatus: L_{inf} = 57.9mm CL for males; 62.5 mm for females; K = 0.35/yr for males and 0.25/yr for females.

H. ensifer: L_{inf} = 32–34mm CL for males; 35-37mm for females; K = 0.46–0.52/yr for males and 0.37–0.52 for females.

Refs: Dailey & Ralston 1986; Tuset et al. *2009*

MAXIMUM SIZE

H. laevigatus: 60-65mm CL
H. ensifer: 39mm CL

Refs: Dailey & Ralston 1986; Tuset et al. *2009*

NATURAL MORTALITY

H. laevigatus: Females may experience mass mortality after egg-bearing – i.e. semelparous, but studies are contradictory.

Ref: Dailey & Ralston 1986

LENGTH-WEIGHT

H. laevigatus: Regressions provided for combinations of CL. CW and Total length & weight.
H. ensifer: Length weight relationships provided for several sites in NE Atlantic.

Refs: Dailey & Ralston 1986; Tuset et al. *2009*

POPULATION SIZE & SEX STRUCTURE

H. laevigatus: Size range 9–60 mm CL. Seasonal length-frequency data suggest that it is not semelparous. Females larger than males in depths < 600m – males larger in depths >600m. Sex ratio depends on depth.

H. ensifer: Size range 9–39 mm CL. Males smaller than females, but grow faster. Size stratification with depth, with larger individuals concentrated in deeper waters. Sex ratio favours females at higher sizes.

Refs: Dailey & Ralston 1986; Tuset et al. *2009*

MIGRATIONS

H. laevigatus (opposite): Depth distribution changes with reproductive activity (season) and size. Small females move from deep to shallow water as they grow, and mature shrimp move between depths of 550 and 700m in synchrony with the ovigerous cycle of females.

H. ensifer: Seasonal vertical migrations related to reproduction or feeding.

Refs: Dailey & Ralston 1986; Tuset et al. *2009*

Metadata

Consultative Workshops identified several valuable long-term databases held by the Governments and Private Organizations in South Africa and Mozambique, and to a lesser extent by the Fisheries Department in Kenya. These were:

1. South Coast Rock Lobster Commercial catch and effort database (South Africa)
2. South Coast Rock Lobster Observer data (South Africa)
3. Deep-water trapping survey; 1994-1997 (South Africa)
4. Deep-water trapping survey; 2004-2007 (South Africa & Mozambique)
5. Longline crab trapping data; 2010 (Kenya)
6. Industrial deep-water lobster trap fishery 1980-1984 (Mozambique)
7. Industrial deep-water lobster trap fishery 1986-2000 (Mozambique)
8. Industrial deep-water lobster trap fishery – biological sampling 1980-1984 & 1986-2000 (Mozambique)
9. Deep-water trapping survey 2005 (Mozambique)
10. Deep-water trapping survey 2010 (Mozambique)
11. Experimental trap fishery for crabs (Mozambique)

Metadata to describe the above databases were compiled in terms of the Memorandum of Understanding between SWIOFP and the participant countries, according to standardized descriptors (Annex 1).

Regional synthesis

1. Four distinct deep-water trap fisheries for large crustaceans have operated in the SWIO region. Only one industrial fishery (for *P. gilchristi* off southern South Africa) is presently active, and another (for *Chaceon macphersoni* off Mozambique) has recently started. The other fisheries are presently inactive, or are occasional exploratory fisheries within EEZs or to distant fishing grounds on the high seas.
2. With some exceptions, the trap fisheries target high-value *Palinurus* spiny lobsters (several species) for lucrative export markets. *Palinurus* lobsters are generally long-lived, slow-growing species, which are often vulnerable to over-fishing (see Groeneveld *et al.* 2006a, 2013a).
3. Slipper lobster (*S. elisabethae*) and deep-sea crab (*C. macphersoni*) make up substantial retained by-catches (or occasionally targeted catches) of the trap fisheries in eastern South Africa and in Mozambique. *Octopus magnificus* is a retained bycatch in traps set for *P. gilchristi* off southern South Africa.
4. A small trap fishery off Kenya targets an unidentified deep-sea crab (possibly *Chaceon* sp.), and virtually no information is available on the extent of this fishery. The fishery is presently inactive because of the threat of piracy.
5. Exploratory trap fisheries for deep-water shrimps *Heterocarpus* spp. have occasionally taken place around Mauritius, La Réunion, and Seychelles, and the potential of these fisheries remain unknown to date.
6. A new trap fishery for deep-water crab (*C. macphersoni*) is now active off the coast of Mozambique – mainly in the Sofala Bank region. Bycatches in this fishery is spiny lobster (*P. delagoae*), although lobster catches can be minimized by targeting appropriate areas and depth range.
7. Trapping in international waters (Walters Shoals and seamounts on the SW Indian Ridge) is not controlled. The numbers of vessels working in this area, frequency of trips, and quantities of lobsters caught by traps are unknown.
8. The Banc d'Etoile near Fort Dauphin in SE Madagascar (approx. 5,000 km^2 between 100-1,000m depth) is an area that can potentially be exploited with traps for *Palinurus* lobsters. The area was previously surveyed in 1969 and 1987, showing traces of *Palinurus* spp. The area is difficult to exploit because of bottom type and currents. The survey methods used in the past may have been inadequate.
9. Stock recoveries of fished down populations of *P. gilchristi* and *P. delagoae* off South Africa have been demonstrated. In both cases a reduction in fishing effort and catches resulted in an increase in relative abundance. Thus rebuilding of stocks through a conservative management strategy can be considered as an option.

10. The species distribution patterns of *Palinurus* in the SWIO remain unclear. It is unknown whether the population in SE Madagascar is *P. delagoae* or *P. barbarae*. It is also unclear how far north-eastwards the distribution of *P. barbarae* extends on the SW Indian Ridge seamounts.
11. Based on their transboundary distribution, *P. delagoae*, *S. elisabethae* and *C. macphersoni* are apparently shared sub-regionally (South Africa and Mozambique; possibly Madagascar).
12. However, this assertion was not supported by a recent population genetic study done on *P. delagoae* populations off South African and Mozambique. A shallow genetic break between populations (indicating separate management units) was consistent with the hydrographic boundary between the Mozambique Channel eddies and the upper Agulhas Current (i.e. close to the SA/Mozambique international boundary). Nevertheless, exchange of larvae and benthic migrants doubtlessly occur across this boundary.
13. Trap-fisheries operating within the Exclusive Economic Zones (200nm) of SWIOFP countries are controlled according to national management strategies. No regional management strategies exist, even where stocks are apparently shared.
14. Considerably more information will be required to justify a shift in fisheries management strategy, from national to sub-regional or regional management plans.
15. The SWIOFP project has now generated a Crustaceans data gap-analysis, an extensive *Endnote* bibliography of published literature, internal- and survey reports, a meta-database on StatBase covering selected fisheries, and a detailed Retrospective Analysis (this document). This information, together with surveys at sea using chartered fishing vessels and observer data collected under SWIOFP in 2011 and 2012 now provide a solid baseline to support the development of management plans.

Recommendations

Recommendations emanating from this Retrospective Analysis are summarized below, by country and for the region as a whole. Note that a key finding of this study is that considerably more information will be required to justify a shift in fisheries management strategy, from national to sub-regional or regional management plans, in most cases.

The recommendations reflect this finding, both in terms of the collection of new information by observers and surveys, further analysis and stock assessments based on existing (historical) information, and the use of the outputs in management and governance at national and regional levels.

SWIOFP Country	*Fishery / Species*	*Narrative and Recommendation*
All countries	All species that are likely to be shared by two or more countries in the region, incl. *P. delagoae.*	Species with a transboundary distribution may benefit from regional or subregional management strategies that encompass its entire distribution and all life-history phases. ***Recommendation:*** Population genetic studies to be undertaken for key transboundary species such as *P. delagoae* to assist in decisions on whether fisheries should be managed at national or regional levels. Results of these studies to be incorporated in decision making.
South Africa	Industrial trap fishery for *P. gilchristi*	*P. gilchristi* is endemic to South Africa and the fishery comprises local vessels only. OMP developed as interface between assessments and management. Present management objective to increase Bsp by 20% over 20 years (2006-2026). ***Recommendation:*** No change to present management strategy.
South Africa	Experimental trap fishery for *P. delagoae*	Both *P. delagoae* and slipper lobster *S. elisabethae* catch rates declined sharply during two short-term experimental fisheries, but showed some recovery in-between. Trapping has been suspended while awaiting the outcome of a formal stock assessment. ***Recommendation:*** Assessment to be done based on existing information from 1994-1997 and 2004-2007.
Mozambique	Industrial trap fishery for *P. delagoae*	Three trapping surveys have been conducted using the FV Cape Flower (2005); and FV Rio Sainhas (2010) and for SWIOFP (2012) to investigate stock status after a collapse of the commercial fishery in 1999. ***Recommendation:*** Survey information to be used to determine stock recovery and status with a view towards reopening the trap fishery.
Mozambique	Experimental trap fishery for *Chaceon macphersoni*	Experimental trap fishery active since 2009; potential for a long-term commercial fishery. Fisheries observers to be deployed to collect fisheries and biological data. ***Recommendation:*** To progress from a monitored experimental fishery to a sustainable long-term commercial trap fishery if indicated by newly collected information.

SWIOFP Country	*Fishery / Species*	*Narrative and Recommendation*
Kenya	Occasional commercial trap fishery (crabs)	Small scale fishery operated until 2010, but now dormant because of security situation. No info available from fishery. ***Recommendation:*** Use SWIOFP survey data to assess species composition of catches, distribution and abundance of crabs and deep-water prawns in Kenya. Collect samples of the targeted crab (likely a *Chaceon* sp.) and identify it.
Madagascar	Occasional historical surveys for *Palinurus* spp.	Historical surveys have shown the presence of *Palinurus* spp., but which species and the extent of their distribution and abundance remain unclear. Although planned, SWIOFP did not survey the shelf of southern Madagascar, because a suitable vessel could not be found. ***Recommendation:*** Collect samples of the *Palinurus* sp. and identify it, using DNA bar-coding and morphology. Survey the Banc d'Etoile with traps to establish its fisheries potential.
Mauritius	Exploratory trapping for deep-water shrimps *Heterocarpus* spp.	Historical and recent exploratory fishing. ***Recommendation:*** Deployment of fisheries observers to collect data on areas fished, catch rates and species composition.
Seychelles	Exploratory trapping for deep-water shrimps *Heterocarpus* spp.	Historical and recent exploratory fishing. ***Recommendation:*** Deployment of fisheries observers to collect data on areas fished, catch rates and species composition.
La Réunion	Exploratory trapping for deep-water shrimps *Heterocarpus* spp.	Historical and recent exploratory fishing. ***Recommendation:*** Deployment of fisheries observers to collect data on areas fished, catch rates and species composition.
SWIO region	Cost and benefits of undertaking deep-water trapping surveys	SWIOFP undertook three deep-water trapping surveys (Mozambique, Tanzania and Kenya), and all of them returned unsatisfactory results, at a high financial cost to the project. Deep-water trapping is a specialized fishing method that relies on vessels that are specifically rigged to set and haul long-lines with multiple (up to 200) traps attached to each line. It requires a line-hauler, storage space for large numbers of traps, and a deck layout that facilitates a rapid turn-around time between hauling a line, removing catches and cleaning traps, rebaiting, and resetting. It requires a large vessel (normally 35-50m LOA) and is labour intensive (crew complement of 25-35). Long-line trapping vessels are scarce in the SWIO, and expensive to lease. Most importantly, however, is that the skipper and crew need to be highly experienced to make the system work effectively, especially in unknown areas, where gear can easily be lost. The vessels available to SWIOFP were unsuitable for the task. The skippers and crew were inexperienced, and lost much of the gear at sea. The scientists on-board were inexperienced, and not able to implement the survey plan. ***Recommendation:*** The potential benefits of deep-water trapping surveys undertaken and funded solely by scientific programmes are heavily outweighed by their cost. Such surveys should only be undertaken in partnership with commercial fishing companies, so that the cost of leasing vessels, equipment and an experienced crew can be offset against the commercial value of the catch.

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Annex:

Metadata: South African long-line trap-fisheries; Kenya trap fishery.

Database Identifier	***ZAF-D001***	***ZAF-D002***	***ZAF-S003***	***ZAF-S004***	***KEN-001***
Dataset name	South coast rock lobster commercial catch and effort, sampling and tagging data	South coast rock lobster - Observer data	KZN deep-water trapping survey 2004-2007	KZN deep-water trapping survey 1993-1997	Kenya long-line crab catches on the MV Golden Wave in 2010
Country or regional body	ZAF-South Africa	ZAF-South Africa	ZAF-South Africa	ZAF-South Africa	KEN-Kenya
Responsible agency	Dept. Agriculture, Forestry and Fisheries	Dept. Agriculture, Forestry and Fisheries	Dept. Agriculture, Forestry and Fisheries	Dept. Agriculture, Forestry and Fisheries	Fisheries Department, Kenya
Source of information	Fishing logbook	Onboard observers	Wet-leased commercial vessel	Wet-leased commercial vessel	Fishing logbook
Juridictional scale	National	National	National	National	National
Nature of the data	Effort Catch Size composition Biological data	Effort Catch Size composition Biological data	Effort Catch Size composition Biological data	Effort Catch Size composition Biological data Tagging	Effort Catch
Gear type	Longline with traps	Longline with traps	Longline with traps	Longline with traps	Longline with traps
Target species	Spiny lobsters	Spiny lobsters	Spiny lobsters Slipper lobsters Crabs	Spiny lobsters Slipper lobsters Crabs	Crabs
Biological data	Size composition Sex & maturity	Size composition Sex & maturity	Species composition; Sex & maturity; Lengths and (or) weight; Genetics	Species composition; Sex & maturity; Lengths and (or) weight	None
Physical data	Depth	Depth	Depth; Wind speed & direction; Current speed & direction; Substrate	Depth	Position
Type of dataset	Raw data	Raw data	Raw data	Raw data	Raw data
Status of data	Data checked and published	Data checked but not published	Data checked and published	Data checked and published	Unchecked data
Data medium	Paper and digitized	Paper and digitized	Paper and digitized	Paper and digitized	Digitized data
Digital medium	Hard disk	Hard disk	Hard disk	Hard disk	Hard disk
Operating system	Unix	Windows XP	Windows XP	Windows NT	Windows XP
Data base software	Oracle	Excel	Access	Sybase	Excel
Digital format		Excel	Access		Excel
Temporal coverage	1977/09/27 - current	2001 - current	2004/05 - 2007/11	1993/06/15 - 1996/08/31	2010/02/20- 2010/10/08
Temporal resolution	Trip	Trip	Irregular	Trip	Day
Spatial coverage	Territorial sea	Territorial sea	Territorial sea	Territorial sea	Territorial sea
Spatial resolution	Other	Other	Survey site	Survey site	Other
Spatial extent	33-37oS; 18-28oE	33-37oS; 18-28oE	24-33°S; 29-36°E	27-32°S; 29-36°E	01-03°S; 40-42°E
Locality	Dept. Agriculture, Forestry and Fisheries	Dept. Agriculture, Forestry and Fisheries	Oceanographic Research Institute	Dept. Agriculture, Forestry and Fisheries	Fisheries Department, Kenya
Language	English	English	English	English	English
Comments	Source of information: log book, observers, research vessels. Spatial resolution=10x10 nautical mile blocks	Source of information: Fisheries Observers. Spatial Resolution=10x10 nautical mile blocks	Database includes Mozambican information for 2005. Data stratified by depth and latitude.	Source of information: Fisheries observers, logbook. Data stratified by depth and latitude.	Limited data, unchecked

Metadata: Mozambique long-line trap fisheries.

Database Identifier	MOZ-D301A	MOZ-D302A	MOZ-D303	MOZ-999	MOZ-998	MOZ-997
Dataset name	Industrial deep-water lobster trap fishery 1980-1984	Industrial deep-water lobster trap fishery 1986-2000	Industrial deep-water lobster trap fishery - biological sampling 1980-1984 & 1986-2000	Deep-water trapping survey 2005	Deep-water trapping survey 2010	Experimental trap-fishery for crabs
Country or regional body	MOZ-Mozambique	MOZ-Mozambique	MOZ-Mozambique	MOZ-Mozambique	MOZ-Mozambique	MOZ-Mozambique
Responsible agency	IIP	IIP	IIP	IIP	IIP	IIP
Source of information	Fishing logbook	Fishing logbook	Port sampling; Observer sampling at sea	Wet-leased commercial vessel: MFV Cape Flower	Wet-leased commercial vessel: MFV Rio Sainhas	Fishing logbook
Jurisdictional scale	National	National	National	Regional with South Africa	National	National
Nature of data	Effort (traps set); Catch	Effort (traps set); Catch	Biological data	Effort Catch Size composition Biological data	Effort Catch Size composition Biological data	
Gear type	Longline with traps	Longline with traps	Longline with traps	Longline with traps	Longline with traps	Longline with traps
Target species	Spiny lobsters	Spiny lobsters	Spiny lobsters	Spiny lobsters Slipper lobsters Crabs	Spiny lobsters Slipper lobsters Crabs	Deep-sea red crabs
Biological data	No	No	Size composition Sex & maturity	Species composition; Sex & maturity; Lengths and (or) weight; Genetics	Species composition; Sex & maturity; Lengths and (or) weight; Genetics	
Physical data	Depth and area	Depth and area	Depth and area	Depth; Wind speed & direction; Current speed & direction; Substrate	Depth and area	
Type of dataset	Data checked and published	Data checked and published	Data checked and published	Data checked and published	Data checked and published	Raw data
Status of data	Data checked and published	Data checked and published	Data checked and published	Data checked and published	Data checked and published	
Data medium	Paper and digitized	Paper and digitized	Paper and digitized	Paper and digitized	Paper and digitized	
Digital medium	Hard disk	Hard disk	Hard disk	Hard disk		
Operating system				Windows XP		
Data base software				Access		
Digital format				Access		
Temporal coverage	1980-1984	1986-2000	1980-1984 & 1986-2000	2005	2010	2009-2011
Temporal resolution	Trap soaktime in hours	Trap soaktime in hours	No	Trap soaktime in hours	Trap soaktime in hours	
Spatial coverage	Territorial Sea	Territorial Sea	Territorial Sea	Territorial sea	Territorial sea	Territorial sea
Spatial resolution	Fishing area	Fishing area	Fishing area	Survey site	Survey site	Fishing area
Spatial extent	17-26°S; 32-36°E	17-26°S; 32-36°E	17-26°S; 32-36°E	24-33°S; 29-36°E	21-37°S; 33-36°E	
Locality	IIP	IIP	IIP	IIP & Oceanographic Research Institute	IIP	IIP
Language	English/Portuguese	English/Portuguese	English/Portuguese	English	Portuguese	Portuguese
Comments	Four fishing area are: Bazaruto A & B; Boa Paz; Inhaca	Four fishing area are: Bazaruto A & B; Boa Paz; Inhaca	Four fishing area are: Bazaruto A & B; Boa Paz; Inhaca	Database includes South African information for 2004-2007. Data stratified by depth and latitude. Inhaca and Boa Paz fishing grounds	Data stratified by depth and latitude. Inhaca and Boa Paz fishing grounds	

5.
PELAGIC FISHERIES

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Previous page: A yellowfin tuna caught on longline is hauled on board. Photo by Gareth Jordaan.

5. PELAGIC FISHERIES

A retrospective analysis of their status in the Southwest Indian Ocean

Kevern Cochrane[1] and Dave Japp[1]

Abstract

This Retrospective Analysis relates to the assessment of pelagic fisheries in the Southwest Indian Ocean undertaken as part of the Southwest Indian Ocean Fisheries Project, SWIOFP. In this study "pelagic" is divided into three basic groups: *Large*, *Medium* and *Small*, reflecting the wide range in size and life history of pelagic fishes. The methodology involved interrogation of key databases including national fisheries reports, submissions to the SWIOFC scientific committee as well as four regional and international sources of data: WIOFish, StatBase, FAO and IOTC. Additional information was sourced from the fisheries independent surveys and the literature.

Reported landings of large pelagics across the SWIO region increased substantially after the 1980s, stabilising in recent years. Highest catches of large pelagics were skipjack tuna (*Katsuwonis pelamis*) and yellowfin tuna (*T. albacares*), each at approximately 50,000t in 2010, followed by bigeye tuna (*Thunnus obesus*) at approximately 10,000t. Catches of other large pelagics were considerably lower with those of swordfish (*Xiphias gladius*) and Indo-Pacific sailfish (*Istiophorus platypterus*) at less than 2,000t in 2010. For medium pelagics, the IOTC and FAO databases provide the most useful information, albeit incomplete. The importance of the Scombridae is highlighted with *Scomberomorus spp*. catches for the region at over 9,000t in 2010. Other species with relatively high catches included *Euthynnus affinis*, with much lower levels of *Auxis thazard*, *A. rochei*, *Coryphaena hippurus*, *Carangoides fulvoguttatus* and *C. gymnostethus*. In some cases medium pelagic carangids are reported only as Carangidae and have thus been included as small pelagics.

Research surveys indicated high concentrations of clupeoid fishes, including *Sardinella gibbosa*. In contrast, the databases document lower harvests, the most important at the regional level being the Indian mackerel *Rastrelliger kanagurta*, as well as a suite of other species reported by individual countries including *Scomber japonicus*, *Trachurus delagoae*, *Decapterus macarellus* and the sardines *Dussumieria acuta*, *Sardinella abdella* as well as *Hilsa kelee*.

In most cases the data are inadequate to reliably assess stock status, with the exception of the key large pelagics monitored by IOTC. In general, those stocks are in reasonable condition with the exception of *T. alalunga* and *X. gladius*, which are overfished. However, the status of several important large pelagic species remains uncertain, including *T. tonggol*, *I. platypterus*, *Makaira nigricans* and *M. indica*, and *Tetrapturus audax*. Individual country reports to SWIOFC indicate that populations of coastal tunas and related species in the SWIO countries are largely under- or moderately exploited. Similarly, most small pelagics were reported as underexploited except in several cases of overexploitation reported by Mozambique, Kenya and Tanzania.

The biological characteristics of a number of key species are described based on FishBase (2012) and the FAO Aquatic Species Fact Sheets (FAO ASFS, 2012), as well as the literature. It is concluded that none of the regional databases provide adequate information with which to reliably estimated catches and assess stock status of pelagic species in the SWIOFP region as a whole.

Introduction

Increasing coastal populations in SWIO countries and use of new technology (more sophisticated fishing gear and motorised vessels for example) have increased the fishing effort on the marine resources significantly in the last decades (since the 1960s at least). A new development has been the industrialisation of the offshore fisheries – in particular the use of large scale commercial operations targeting tuna and other large pelagic resources using primarily longlines and purse seine vessels. The target areas of these large scale commercial operations are the high seas. They are also licensed by

1. CapFish Consulting, Cape Town. www.capfish.co.za.

the coastal states to fish inside the national Exclusive Economic Zones (EEZs or also referred to in this report as the economic fishing zones). The target species in the Indian Ocean were initially the highly valuable tuna for the Asian and global sashimi markets including yellowfin (*Thunnus albacares)* and bigeye tuna (*Thunnus obesus)* as well as the albacore, also called longfin, tuna (*Thunnus alalunga)* and the broadbill swordfish (*Xiphias gladius).* Further, as in all other tropical oceans, the smaller tunas are targeted using large purse seine vessels, in particular skipjack (*Katsuwonus pelamis)* and kawakawa (*Euthynnus affinis).* The fishery for these pelagic species has changed in the last decade as stocks of the preferred species have declined and increasing fishing pressure has been put on the many lesser known pelagic species, including mackerels, billfishes and shark.

Fundamental to the commercial potential and dynamics of the pelagic stocks in the SWIO is an understanding of the migratory patterns of the pelagic species, as unlike the demersal species, many pelagic species undertake extensive migrations, which can be around the whole Indian Ocean or in only a part of it. Also important is that the extent of these migrations varies between species. Most of the catches of small and medium pelagic species are variable but form an important part of the harvest by artisanal fishers in the region. There is also increasing pressure by both the artisanal and coastal fishers to move further offshore, thereby increasing the fishing pressure on these stocks from both the high seas and territorial (from the coast to 12 nautical miles offshore) fishing sectors. The development of anchored Fish Aggregating Devices (FADs) in the region has been one of the means for artisanal fishers to have greater access to and a share of the pelagic resource, in particular the large pelagics. It is important that the influence of FADs on the amount and species and size composition of catches must be included in the assessments and management plans for IOTC to avoid increasing the risk of over-exploitation.

OBJECTIVES

The goal of this study is not to undertake a rigorous stock assessment but to provide a broad overview on the stock trends based on the available information. A second output of this Retrospective Analysis is to evaluate the usefulness of the available data to provided information that can be used to assess the different species and stocks.

This study covers the countries of Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania and considers only the species in the SWIO defined as "pelagic". Pelagic species are species found near the surface or in the water column but not on or near the seafloor; they undertake both horizontal and vertical migrations and are mostly aggregating species. Pelagic species can be targeted by any number of fishing gears, including purse seines, gill nets, hook and line and midwater trawl. For the purpose of this study the pelagic species of most interest in the Indian Ocean are divided into three basic groupings – Large, Medium and Small (Table 1).

Table 1. "Pelagic" species and categories as defined by the SWIOFP Gap Analysis, Including their StatBase codes.

Code	*Common Name*	*Scientific Name*	*Family*
LARGE PELAGICS			
SKJ	Skipjack tuna	*Katsuwonus pelamis*	Scombridae
ALB	Albacore	*Thunnus alalunga*	Scombridae
SBF	Southern bluefin tuna	*Thunnus maccoyii*	Scombridae
YFT	Yellowfin tuna	*Thunnus albacares*	Scombridae
BET	Bigeye tuna	*Thunnus obesus*	Scombridae
LOT	Longtail tuna	*Thunnus tonggol*	Scombridae
SFA	Indo-Pacific sailfish	*Istiophorus platypterus*	Istiophoridae
BUM	Blue marlin	*Makaira nigricans*	Istiophoridae
BLM	Black marlin	*Makaira indica/mazara*	Istiophoridae
MLS	Striped marlin	*Tetrapturus audax*	Istiophoridae
SWO	Swordfish	*Xiphias gladius*	Xiphiidae
MEDIUM PELAGICS			
LTD	Indian threadfish	*Alectis indicus*	Carangidae
FRI	Frigate tuna	*Auxis thazard*	Scombridae
NGH	Longnose trevally	*Carangoides chrysophrys*	Carangidae
NGU	Yellowspotted trevally	*Carangoides fulvoguttatus*	Carangidae
NGY	Bludger	*Carangoides gymnostethus*	Carangidae
NGS	Malabar trevally	*Carangoides malabaricus*	Carangidae
NXH	Blacktip trevally	*Caranx heberi*	Carangidae
NXI	Giant trevally	*Caranx ignobilis*	Carangidae
NXM	Bluefin trevally	*Caranx melampygus*	Carangidae
CXS	Bigeye trevally	*Caranx sexfasciatus*	Carangidae
DOL	Dolphinfish/dorado	*Coryphaena hippurus*	Coryphaenidae
RRU	Rainbow runner	*Elagatis bipinnulata*	Carangidae
KAW	Kawakawa	*Euthynnus affinis*	Scombridae
BIP	Striped bonito	*Sarda orientalis*	Scombridae
COM	Narrow-barred Spanish/king mackerel	*Scomberomorus commerson*	Scombridae
SMALL PELAGICS			
BAF	Flat needlefish	*Ablennes hians*	Belonidae
AGS	Spotted sardinella	*Amblygaster sirm*	Clupeidae
MSD	Mackerel scad	*Decapterus macarellus*	Carangidae
DCC	Shortfin scad	*Decapterus macrosoma*	Carangidae
RUS	Indian scad	*Decapterus russelli*	Carangidae
RAS	Rainbow sardine	*Dussumieria acuta*	Dussumieridae
	Spotback herring	*Herklotsichthys puntatus*	Clupeidae
HES	Bluestripe herring	*Herklotsichthys quadrimaculat*	Clupeidae
HAS	Torpedo scad	*Megalaspis cordyla*	Carangidae
RAG	Indian mackerel	*Rastrelliger kanagurta*	Scombridae
SDB	White sardinella	*Sardinella albella*	Clupeidae
CHP	South American (African) pilchard	*Sardinops sagax*	Clupeidae
MAS	Chub mackerel	*Scomber japonicus*	Scombridae
BIS	Bigeye scad	*Selar crumenophthalmus*	Carangidae
TUD	African scad	*Trachurus delagoa*	Carangidae

Broadly these three groupings are interpreted as follows:

Large pelagic species: mostly the primary species of international importance and managed by the Regional Fisheries Management Organisations (RFMOs), which is the Indian Ocean Tuna Commission (IOTC) for the Indian Ocean. Includes the *Thunnus* species and billfishes.

Figure 1. Large pelagic species: yellowfin tuna (left) and broadbill swordfish. (Photos: David Japp)

Medium pelagic species: mostly the larger mackerels *(S. commerson* & *A. solandri)*, the kingfishes (*Caranx* sp. & *Carangoides* sp.) and dorado (*C. hippurus).*

Figure 2. Species classified as "medium" pelagic species include from left to right: kingfishes (Carangidae), kawakawa and Spanish/king mackerel. (Photos: David Japp)

Small pelagic species: small shoaling anchovy-like species, sardinellas, small mackerels (jack mackerels) and chub mackerel. These species are commonly caught by coastal fishers, often at night with purse nets and gill nets. In most cases they are a staple food source and may also be used for animal feed. These species are also the primary source of bait for many fisheries, in particular live bait for the large pelagic tuna pole and line fisheries.

Figure 3. Small pelagic species (Mafia Island – Tanzania) referred to as dagaa (anchovies, jack mackerels, sardinellas and halfbeaks). (Photos: David Japp)

METHODOLOGY

The approach to this study was desk-top and included:

i. Reviewing available literature and historical information of pelagic fisheries and fish species in the SWIO region.
ii. Accessing and interrogating the known data and metadata sets and databases.
iii. Spatial and temporal trends in fishing effort, catches, and catch rates were extracted from historical data.
iv. Basic biological parameters describing average size, sex ratios, size at sexual maturity, growth and mortality rates, fecundity, and reproductive activity for priority species.
v. Assessment of the state of key pelagic species.

Review of available knowledge and information

A Regional Gap Analysis for pelagic fisheries preceded this study and identified relevant regional metadata (SWIOFP 2009). This included fisheries dependent metadata sets compiled by IOTC, FAO and WIOFish. In addition, Romanov (2012) reports on a survey of fisheries' independent historical data sets derived from earlier fisheries research and exploratory cruises undertaken in the SWIO region. In this retrospective analysis these regional metadata, together with other sources of data and information are discussed.

The following databases are particularly important repositories of fisheries data in the region (see Chapter 1):

a. The WIOFish database was accessed in 2011, thus reflecting information for the year 2010, which lists 69 different fisheries that catch SWIOFP priority pelagic species in the eight countries included in this Retrospective Analysis (WIOFish 2011). This includes eight distinct fisheries in each of Kenya, Madagascar, Mauritius and South Africa, nine each in Mozambique and in the Seychelles, and ten fisheries each in Comoros and in Tanzania.

b. StatBase was developed by the French *Institute of Research and Development* (IRD) for the analysis of statistical fisheries data and adapted for SWIOFP. The following datasets were interrogated as they contain information on catches by species of higher taxonomic level that include pelagic species:
   - Comoros Artisanal Fisheries (Dataset 49)
   - Kenya Artisanal Fishery (Dataset 145)
   - Madagascar Peche aux poissons
   - Mauritius Coastal Fishery (Mus-3)
   - Mozambique Sport fishery
   - Seychelles Artisanal Fishery (Dataset 47)
   - Seychelles Industrial Longline Fishery (Dataset 204)
   - South Africa KwaZulu-Natal Industrial Fisheries (Table 103)
   - Tanzania Artisanal Fishery (Dataset 199)
   - Tanzania Industrial Fishery (Dataset 198)

c. FAO is a repository for national and regional information on fisheries catches that can be accessed through FishStat[2], a software package with the following datasets relevant to this analysis: Total Fishery Production

1950-2010; Capture Production 1950-2010; and Fisheries Commodities Production and Trade 1976-2009. The capture data available from FAO for the eight countries included in this study were examined and note was taken of the analyses undertaken on this database at the FAO/SWIOFC Working Group on small pelagic and demersals held in Mombasa, Kenya from 11-15 October 2010 (FAO SWIOFC 2011).

d. The principal regional management organisation with the mandate to manage tuna and tuna-like species in the Indian Ocean and adjacent seas, is the Indian Ocean Tuna Commission, as outlined in Chapter 1. IOTC undertakes regular, comprehensive stock assessments of most of the key resources of tuna and tuna-like species, For surface fisheries, catch weight by species is provided by 1° grid area and month strata, for longline fisheries these data are provided by 5° grid area and month strata, while for coastal fisheries data may be provided using an alternative geographical area if it represents the fishery concerned better than the grid areas.

e. The Southwest Indian Ocean Fisheries Commission (SWIOFC) is a regional body established under the auspices of FAO to promote the sustainable utilization of the living marine resources of the region. While it does not collate or host databases, its Scientific Committee reports regularly on the status of fishery resources. Such reports have been used as sources of information for this Retrospective Analysis.

National fishery databases, trends and biological information

The regional gap analysis, SWIOFP (2009), identified national datasets that were relevant to pelagic fishes and fisheries. These datasets contain information on historical catches, fishing effort and biological information obtained from fishing logbooks and sampling programmes, including from on-board observer programmes, fishery surveys and research vessels. However, it was also concluded that most of these datasets were of moderate use because of their limited reporting period and inadequate verification (SWIOFP 2009).

2. http://www.fao.org/fishery/statistics/software/fishstat/en

Country profiles

The following section provides a synopsis of pelagic fisheries for each of the SWIO countries. A diversity of data sources have been used with a focus on regional databases, supplemented by national and additional information where possible, including Baseline Reports for the pelagic fisheries of Kenya (Maina 2012) and Tanzania (FDD, Tanzania, 2012).

COMOROS

The WIOFish database for 2010, contains information on ten different fisheries in Comoros that report catches of SWIOFP priority pelagic species.

- Hook & line, drift line, fish
- Hook & line, handline, fish
- Hook & line, longline surface, tuna
- Hook & line, small boat & motor, night fishing with lamps
- Hook & line, trolling, fish, vertical lines, fish
- Industrial nets, purse seine, tuna
- Small nets, drift nets, fish
- Small nets, gill nets surface, fish
- Small nets, seine, tuna (local)

StatBase only lists data from a single fishery collectively named as “artisanal” and just for 1994. The following pelagic species or taxonomic groups are listed as having been caught: albacore, Carangues (including longfin yellowtail *S. rivoliana*, rainbow runner *E. bipinnulata*, and doublespotted queenfish *S. lysan*), common dolphin fish (Coryphéne), Large Pelagics (defined in this particular dataset as including *A. thazard* and *A. rochei*, kawakawa, bigeye tuna, *A. solandri, S. commerson, S. barracuda* and *Sphyraena* spp.), skipjack tuna (Listao), Small Pelagics (including *S. crumenophthalmus, Sardinella* spp, *Decapterus* spp, *Hemiramphus* spp), and Indo-Pacific sailfish (Voilier). Albacore and skipjack tuna dominated the catches in 1994, followed by Large Pelagics and Small Pelagics (Figure 4).

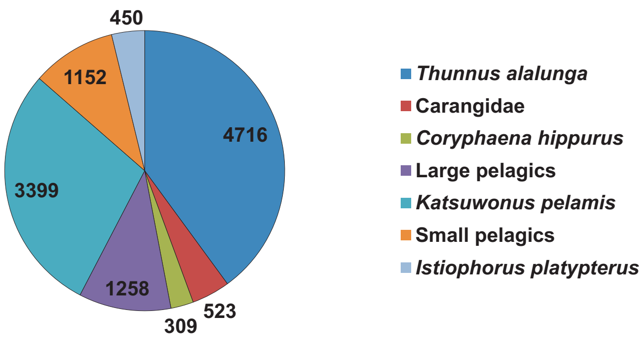


Figure 4. The annual catch (tonnes) for 1994 by the Comoros Artisanal Fishery as recorded in StatBase.

The IOTC Nominal Catch database includes catches recorded by species from the Comoros for the period 1950-2013. Catches are reported for handline, troll line and ‘Other UNCL’. Species caught with these gears include yellowfin tuna, bigeye tuna, skipjack tuna, Indo-Pacific sailfish, billfish *nei,* kawakawa, seerfishes *nei* and tuna-like fishes nei. Of these, yellowfin and skipjack tuna have clearly dominated the recorded catches (Figure 5).

FAO FishStat contains landings from 1950-2012 for the following species and taxonomic groups (Figure 6): Carangidae, Engraulidae, *E. affinis, I. platypterus K. pelamis, Rastrelliger* spp., *Sardinella* spp., *Scomberomorus* spp., *T. albacares* and *T. obesus*. The catches of pelagic species by Comoros fishers reported to FAO are dominated by large pelagic species, in particular *K. pelamis* and *T. albacares.* Engraulidae and *Sardinella spp.* are the most abundant species of small and medium pelagics with reported catches of approximately 1,000t in recent years, followed by *Scomberomorus spp.* which reached approximately 800t in 2010.

At the 4th Session of the SWIOFC Scientific Committee in Seychelles, the Comoros delegation confirmed the lack of fisheries data since 1994 (FAO, 2011). However, at the 5th Session in Cape Town, information was presented on the status of their fishery resources, confirming them to be exclusively artisanal and exploiting mostly pelagic species, in particular tunas. The fishery annual production was reported to be almost 16,000t with a commercial value of approximately EUR 28M[3]. Citing a publication by Youssouf & Naji (2007), it was also reported that the potential sustainable production of its marine resources had been estimated at 33,000t and that only 64% of that potential production was being taken at that time (Ibrahim Mohamed Toihir, unpublished presentation to SWIOFC). Failler (2011) reported that FAD fishing also takes place in the Comoros.

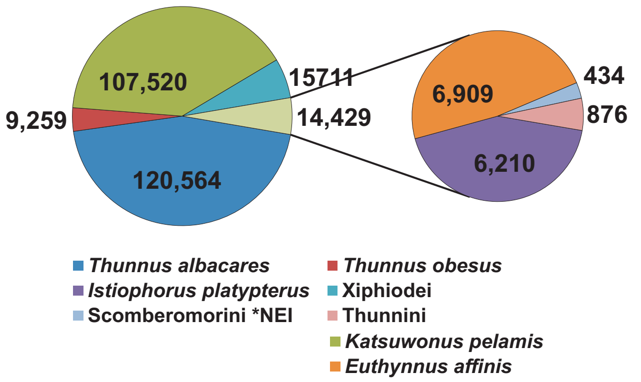
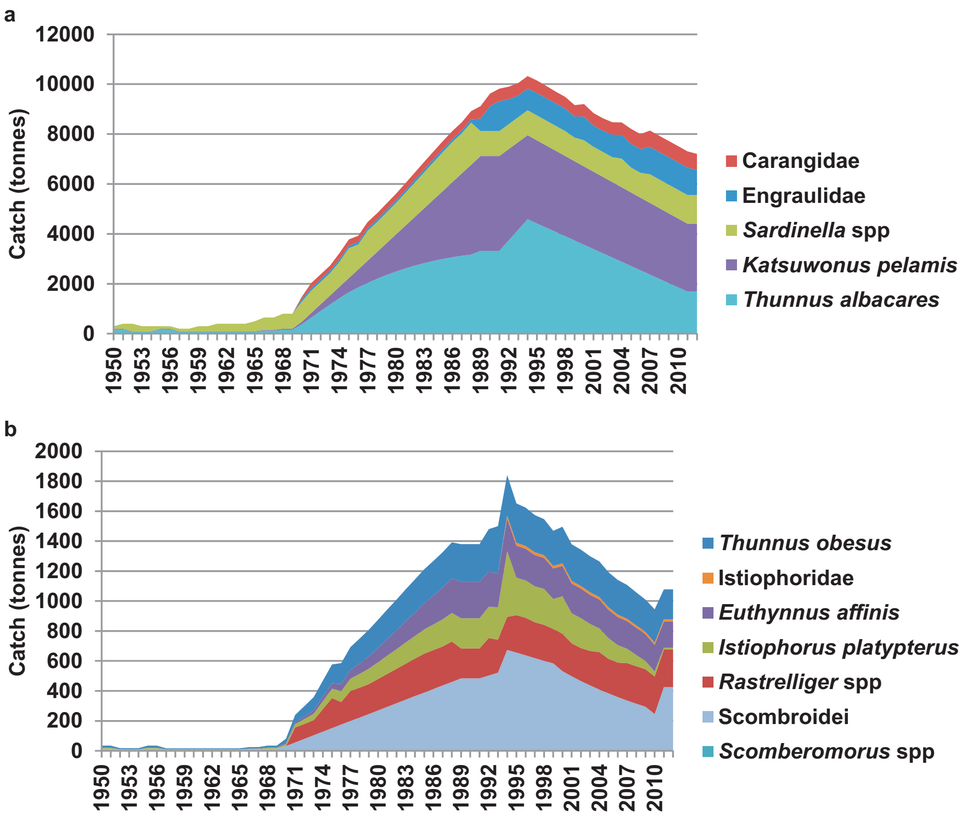


Figure 5. Composition of catches reported to IOTC by Comoros. Aggregated Total 1950-2013 (tonnes).

Figure 6a & b. Catches of pelagic species reported to FAO by Comoros (tonnes).



3. State of fisheries resources of Union of the Comoros. Unpublished powerpoint presentation made at the 5th Scientific Committee in Cape Town, South Africa in March 2012.

KENYA

The WIOFish database contains information on eight different fisheries in Kenya that report catches of SWIOFP priority pelagic species.

- Hook & line, longline – surface, pelagic (Ind)
- Hook & line, longline – surface, pelagic (Art)
- Hook & line, trolling, fish/sharks/rays
- Industrial nets, inshore, prawns
- Industrial nets, purse seine, tuna
- Large nets, reef seine, fish
- Large nets, ring nets, fish
- Small nets, surface gill net, sharks/rays/fish

StatBase lists data including information on pelagic species from the following fisheries (in years and pelagic species recorded on each file shown in brackets):

- Artisanal (1990-2008: *C. hippurus, R. kanagurta, K. pelamis, E. affinis, I. platypterus*, as well as the blacktip sardinella, *Sardinella melanura* which is not included as a SWIOFP priority species) (Figure 7).
- Sportfishing (1987-2006: total catch only)
- Industrial Register (2004, number and characteristics of vessels listed as catching yellowfin or bigeye tuna).

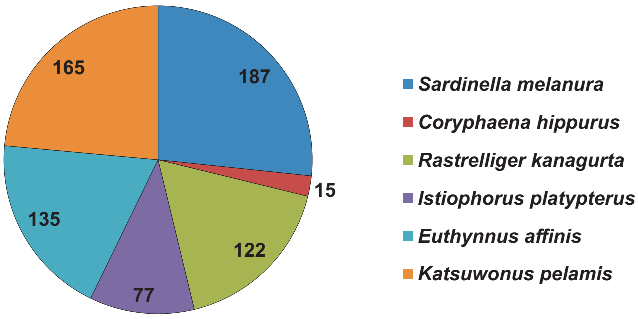


Figure 7. The average annual catch (tonnes) for the period 1990-2008 by the Kenya Artisanal Fishery as recorded in StatBase.

The IOTC Nominal Catch database includes catches for gillnet, handline, troll line, longline (targeting swordfish) and 'others UNCL' gear from Kenya for the years 1975-2013. The species caught are: yellowfin tuna, bigeye tuna, skipjack tuna, albacore, swordfish, blue marlin, black marlin, striped marlin, Indo-Pacific sailfish, short-billed spearfish, spanish mackerel, wahoo, seerfishes *nei,* tunas and bonitos *nei,* and Tuna-like fishes nei. Of these, the narrow barred Spanish mackerel made up the largest portion of catches during this period, followed by Indo-Pacific sailfish, seerfishes *nei* , and yellowfin tuna (Figure 8).

The data reported to IOTC include the catches by artisanal fisheries (Ndegwa & Sigana, 2010), which consist of multigear fleets of locally manufactured vessels (Wekesa & Ndegwa, 2011). In the Kenya Annual Report of 2011, Wekesa & Ndegwa (2011) reported that the tuna fisheries in Kenya play an important role in the socio-economic development of the country. The artisanal fisheries produced landings of 180t of tuna in 2010, the local longline fishery 137t and the recreational fishery for tuna and billfishes landed 60t.

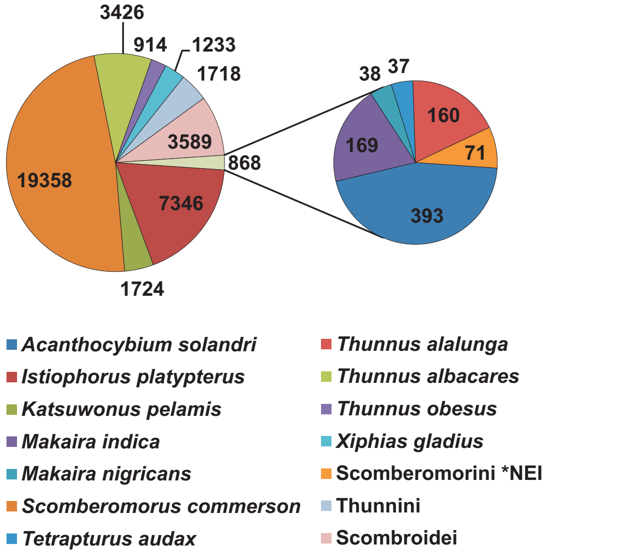
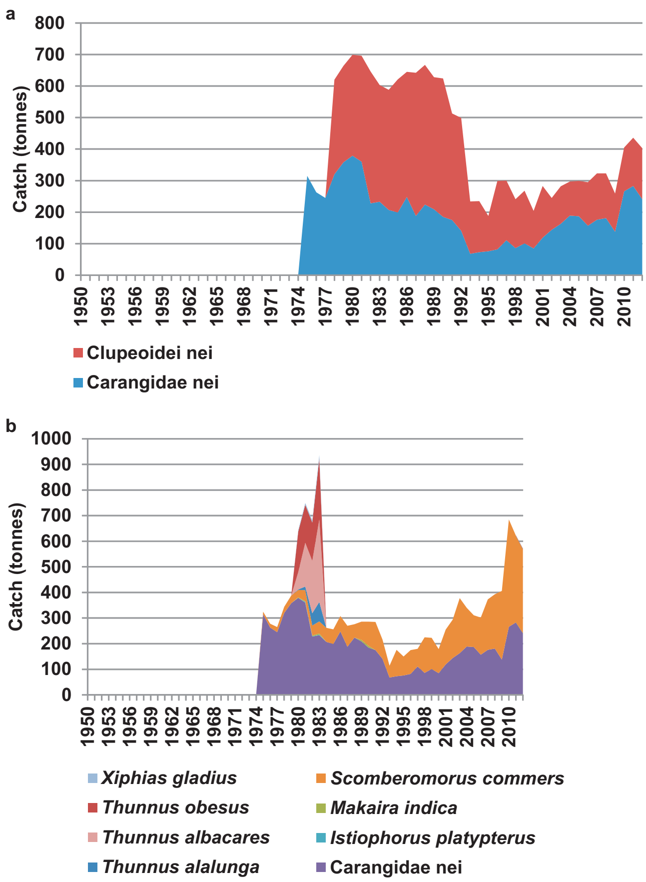


Figure 8. Species composition of catches reported to IOTC by Kenya. Aggregated Total 1975-2013 (tonnes).

FAO FishStat contains landings from 1950-2012 for Kenya for the following (Figure 9): Carangidae, Clupeoidei, *I. platypterus K. pelamis, M. indica, S. commerson, T. alalunga, T. albacares, T. obesus and X. gladius.* For medium and small pelagics the records are aggregated into the two groups: Carangidae and Clupeoidei. The former show a peak of nearly 400t in 1980 after which they declined to 68t in 1993 before starting to increase again, reaching 266t in 2010. Catches of

Figure 9 a & b. Catches of pelagic species by Kenya fisheries in the western Indian Ocean, as reported to FAO, 1950-2012.



Clupeodei were also higher in the 1980s and early 1990s, peaking at 454t in 1987, and then declining but they have remained relatively low since then and fluctuated between about 100 and 150t from 2000 to 2010. These trends are likely to be influenced by the declining effort in the number of artisanal fishers in the late 1990s referred to in Maina (2012) as discussed below.

The delegation of Kenya reported to the 5th Scientific Committee in Cape Town, South Africa in March 2012 that the total annual catch from the artisanal fishery in that country was estimated to be about 8,000t (FAO SWIOFC, 2012). The fishery is multi-species and multi-gear and data collection from it is a major challenge. It was reported that catch data exist for the following pelagic species or fisheries: "artisanal pelagics (excluding tunas and bonitos), sardines (small pelagics), and artisanal tuna and tuna-like species". For the coastal tunas and related species (artisanal tunas), the catch for 2010 was estimated to be 157t and the status of these stocks uncertain. The catch of artisanal pelagics excluding tunas and bonitos was estimated to be 2,107t in 2009 and the resources to be under-exploited. However, these stocks are shared and straddling stocks and national assessments may not reflect the true status of the stock as a whole. The catch of sardines (small pelagics) was estimated as 195t in 2010 and the resource was considered to be fully exploited. The delegation also reported that the sport fishery caught an estimated 318t of pelagic species in 2009 and that the resources were under-exploited (Cosmas Munga, Stephen Ndegwa, Renison Ruwa and Harrison Ong'anda, unpublished presentation to SWIOFC Scientific Committee). In addition to the information available from the above sources, the Fisheries Annual Statistical Bulletin 2010 (Fisheries Department Kenya, 2010) reported that in that year a total of 8,406t of assorted fish species was landed by the national marine artisanal fishery. This was an increase of 6.1% from the production of the previous year but this probably does not indicate a trend as annual landings from the artisanal fishery have tended to follow a cyclical pattern. In 2010, the pelagic fish category made up 2,344t or 28% of the total landings while demersal species dominated with approximately 50% of the landings; the remainder consisting of sharks, rays and sardines (9%), molluscs (7%) and crustaceans (6%).

A baseline review of the fisheries for small and medium pelagic species by Maina (2012) provides additional valuable information on the data available and trends in those fisheries. Of particular relevance is his reference to and reporting on Fisheries Department catch data and data from the Fisheries Department frame surveys of 2004, 2006 and 2008[4]. He also states that the Kenya Fisheries Department started to collect sport fishing data in the 1940s and that digitisation of these data started in 2006. He notes that under-reporting is a problem and that further improvements in the sport fishery statistical records are required. Using information from the Kenyan Fisheries Department catch database, Maina (2012) analysed the trends in catches of pelagic species. He reported that the pelagic fishery accounted for an average of 27% of the annual production for Kenya's marine fisheries during the two decades from 1990 to 2010. During this period catches from the pelagic fisheries varied between just less than 1,000t to just over 2,000t (mean 1,843 ± 128.4t) but showed an increasing trend from 1993 to 2010. Maina further reports that the annual pelagic fish production between 1978 and 1981 fluctuated between 997t and 1,150t. The small pelagic fisheries contributed between 429 and 1,290t and the medium pelagics fishery between 347 and 1,357t to these catches during the same period, representing a combined total of 85.4% of the pelagic fishery catches (Figure 10). Records from the Kenyan sport fishery presented by Maina (2012) are summarised in Figure 11. These are shown at the taxonomic level of family in contrast to the single aggregate figures presented in StatBase.

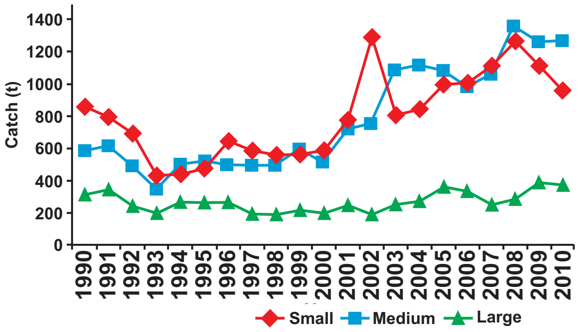


Figure 10. Annual yield of marine artisanal small, medium and large pelagic fishery, 1990 to 2010. Small pelagic fishery = 43.3%, medium pelagic fishery = 42.1% and large pelagic fishery = 14.6% (Maina 2012, Data source: FiD).

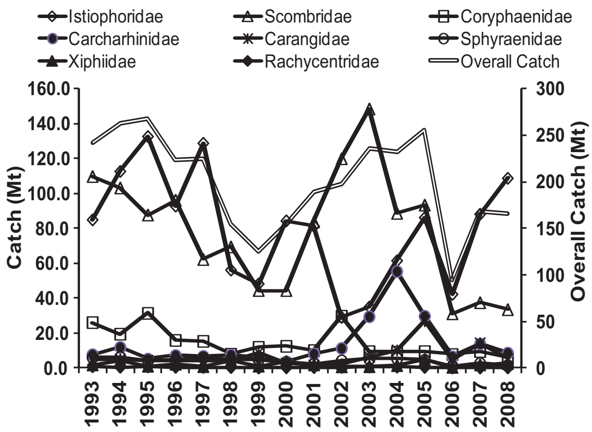


Figure 11. Trends in sport fishery landings by family, 1993-2008. Total catch annual average = 206 ± 14.01t (SE), maximum = 318t, minimum = 94t. (Reported in Maina 2012 as coming from Fig 12 of Ndegwa & Sigana 2010).

4. References and Datasets Containing Pelagics Information Referred to by Maina 2012. i) FiD 2008 – Fisheries Department. (2008). Frame survey report. Ministry of Fisheries Development, Kenya. Provincial Headquarters, Mombasa, 143 pp. ii) Okwemwa G, Kimani E, Fondo E, Agembe S, Munga C, Aura C. 2009a. Status of artisanal fisheries at the Kenyan coast: 2001-2008. Mombasa: KMFRI Unpublished report. 19pp. iii) FiD Marine fisheries frame surveys 2004, 2006, 2008. iv) Fisheries department catch data. v) Wakwabi E, Abila RO, Mbithi ML. 2003. Kenya Fish Sub-sector: Fish Sector Development strategy for Kenya. Consultancy Report for the International Trade Centre/ United Nations Conference on Trade And Development/ WTO Joint Integrated Technical Assistance Program to Least Developed and Other African Countries. Kenya Dept. of Fisheries/Assoc. of Fish Processors and Exporters of Kenya. Nairobi. (Final draft). vi) Ndegwa and Sigana 2010. vii) Ndegwa 2011.

MADAGASCAR

The WIOFish database contains information on eight different fisheries in Madagascar that report catches of SWIOFP priority pelagic species;

- Hook & line, longline, artisanal (demersal)
- Hook & line, longline, tuna (foreign)
- Hook & line, longline, tuna and tuna-like species
- Industrial nets, purse seine, tuna
- Small nets, cast nets, fish & shrimps
- Small nets, gill nets, sharks & rays
- Traps, barrages, mangroves
- Traps, fence traps, Valakiras (Barrage côtier)

There is only one fishery for pelagic fish species shown for Madagascar under StatBase, described as 'Peche aux Poissons'. Information on catches for 2005 is provided, which indicate an annual catch of Carangids of 23t and of mackerels of 11t.

Rahombanjanahary *et al.*, (2011) reported to IOTC that the fishery in Madagascar is divided into three categories: industrial, artisanal and traditional fisheries. Tuna are caught in the artisanal fishery (USTA Madagascar, 2010). The data reported to IOTC by Madagascar include catches for the years 1950-2013 from baitboat, troll handlines, longline and longline (targetting swordfish) gears. It is not clear whether this includes catches from the artisanal fisheries. The species caught are: yellowfin tuna, bigeye tuna, skipjack tuna, albacore, swordfish, blue marlin, black marlin, striped marlin, Indo-Pacific sailfish, short-billed spearfish, longtail tuna, frigate tuna, bullet tuna, kawakawa, narrow barred Spanish mackerel, Indo-pacific king mackerel *S. guttatus*, and wahoo. Kawakawa, skipjack tuna and yellowfin tuna made the biggest contributions to these catches (Figure 12).

The national report by Madagascar to the 5th session of the SWIOFC Scientific Committee indicated that the catch of tuna and tuna-like species was 14,000t in 2010 and that the status of the resources in the oceanic areas was "moderately exploited" (FAO SWIOFC 2012; and Unpublished PowerPoint presentation, Statut des Ressources Halieutiuqes Madagascar).

FAO FishStat contains landings of pelagic species from 1950-2012 for the following: *A. thazard & A. rochei, E. affinis, I. platypterus, K. pelamis, M. nigricans, S. commerson, T. audax, T. alalunga, T. albacares, T. obesus, T. tonggol* and *X. gladius* (Figure 13). The large pelagics *K. pelamis* and *T. albacares* account for the greatest weight taken, followed by the medium pelagic species *S. commerson,* for which catches of over 6,500t were reported in 2010. The remaining species and taxonomic groups accounted for less than 2,000 t each throughout the time series (Figure 13).

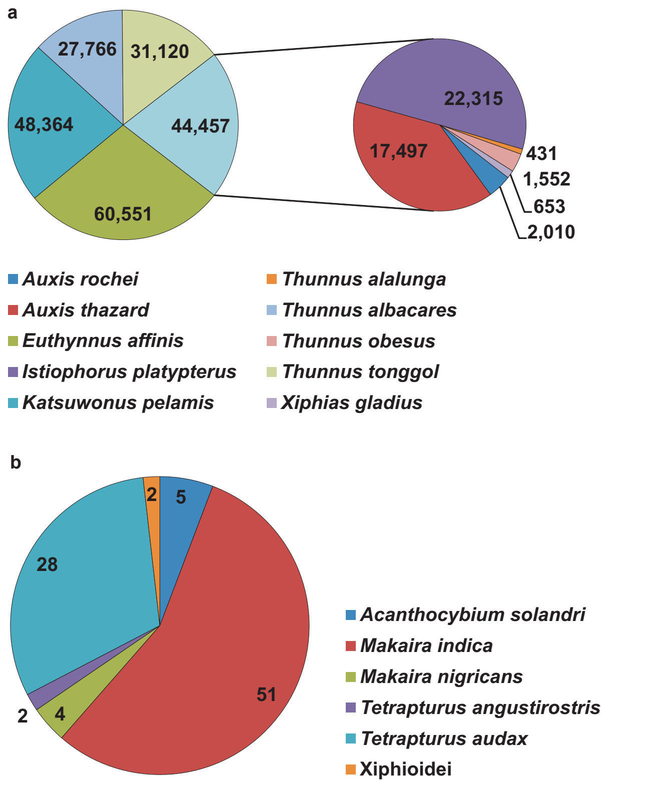


Figure 12 a & b. Catches (t) reported to IOTC by Madagascar. Aggregated total 1950-2013. a) Catches >200t. b) Catches <200t.

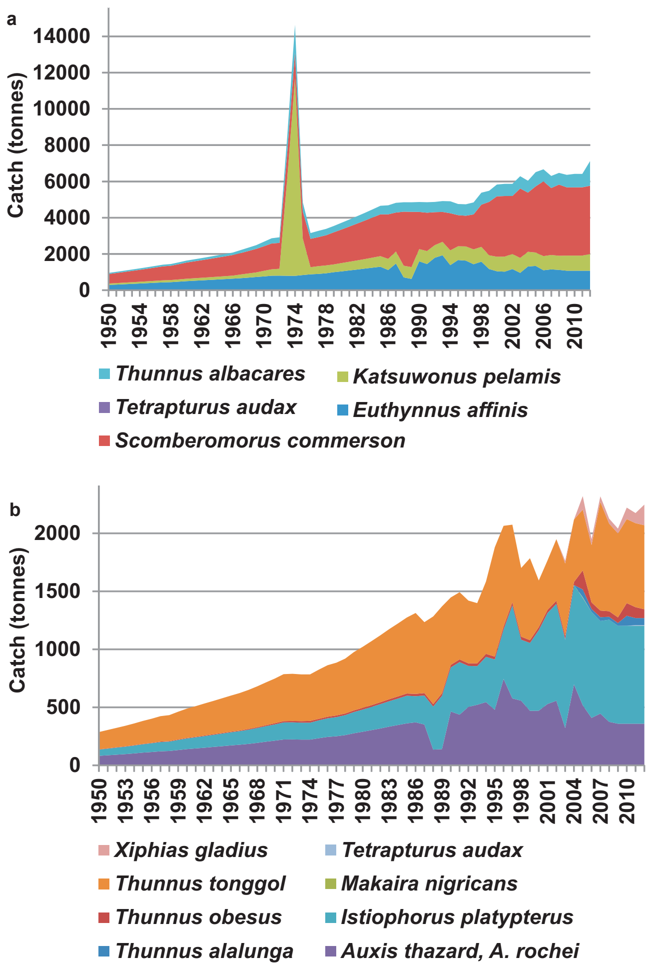


Figure 13 a & b. Catches of pelagic species by Madagascar fisheries in the western Indian Ocean, as reported to FAO, 1950-2012.

MAURITIUS

The WIOFish database contains information on eight different fisheries in Mauritius that report catches of SWIOFP priority pelagic species:

- Hook & line, FADs, pelagic fish
- Hook & line, fish, artisanal
- Hook & line, longline surface, semi-industrial
- Hook & line, longline, tuna
- Industrial nets, purse seine, tuna
- Large nets, seine, fish,
- Mixed gears, traps and lines, artisanal
- Traps, Basket, Artisanal

StatBase lists two fisheries for Mauritius: the Coastal fishery and the Bank fishery. The former has recorded catches of carangids for the years 2003-2008 and yellowfin tuna for the years 2003-2004. The average annual catches during those periods were 23t and 99t respectively.

The IOTC database includes catches reported by Mauritius from 1977-2010. Catches are reported from troll line, handline and troll line, longline, longline (targeting swordfish), and purse seine gears. The species recorded as having been caught during this period are yellowfin tuna, bigeye tuna, skipjack tuna, albacore, southern bluefin tuna, swordfish, black marlin, striped marlin, Indo-Pacific sailfish, billfish *nei,* wahoo, tunas and bonitos *nei,* and tuna-like fishes *nei*. Of these, the biggest contributions by weight were made by skipjack and yellowfin tuna, followed by bigeye tuna and tunas and bonitos *nei* (Figure 14).

In their 2010 and 2011 annual reports to IOTC, Mauritius reported that FADs have been in use since 1985 and that an artisanal tuna fishery has developed around them. Failler (2011) also presents information on the FAD fisheries in this country. Twentyfour FADs are maintained and about 300 fishermen are involved in the FADs fishery in which approximately 390t of fish, mainly tuna, were caught in 2009 (Norungee, 2010; Bauljeewon 2011).

The FAO database contains landings from 1950-2012 for the following species and taxonomic groups: Carangidae, Clupeoidei, Scombridae, *I. platypterus, K. pelamis, M. indica, T. audax, T. alalunga, T. albacares, T. obesus, X. gladius*. Three species, *K. pelamis, T. albacares* and *T. obesus* have dominated catches over the time series as a whole (Figure 15). The landings of these species peaked in 1993 (6,902t), 1991 (2,741t) and 1989 (1,311t) respectively. They subsequently declined and, along with all the other species and taxonomic groups reported to FAO, catches totalled less than 250t in 2010.

In the report by Mauritius to the 5th Scientific Committee, the 2009 catch of coastal tunas and related species taken around FADs was given as 390t and the stock status to be moderately exploited (M) (FAO SWIOFC 2012). The catch of tunas and swordfish in oceanic waters was given as 246t in 2009 (no estimate was provided for 2010) and the stock status was regarded as moderately exploited (M). Again, these status assessments need to be considered within the context of the status of the stocks over the whole of their distribution in the Indian Ocean. No catch estimates were provided for the small pelagic fishery for *Decapturus* spp. in the mid-water of Saya de Malha and Nazareth Banks but the stock status was reported to be under-exploited (U) (FAO SWIOFC 2012).

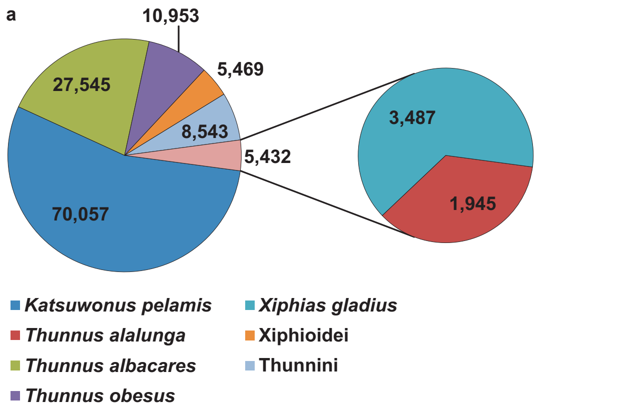


Figure 14 a & b. Species composition of catches (t) reported to IOTC by Mauritius. Aggregated total for 1977-2013 (tonnes). (a) Catches > 300t. (b) Catches <300t.

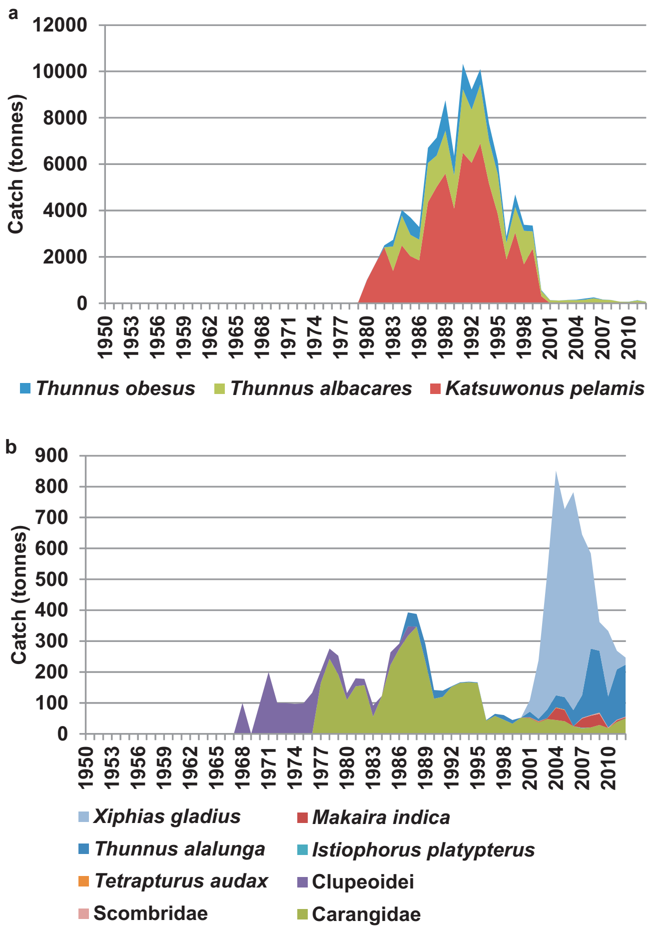


Figure 15 a & b. Catches of pelagic species in the western Indian Ocean by Mauritius fisheries, as reported to FAO, 1950-2012.

MOZAMBIQUE

The WIOFish database contains information on nine different fisheries in Mozambique that report catches of SWIOFP priority pelagic species:

- Diving, fish, seagrass
- Diving, speargun, recreational
- Hook & line, artisanal
- Hook & line, large vessel, commercial
- Hook & line, longline, tuna
- Hook & line, shore angling
- Hook & line, small motorboat, recreational
- Hook & line, small motorboat, sport
- Industrial nets, purse seine, tuna

StatBase includes data from the following fisheries' sectors in Mozambique: Artisanal, Semi-industrial, Industrial and Sport. Of these, only the sport fishery records are noted to have caught pelagic species, although clearly this cannot be true as all the other sectors are known to catch pelagic fishes routinely (see also chapter 6). The sport fish data are provided for the period 2000-2009 and broken down into marlin and 'Serra', the Mozambican name for *S. commerson*. The average annual sport catch for this period for each of the two taxonomic groups is given as 160t. There are also reports of the use of FADs in Mozambique in recent years (R. Payet, SWIOFP, *pers. comm.*)

Mozambique only became a member of IOTC in February 2012, hence the catch database does not include records for the country. In their national report to the IOTC in November 2011, Mozambique reported that only foreign fleets fish for tuna within the Mozambique EEZ and that the primary gears used are purse seine and longline (Palha de Sousa, 2011). The report provides information on catches, which are shown in Table 2.

Palha de Sousa (2011) also provides some insight into the species caught in the Mozambique sport fishery than that available in StatBase. This shows six species, and a group called 'Tuna" as being caught in the fishery with yellowfin tuna and kawakawa being the dominant species in reported catches.

FAO FishStat contains landings from 1950-2009 for the following species and taxonomic groups: *E. affinis, K. pelamis, Scomberomorus* spp., *T. alalunga, T. albacares, T. obesus* and *X. gladius*. However, reported landings are too sporadic and no meaningful trends or comparative information can be obtained from them.

Mozambique reported to the 5th SWIOFC Scientific Committee that the 2010 catch of "coastal tuna" (*Thunnus albacares, T.alalunga, T. obesus*) was 2,941t (3,087t in 2009), (FAO and SWIOFC 2012). The catch of small pelagics was estimated to be between 55,000 and 85,200t and these resources were said to be fully exploited, although in a Powerpoint they were reported as low to moderately exploited[5]. The major species caught in this fishery were listed as species of *Pellona, Thryssa* and *Hilsa* with a reported catch of 96,724t in 2009 (FAO 2014). The semi-industrial line fishery was reported as having landed 630t in 2009 and 833t in 2010. The most significant priority pelagic species in these landings is *S. commerson*, the bulk of the catch comprising a range of demersal sparids.

Table 2. Number of fishing vessels and annual catch per primary species, for the Mozambican waters from 2004 to 2010 (Source: ADNAP annual reports). The 2010 catch data may be incomplete.

Year	No. vessels	Skipjack	Albacore tuna	Bigeye tuna	Yellowfin tuna	Swordfish	Black marlin	Tuna	Total
2004									17470
2005	143								5629
2006	142								6668
2007	181	641	541	350	3402	218	1	428	5581
2008	122	2550	341	322	2647	209	9	471	6549
2009	111	1942	106	173	624	721	9	538	4313
2010	71	764	99	166	1267	600	27	603	3909

5. Status of the Fisheries Resources Mozambique 2010. Unpublished Powerpoint presentation and a stock status report presented to the FAO/SWIOFC Scientific Committee in Cape Town, 2012.

SEYCHELLES

The WIOFish database contains information on nine different fisheries in Seychelles that report catches of SWIOFP priority pelagic species:

- Hook & line, inboard, artisanal
- Hook & line, longline - pelagic, tuna (i)
- Hook & line, longline, swordfish & tuna (s/i)
- Hook & line, shore, flyfishing
- Hook & line, small boat & motor, fish (art)
- Industrial nets, purse seine, tuna
- Small nets, beach seine, fish
- Small nets, pelagic gill net, mackerel
- Small nets, purse seine, small pelagics

StatBase includes two Seychelles fisheries that report pelagic species (in years and species recorded on each file shown in brackets):

- Artisanal fishery (2000-2008; bonitos, carangids, Indian mackerel)
- Industrial longline fishery (2000-2008; albacore, bigeye tuna, black marlin, blue marlin, Indo-Pacific sailfish, southern bluefin tuna, striped marlin, swordfish and yellowfin tuna).

The gears recorded as catching pelagic species in the artisanal fishery are beach seines, encircling gill nets, handlines and pole-lines (hand-operated and mechanised), set gillnets, traps and traps & lines. Carangids were by far the dominant component of the catch by weight during the period for which data are available (Figure 16). The industrial longline fishery uses set longlines with bigeye and yellowfin tuna forming the biggest portion the catches by weight (Figure 17).

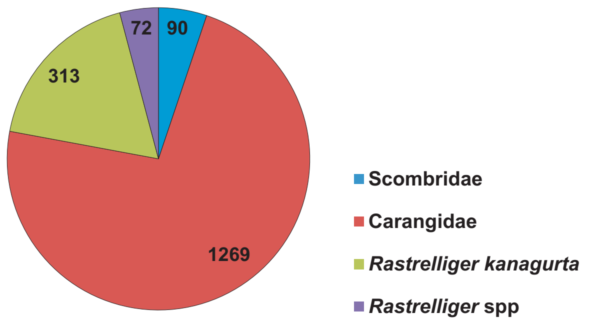


Figure 16. Average annual catch (tonnes) of pelagic species reported for the Seychelles artisanal fishery: 2000-2008.

Seychelles reported catches of the following species to FAO for the period 1953-2012 (Figure 18): *A. thazard, A. rochei,* Carangidae, *E. affinis, I. platypterus, K. pelamis, M. indica, M. nigricans, R. kanagurta, Rastrelliger* spp., *T. audax, T. alalunga, T. albacares, T. maccoyii, T. obesus, T. tonggol* and *X. gladius.* According to these records, catches of all species, apart from the Carangidae, totalled less than 1,000t until 1998 when catches of three species in particular increased substantially. These were *T. albacares,* which peaked at nearly 53,000t in 2004, *K. pelamis,* which reached a maximum of 47,500t in 2006 and *T. obesus,* which exceeded 10,000t in 2004.

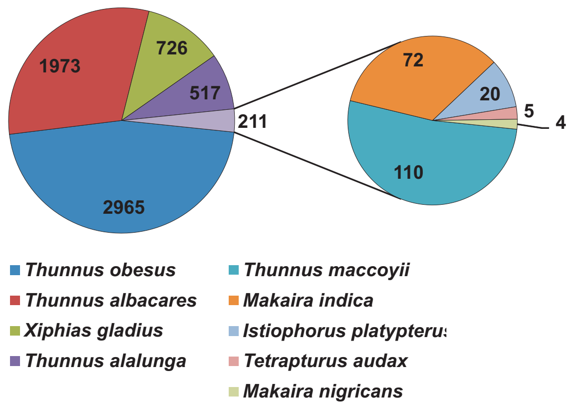
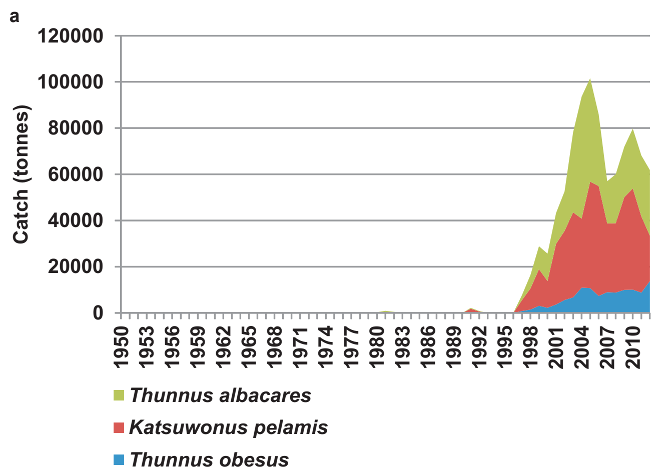


Figure 17. Average annual catch (tonnes) of pelagic species recorded on StatBase for the Seychelles industrial longline fishery: 2000-2008.



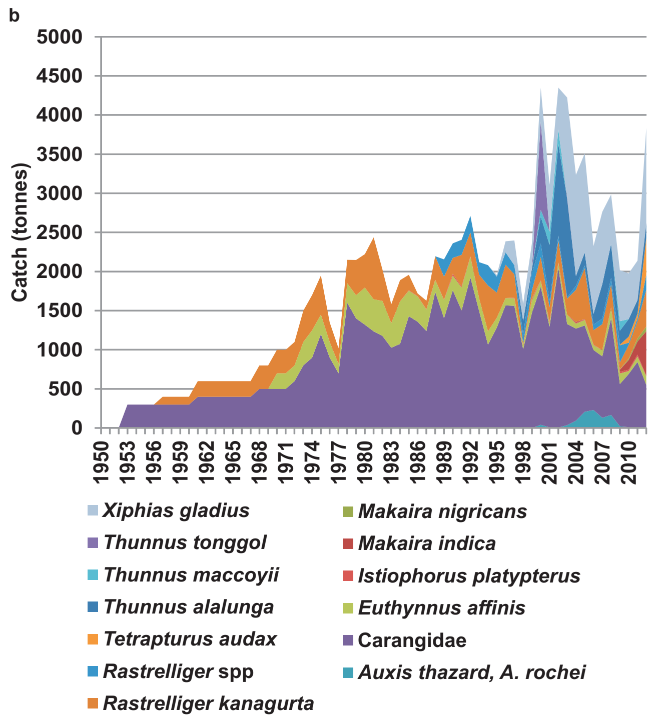


Figure 18 a & b. Catches of SWIOFP priority pelagic species reported to FAO by Seychelles. (a) dominant species, (b) other species.

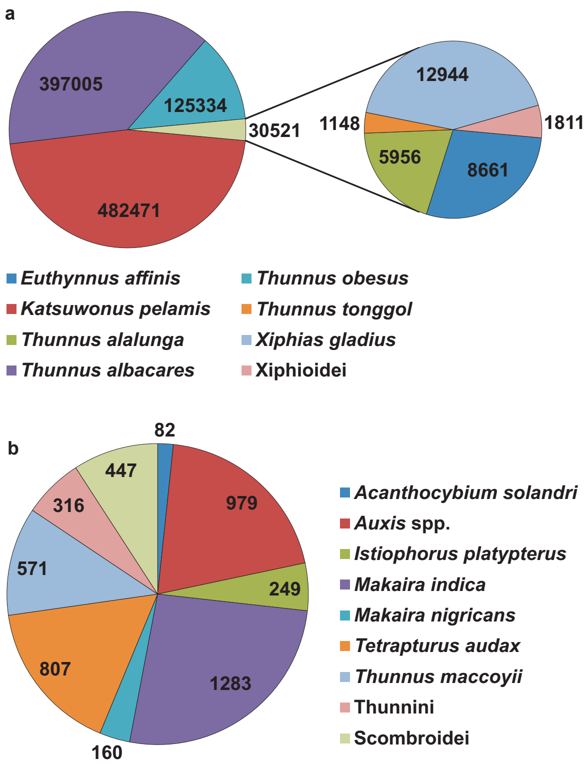


Figure 19 a & b. Species composition of catches reported to IOTC by Seychelles. Aggregated Total for 1970-2012 (tonnes). (a) dominant species, (b) other species.

Records of catches reported to IOTC by Seychelles cover the period 1970-2012. A total of 17 species or species groups have been reported: yellowfin tuna, bigeye tuna, skipjack tuna, albacore, southern bluefin tuna, swordfish, blue marlin, black marlin, striped marlin, Indo-Pacific sailfish, billfish (marlins, sailfishes & spearfish), longtail tuna, frigate and bullet tunas (*Auxis* spp.), kawakawa, wahoo, tunas and bonitos nei, and tuna-like fishes nei. Skipjack and yellowfin tuna are by far the two dominant species reported to IOTC followed by bigeye tuna (Figure 19).

Seychelles provided a comprehensive report to the SWIOFC Scientific Committee in 2012 (FAO/SWIOFC 2012), including catch estimates for the period 2005–2010 (only from 2006 for the offshore tuna fishery) for the following fisheries (maximum and minimum reported catch and percentage pelagic species in catch shown in brackets)[6]:

- Encircling gillnet fishery (676.5t, 236.3t; *R. kanagurta* – 65.7%, *o*ther mackerel-10.9% and other carangids – 7.5%);
- Semi-pelagic line fishery (1526.2t, 736.6t; Carangoides spp. (*C. gymnostethus* and *C. fulvoguttatus*) – 83.3%, *E. affinis* – 5.1%);
- Offshore tuna and related species – semi-industrial (329t, 233t; *X. gladius* – 63%, *T. albacares* – 19.7% and *T. obesus* – 8.8%).

6. Seychelles Status tables 2012. Unpublished report submitted to the FAO/SWIOFC Scientific Committee in Cape Town, 2012.

SOUTH AFRICA

There are eight South African fisheries, all taking place within KwaZulu-Natal Province, listed on the WIOFish database as catching priority pelagic species in the SWIOFP area:

- Diving, speargun/no scuba, fish
- Hook & line, jetski, fish
- Hook & line, longline, swordfish & tuna
- Hook & line, paddleski, fish
- Hook & line, small boat & motor, charter/party
- Hook & line, small boat & motor, fish (rec)
- Hook & line, vessel, commercial
- Industrial nets, offshore, crustaceans

The StatBase entry for South Africa is described collectively as KwaZulu-Natal Industrial Fisheries and includes the KZN traditional linefishery consisting of line fishing and prawn trawling vessels. The catch data cover the years 1985-2010. Approximately 30 pelagic species are included in the list of species caught but for the large majority, the average annual landings are low, at less than one tonne (Figure 20). The ten species with the highest average annual catch, in descending order, are: *S. commerson, T. albacares, C. hippurus, Scomberomorus plurilineatus*, mackerels *nei, S. japonicus*, *S. sagax*, tunas *nei, M. indica* and *E. affinis.*

In their 2011 report to the Scientific Committee of IOTC, South Africa reported there to be three commercial fisheries in South Africa that catch tuna and tuna-like species in the Indian Ocean, either as directed or as by-catch. These fisheries are a swordfish and tuna longline fishery, a rod and reel fishery and a shark longline fishery. The boat-based recreational fishery along the South African Indian Ocean coast also catches tuna (West & Smith, 2011). The swordfish and tuna longline fishery catches mainly bigeye tuna, albacore, yellowfin tuna, southern bluefin, swordfish, while the rod and reel fishery catches mainly albacore, yellowfin tuna and Tunas *nei* (Figure 21). Note that the South African large pelagic longline fishing sector is split between "foreign" and locally flagged fleets. Since 2005, South African rights holders have fished under joint venture with mostly Japanese flagged longline vessels. These catches are reported as "South African" to the RFMOs.

The catches reported to FAO by South Africa includes a relatively large number of pelagic species and other taxonomic groups (Figure 22), predominantly large and medium pelagics. The earliest landings on the FAO database are from 1973. The landing totals are modest with *X. gladius*, *T. albacares* and *T. obesus* being the only species with catches in excess of 100t in recent years. The IOTC catch records from South Africa start from 1979 and, again, include a relatively high species diversity (Figure 22). The highest aggregated catches were of *X. gladius*, *T. albacares* and *T. obesus*, *S. commerson,* smaller tunas and bonitos *nei* and *Thunnus alalunga*.

South Africa's report to the 5th SWIOFC Scientific Committee included information on catches and stock status of large pelagics falling under the mandate of IOTC, but not on any of the medium and small SWIOFP priority pelagic species (FAO and SWIOFC 2012). The South African fisheries for large pelagics are spread across both the ICCAT and IOTC areas. South Africa also has a large midwater trawl

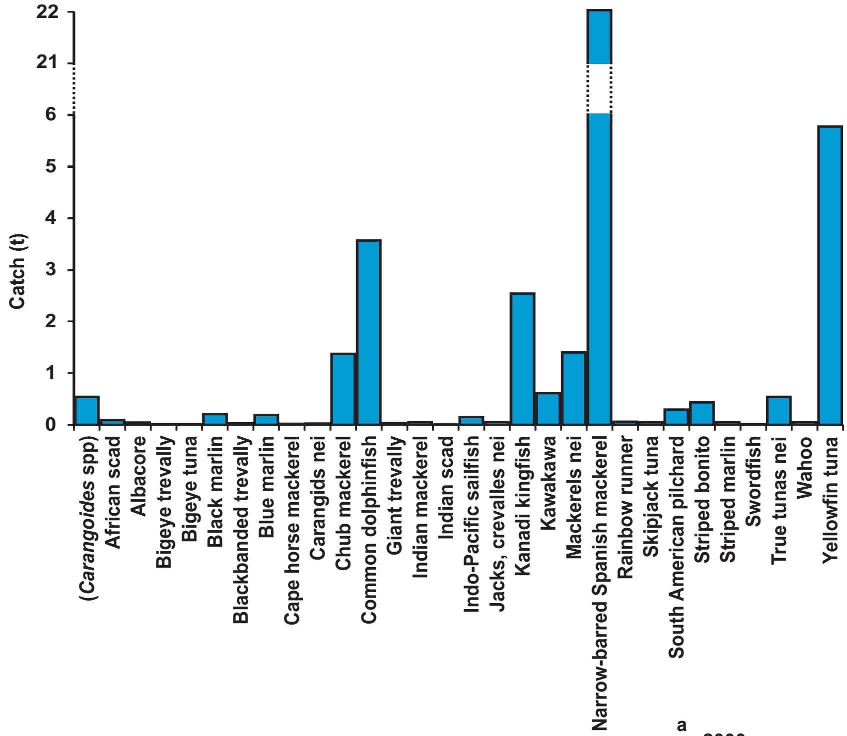
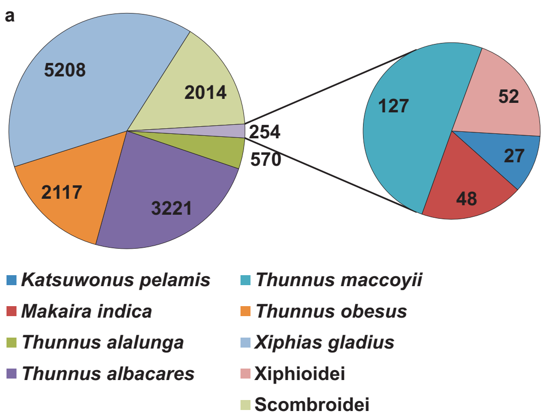


Figure 20. Average annual catch (tonnes) of pelagic species recorded on StatBase for the KwaZulu-Natal commercial line fisheries: 1985-2010.

fishery for horse mackerel *Trachurus trachurus capensis*. This fishery takes approximately 48,000t of "small pelagics" per annum under a precautionary catch regime. Although it technically operates in the Indian Ocean, this species is not included in this study as, for management purposes, it is considered part of the west and south coast fisheries.



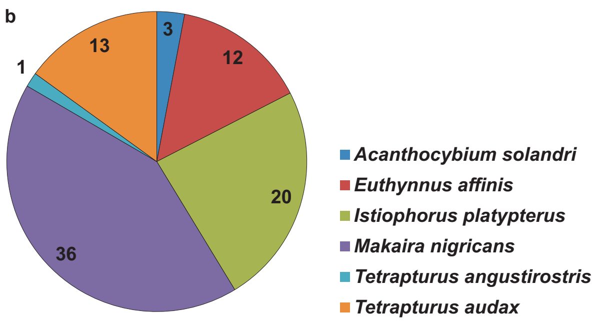
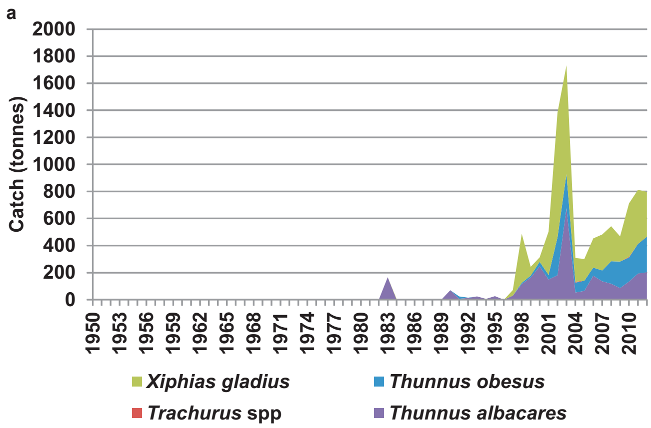
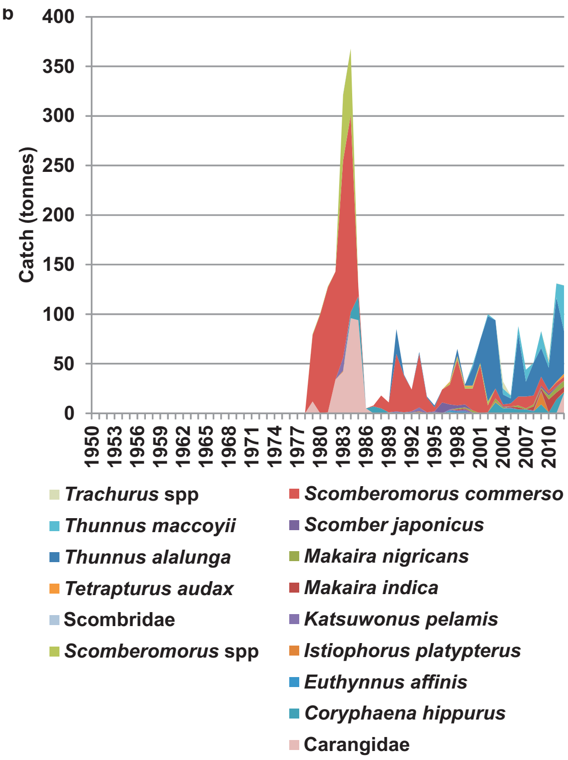


Figure 21 a & b. Species composition of catches reported to IOTC by South Africa. Aggregated total for 1970-2013 (tonnes) (a) dominant species, (b) other species.

Figure 22 a & b (below). Catches of SWIOFP priority pelagic species reported to FAO by South Africa.





TANZANIA

The WIOFish database contains information on ten different fisheries in Tanzania that report catches of SWIOFP priority pelagic species:

- Diving, speargun & snorkel
- Hook & line, charter boat, gamefish
- Hook & line, longline, surface
- Hook & line, small boat and motor, sport
- Industrial nets, offshore, tuna, industrial nets, purse seine
- Small and large mesh nets, bottom gill net
- Small nets, hand/scoop net, surface (drift) gill net, pelagics
- Traps, staked (uzio/wando), fish

StatBase lists data from the following sectors: (in years and pelagic species recorded on each file shown in brackets):

- Artisanal fishery (1990-1996: *Trachurus* spp., *S. plurilineatus*, *Decapterus macarellus*, *Dussumieria acuta, X. gladius*, tunas *nei*).
- Industrial fishery (2008: *T. alalunga, T. obesus, M. indica, K. pelamis, X, gladius, T. albacares*).

The rainbow sardine *D. acuta* makes up the biggest part of the catches recorded for the artisanal fishery in Tanzania with average annual landings between 1990 and 1996 of 3,561t, followed by *D. macarellus* at 1,761t. The genus *Trachurus* and kanadi kingfish (*S. plurilineatus)*, although not SWIOFP priority species, are also important pelagic components of the catches (Figure 23).

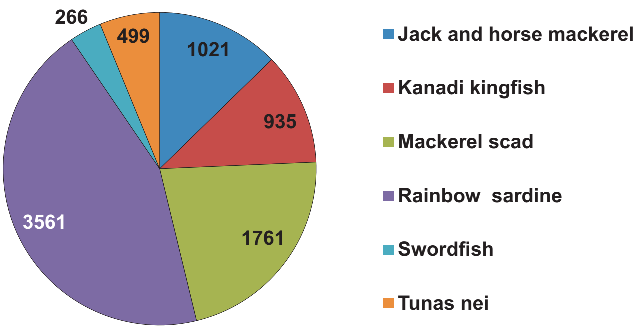


Figure 23. Average annual catch (tonnes) of pelagic species recorded on StatBase for the Tanzania artisanal fishery for the years 1990-1996, excluding 1994.

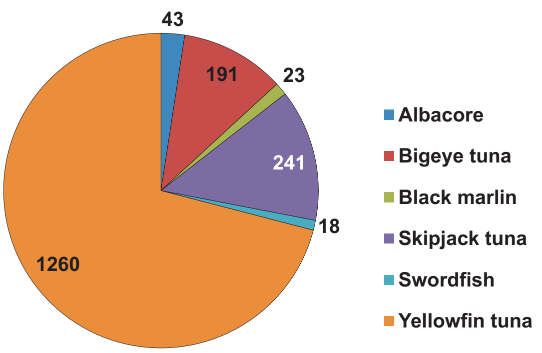


Figure 24. Average annual catch (tonnes) of pelagic species recorded on StatBase for the Tanzania industrial fishery for 2008.

All the catches of pelagic species in the industrial fishery come from Japanese longline and tuna purse seine fisheries and only those from 1998 are included. The highest catches by weight were of *T. albacares*, followed by substantially lower catches of *K. pelamis* and *T. obesus* (Figure 24).

Landings reported to FAO by Tanzania from 1971-2012 included the following: Carangidae, *I. platypterus, K. pelamis, M. indica, M. nigricans, R. kanagurta, Sardinella* spp., *Scomberomorus* spp., *T. audax, T. alalunga, T. albacares, T. obesus* and *X. gladius.* These records show high variability but catches of *Sardinella* species have been the highest for much of the previous 25 years with peak landings of 15,500t in 2001 and 2005, followed by a low of 3,095t in 2006. For much of the last two decades *R. kanagurta* and Carangidae made up the second and third highest catches by weight respectively (Figure 25).

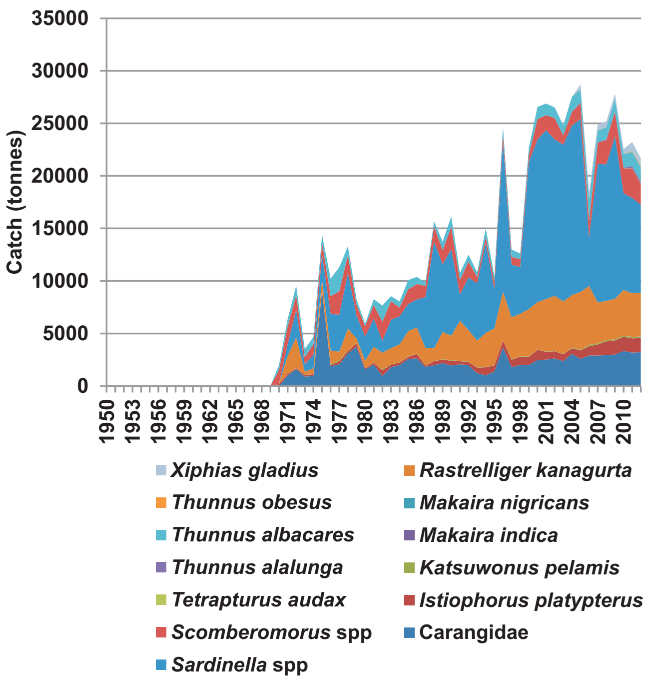


Figure 25. Catches of pelagic species in the western Indian Ocean by Tanzanian fisheries, as reported to FAO, 1950-2012.

The Scomberomorini, (wahoo and seerfishes) provided the highest aggregated catches reported to IOTC, followed by tunas *nei* and billfishes *nei* (Figure 26). A National Report from Tanzania to the IOTC Scientific Committee was not available on the IOTC website. At the 13th Session of the Scientific Committee in December 2010, Tanzania had informed the Committee that it had not been able to prepare a National Report for administrative reasons and that, as a result of recent structural changes in the government, they would not be able to present a National Report in 2011 (para. 28, IOTC-2010-SC-R[E]).

The Tanzanian National Report to the 5th Session of the Scientific Committee of SWIOFC provided a number of time series of catches from several fisheries, including catches of some pelagic taxonomic groups (Kuguru & El Kharousy 2012). This included catches of clupeids, which ranged

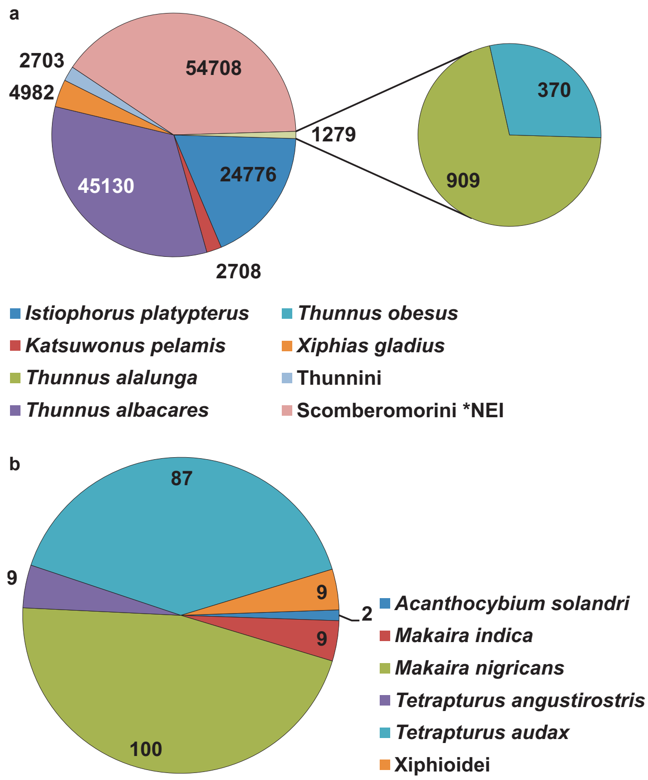


Figure 26 a & b. Composition of catches reported to IOTC by Tanzania. Aggregated total for 1970-2012 (tonnes).

between 8t-18t between 2007-2010 and of *Rastrelliger* spp., which ranged between 3.9t-4.6t in the same period. The total catch from the artisanal fishery from 1995-2008 fluctuated around 300t per annum.

In addition to the results included in the various reports referred to above, the Fisheries Department of Tanzania (FDD) reported on findings by Berachi (2003) that small pelagic fish such as sardines (Clupeidae), anchovy (Engraulidae), small mackerel (Scombridae) and horse mackerel accounted for approximately one-third of the total catch from the marine artisanal fisheries of mainland Tanzania[7]. These were described as being subject to large demand as they are much cheaper than others. Large pelagic fish species mainly included jacks and trevallys (Carangidae), kingfish (Scomberomoridae), tunas, mullet, swordfish and sharks (Berachi 2003). Also referred to in the FDD report, Everett, *et al.* (2010) pointed out that there were 35 unique pelagic resource catch items listed in the WIOFish database for the Tanzanian fisheries. Bianchi (1985) reported 70 commercial pelagic fish species for Tanzania.

According to the FDD, the status of Tanzanian marine fisheries resources is considered to range from underexploited to depleted with the majority considered to be under to moderately exploited (FAO SWIOFC 2012). Amongst the large pelagics, *T. alalunga, T. albacares, T. obesus, K. pelamis, X. gladius* and marlins were reported as being underexploited.

Nevertheless, as presented earlier in this chapter, the local concentrations of shared and straddling stocks cannot be assessed in isolation from the wider distributed stock as a whole. Large concentrations of small pelagics are frequently encountered along the whole coast, particularly in Mafia Island, Tanga and Zanzibar regions and were considered to be moderately exploited. Large pelagics, particularly *Scomberomorus,* are fished mainly in the Zanzibar Channel and beyond the shelf drop-off.

7. Small pelagic species in Tanzania are mostly referred to as dagga and may include many different species of clupieds, sardinellas and mackerels.

Regional fishery databases: trends in landings

The previous section examined the available data at the country level in an attempt to determine the magnitude of pelagic catches in each country and the species making the largest contributions to those catches. As the stock structure of few, if any, pelagic species in the SWIO region is defined, it can be concluded that these stocks are shared between neighbouring countries, straddle the boundaries between national EEZs and the high seas, or both. Some of them also undergo migrations across national borders. In order to determine the total yields being obtained from stocks and the full impacts of fisheries on shared and straddling stocks, it is necessary to examine the total catches from the stock as a whole.

In this section, the data available from the four primary regional databases, FAO, IOTC, StatBase and WIOFish are integrated, as far as possible, in an attempt to estimate the total catches by species or higher taxonomic group. This can help to identify the species of greatest importance to fisheries at the regional scale, and to identify any trends that may be discernible in the time series of catches of the most important species.

LARGE PELAGICS

The data available on WIOFish, summed for all fisheries recorded in WIOFish as catching species in this category, indicate that catches of large pelagic species are predominantly taken by Seychelles, which reported annual catches of the SWIOFP priority species of >264,000t compared with the next highest country, which was Madagascar at >10,000t, followed by Mauritius (8,163t) and Mozambique (6,443t) (Figure 27). Significantly, it is noted that catches attributed to the industrial fleet of the Seychelles in the WIOFish database include those taken by other fleets under license (Vincent Lucas, SFA, *pers. comm.*)

The relative contributions of the different countries as reflected in WIOFish are broadly consistent with the data reported to IOTC, which show that in 2010, Seychelles accounted for 70% of the large pelagic catches of SWIO countries that reported to IOTC, followed by Madagascar at nearly 15% and Comoros at 12%. As a new member of IOTC, data from Mozambique were not included in the IOTC catch dataset available at the time of writing. There are differences in the totals reported, however, and the WIOFish data indicate a total catch of large pelagics of 291,000t while that reported to IOTC in 2010 was 117,000t. This may be at least partially explained by the inclusion of other fleets in the Seychelles industrial catches. WIOFish data indicate that the most important contributing species to these catches are *K. pelamis* and *T. albacares* (Figure 28).

The data recorded on StatBase are clearly incomplete compared with those available from FAO and IOTC and the totals shown are much lower than those recorded on the two databases as well as on WIOFish (Figure 29). A significant contributing factor to this discrepancy is that StatBase only includes data from the Seychelles industrial longline fishery and not from the line, purse seine and 'other' industrial fisheries. This also leads to a difference in the species contributions to StatBase catches, which are predominantly of *T. albacares* and *T. obesus*. For the non-tuna species, the StatBase data shows *X. gladius* as being the most important component of catches for most years since the turn of the century but these have declined since 2007. Catches of Istiophoridae reached a peak of 297t in 2000 but have declined since then with those of *M. indica* having fluctuated between 50 and 200t for much of the time series.

The FAO statistics show that catches of large pelagics by SWIO countries started to increase rapidly in the early 1980s but, notwithstanding considerable inter-annual variability, have generally stabilised in the last decade or so. Tuna catches are made up largely of *K. pelamis* and *T. albacares* (both recently varying around 50,000t per year), followed by *T. obesus*, catches of which have been stable at about 10,000t since 2004. Catches of large pelagics other than tunas are much lower than for the main tuna species and consist mainly of *X. gladius* and *I. platypterus*. Catches of the former peaked at >2,500t in 2005 but declined to <1,500t in 2009 and 2010, while those of *I. platypterus* have levelled off at just less than 2,000t in later years (Figure 30 a & b).

The FAO and IOTC statistics are very similar (Figures 30 & 31), indicating that both are receiving data from the same, or at least consistent, national sources. The IOTC data also include catches of *Xiphias* of between 1,000-1,500t after the mid-1990s but falling well below 1,000t in 2009 and 2010.

Examination of the national catches of both large and medium pelagic species, reported to IOTC, aggregated across the entire time-series reported by each country (Figure 32), indicates that Seychelles has taken the highest catches with a total of approximately 850,000t (2010 catches= 82,305t), followed by Madagascar at nearly 720,000t (2010 catches= 27,668t), Comoros at over 260,000t (2010 catches= 15,000t), Mauritius at nearly 130,000t (2010 catches= 448t) and Tanzania at just over 100,000t (2010 catches = 2,988t). South Africa and Kenya had aggregated catches of less than 50,000t and catches reported to IOTC in 2010 were 767t and 1,874t respectively.

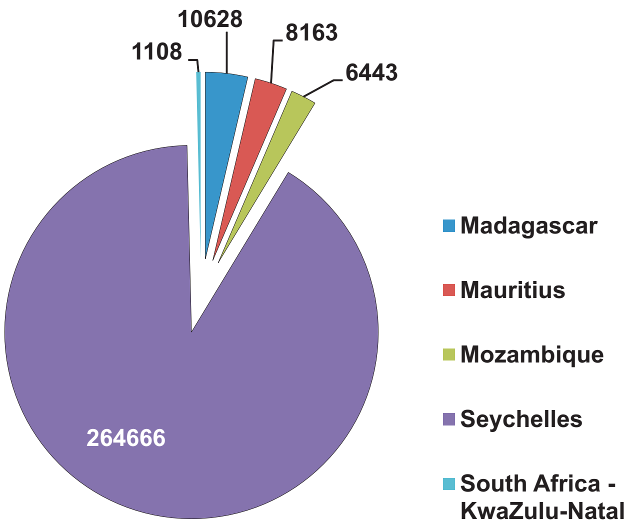


Figure 27. Total annual catch of large pelagic species by country as reported on WIOFish.

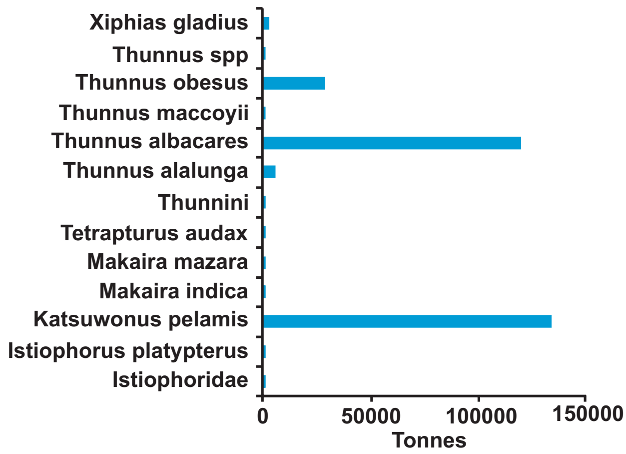


Figure 28. Annual catches of large pelagic taxonomic groups recorded on WIOFish, summed for all fisheries that reported catches of this group in all countries.

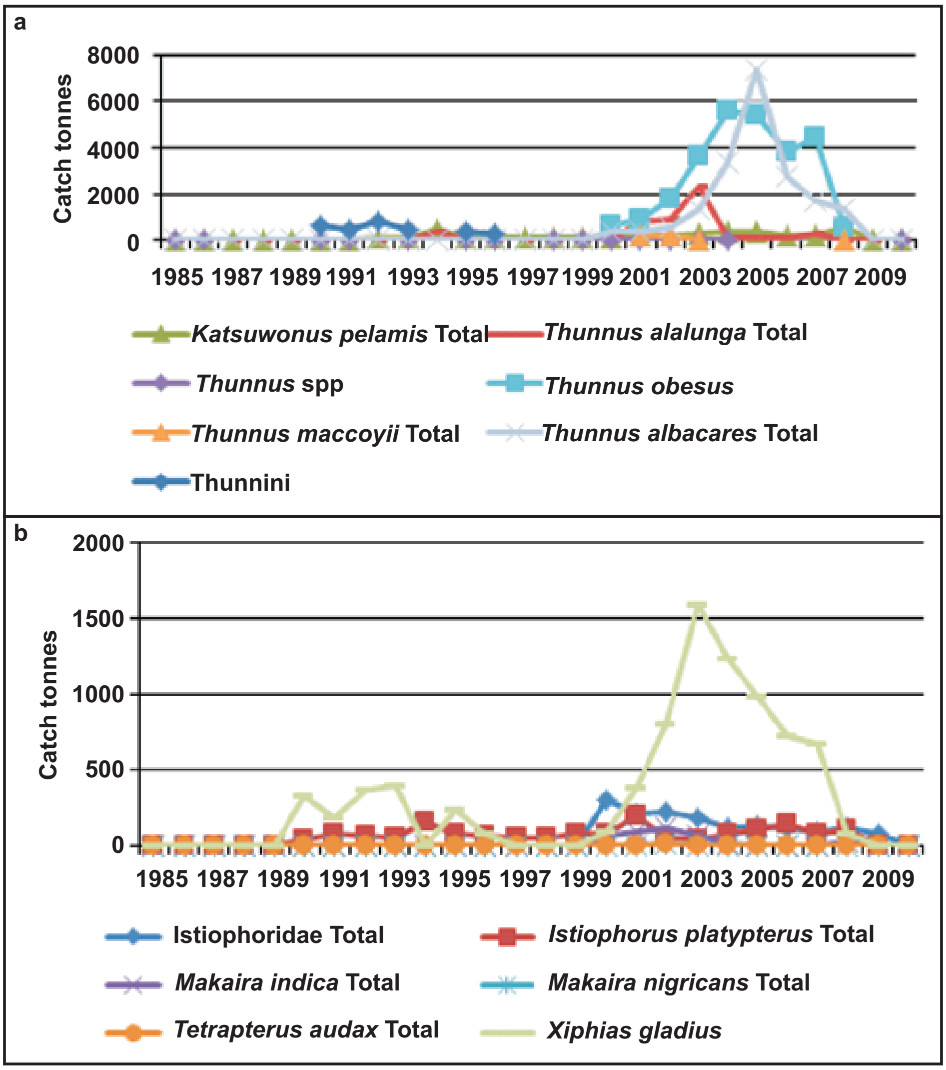


Figure 29 a & b. Time series of annual catches of large pelagic species and species groups recorded on StatBase. a) Tunas, including the group Tunas nei and b) other large pelagic species.

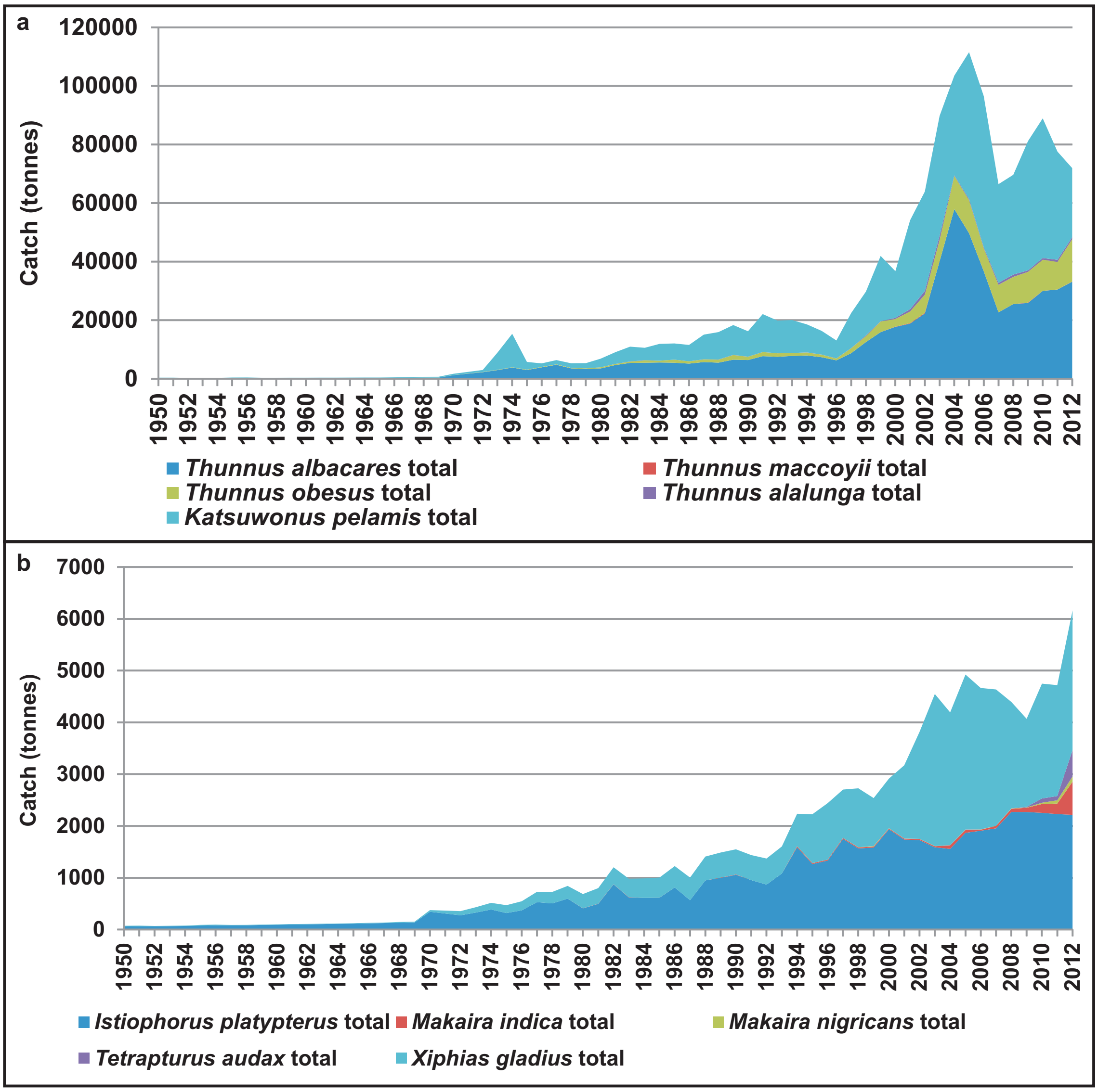


Figure 30 a & b. Total landings of priority large pelagic species reported by SWIO countries to FAO. a) Tuna species and b) large pelagic species other than tuna.

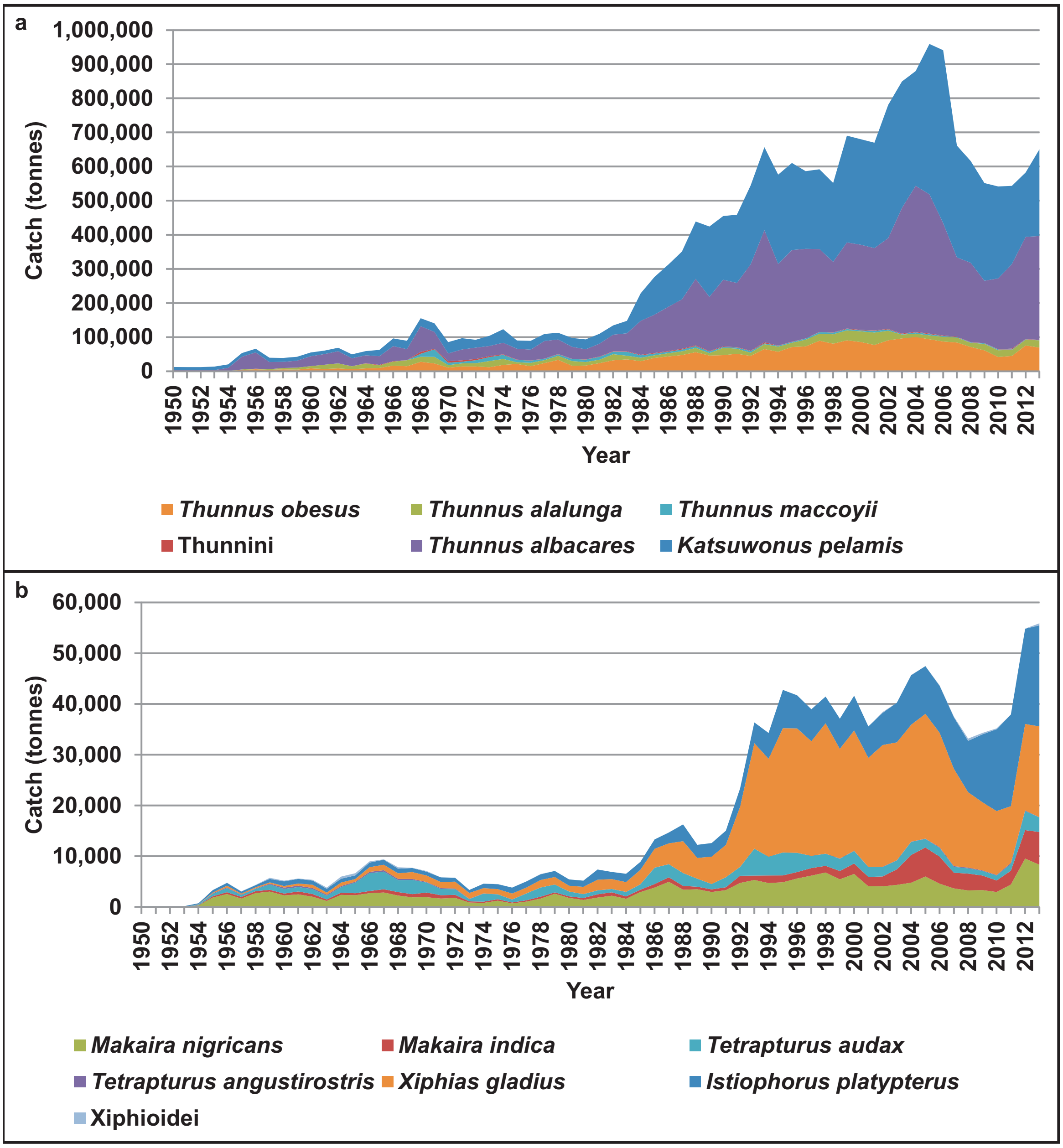


Figure 31 a & b. Catches of SWIOFP priority large pelagic species reported to IOTC. a) tuna species b) other large pelagic species.

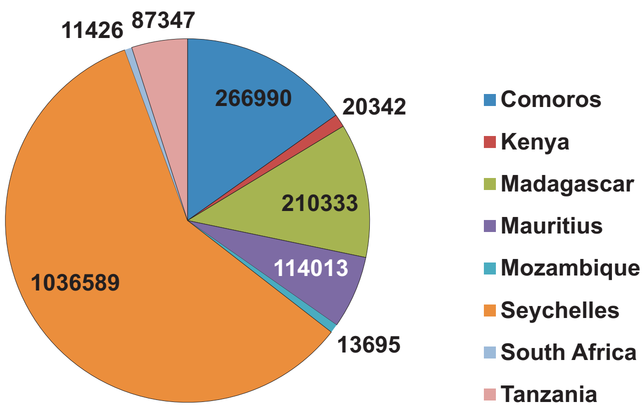


Figure 32. National catches of both large and medium pelagic species, reported to IOTC, aggregated across the entire time-series reported by each country.

MEDIUM PELAGICS

Medium pelagic species are especially important for the SWIO countries because they are accessible in coastal waters at relatively low input costs thereby providing development opportunities. However, the catch data available on regional databases for these species are frequently incomplete in terms of taxonomic detail, continuity of time-series and in coverage of total landings in each country. As shown in Table 1, the family Carangidae is a very important component of both medium and small pelagic catches in the region. Consequently, catches that are reported just at the family level cannot be accurately allocated to either group so that for the purpose of this Retrospective Analysis, Carangidae have been included as small pelagic catches. The rationale for this is the assumption that medium pelagic species are more visible and generally of higher value, so that it is more likely that they would be recorded at species or genus level, while the smaller species would be more likely to be grouped in the general category of Carangidae. However, whichever way the decision was made, it is an approximation only.

The annual catches of medium pelagics, summed for all fisheries recorded in WIOFish as catching species in this category, range from 0t in four of the countries to 8,165t in South Africa, with Mozambique and Seychelles reporting values of between 500 and 600t (Figure 33). Sixteen species or species groups of medium pelagics are reported as being caught but no catch estimates are provided for 11 of those taxonomic groups (Figure 34). The highest catches are recorded for *S. commerson* (6,977t) while other non-zero catches are for *C. hippurus* (999t), *E. affinis* (793t), *C. fulvoguttatus* (220t), *C. gymnostethus* (300t) and *Caranx* spp. (68t).

The catches of medium pelagics reported on StatBase are irregular and incomplete. The only countries reporting catches of medium Carangidae species are Comoros and South Africa (Figure 35a). There is only a single record of an annual catch from Comoros, a catch of 40t of *E. bipinnulata* in 1994 which is not included in the figure. The reported landings from South Africa are generally less than 1 tonne, apart from an annual catch of 2.9t of species identified as being from the sub-order Carangoides in 1988. Catches of *C. hippurus* recorded on StatBase, have been reported by Comoros (1994 only), Kenya and South Africa (Figure 35b).

Total catches are low and have varied without any clear trend between 10-30t between 1990 and 2009, apart from the peak of over 300t in 1994 (not shown in the graph), which was caused by the single reported catch from Comoros of 309t in that year. The highest recorded catches of medium pelagics on StatBase are for the family Scombridae, made up of catches of *E. affinis, S. orientalis* and *Sarda* species unidentified, *S. commerson, Scomberomorus* species unidentified ('Serra' reported by Mozambique) and *S. plurilineatus,* and those identified only as Scombridae. These were reported by Kenya, Madagascar, Mozambique, South Africa and Tanzania. The highest catch was reported by Tanzania of *S. plurilineatus* of >2,000t in 1990 but for the rest of that time series (1990-1996) catches were lower at less than 1,000t. Excluding those catches, total reported catches of this family varied between 360 and 500t between 2000 and 2008 without any clear trend, or trends in any of the time series contributing to this total (Figure 35).

There are a number of differences in the data reported to FAO compared with those included in StatBase. South Africa is the only country that has reported catches of *C. hippurus* to FAO while three other countries reported catches of the species to StatBase. The total landings of *Scomberomorus* spp. reported to FAO show an increasing trend, with inter-annual variability from <1,000t in the 1960s to >9,000t in 2012 (Figure 36). These figures contrast markedly with the total Scombridae catches of 500t or less reported on StatBase over the same period. The combined catches of *E. affinis, A. thazard* and *A. rochei,* reach peaks of over 1,000t in the catches reported to FAO. There are no records of medium-sized Carangidae on the FAO database.

Countries report their catches of tuna-like species to IOTC and these include several of the SWIOFP priority medium pelagic species. The time series available on IOTC appear to be complete and consistent from year to year but do not include data from Mozambique which only joined IOTC in 2012.

The most common medium pelagic species in catches of the SWIO countries in recent years has been *S. commerson,* catches of which started to climb rapidly in the early 1980s and have varied between approximately 5,000 and 9,000t during the last decade (Figure 37). *E. affinis* has been the next most abundant species in catches at approximately 2,500t each in recent years. Catches of *A. thazard* fluctuated around 60t from 1990 until 2006 but have been increasing since then.

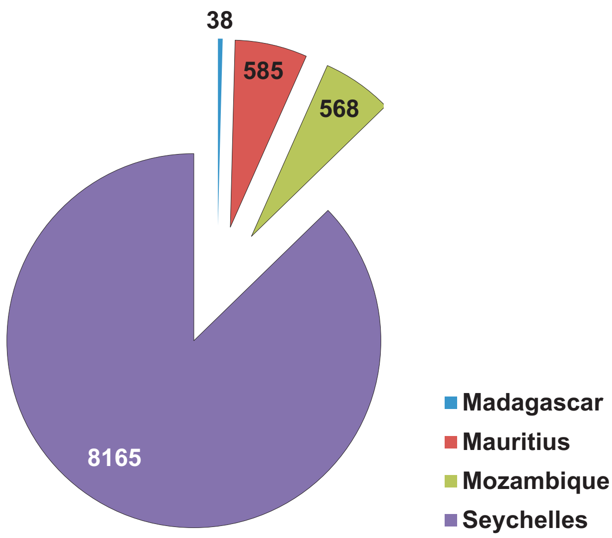


Figure 33. Total annual catch (t) of medium pelagic species by country as reported on WIOFish. The years for which records are provided vary from fishery to fishery and country to country and are not always specified on the database.

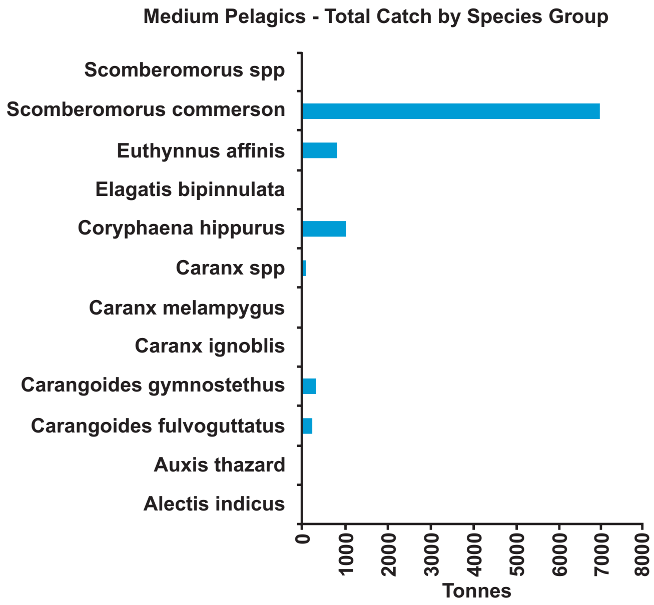


Figure 34. Annual catches of medium pelagic taxonomic groups recorded on WIOFish (2011), summed for all fisheries that reported catches of this group in all countries.

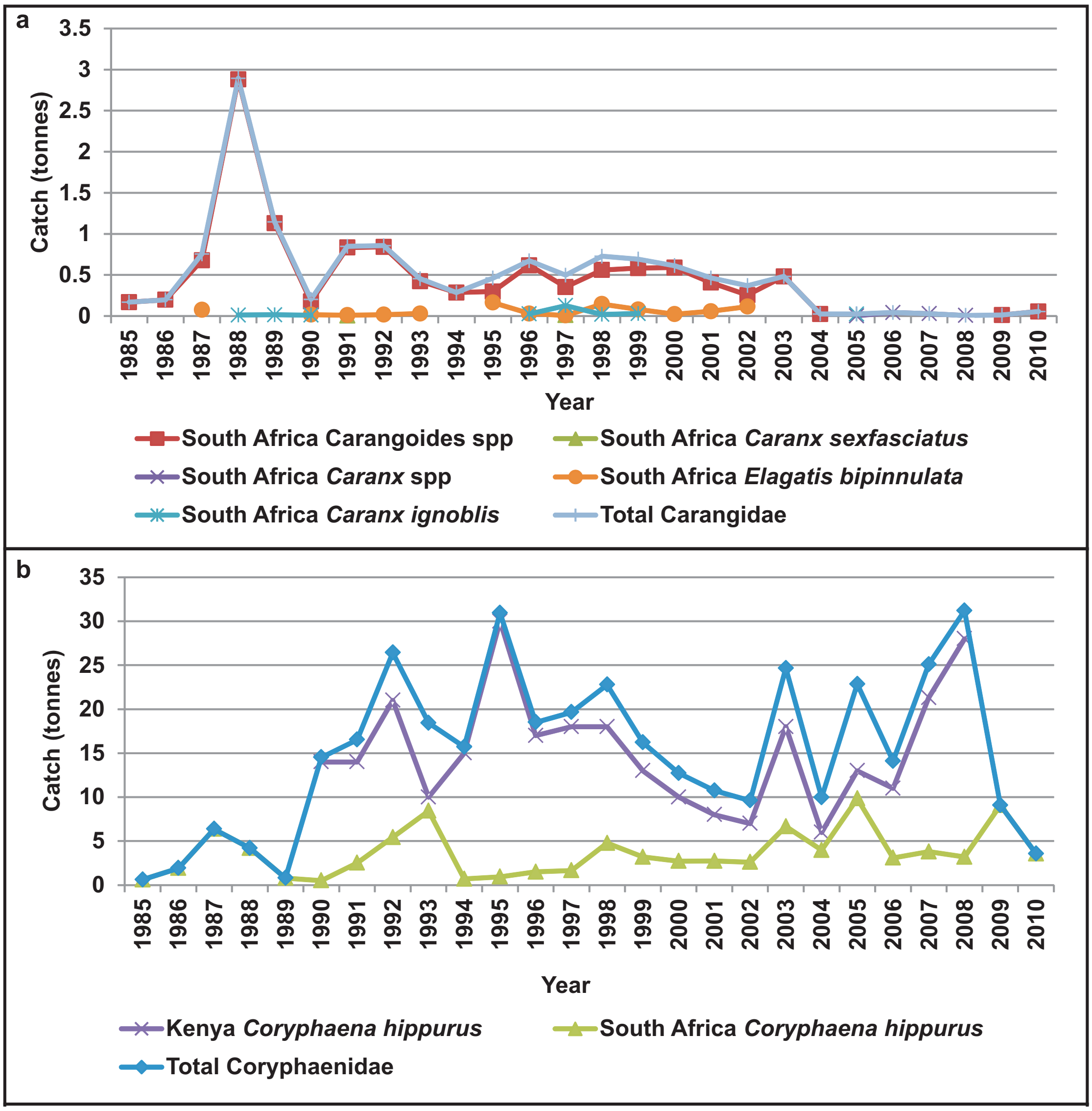


Figure 35 a & b. Time series of annual catches of medium pelagic species and species groups recorded on StatBase. a) Carangidae; b) Coryphaenidae.

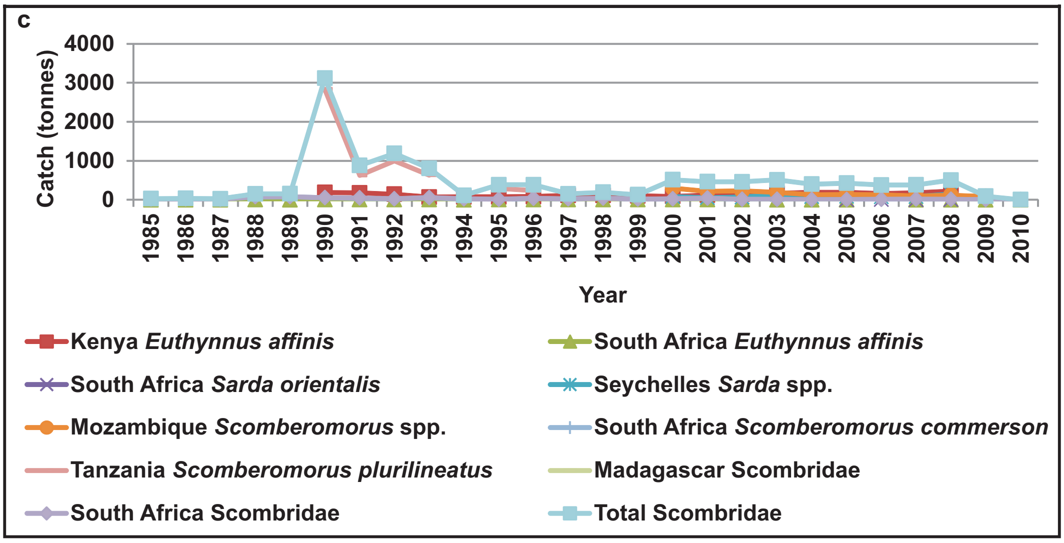


Figure 35c. Time series of annual catches of medium pelagic species and species groups recorded on StatBase: c) Scombridae.

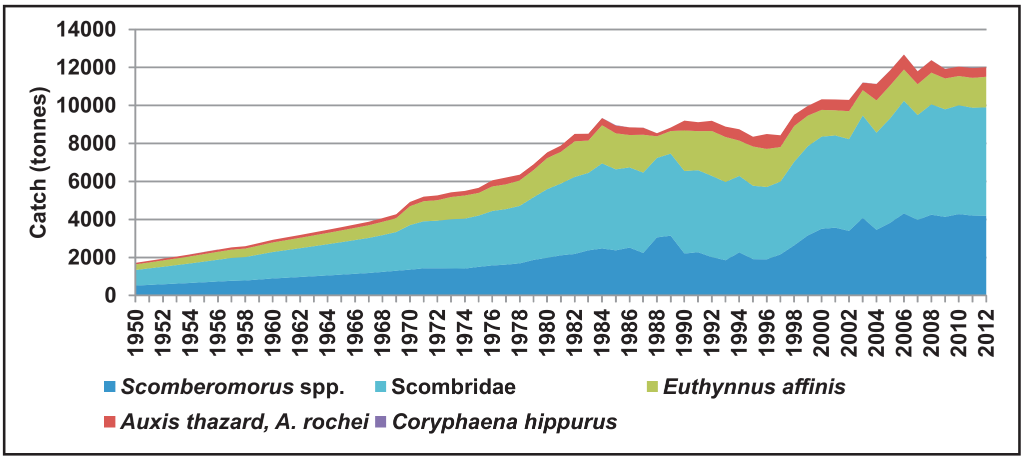


Figure 36. Total landings reported by SWIO countries to FAO of medium pelagic species grouped by family or higher taxonomic level. *nei* = not elsewhere identified.

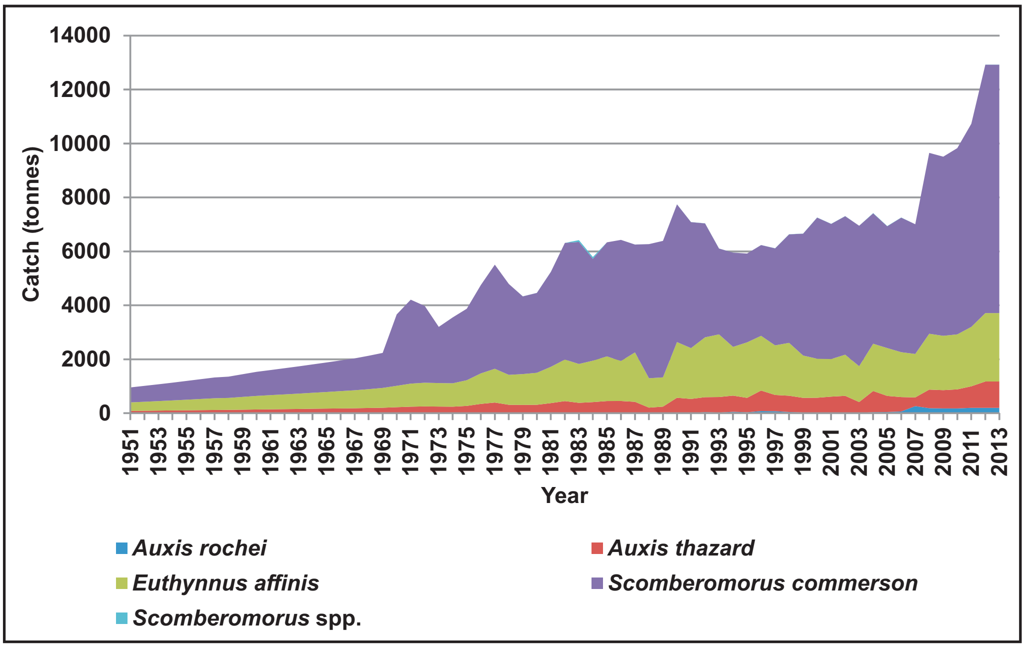


Figure 37. Catches of SWIOFP priority medium pelagic species reported to IOTC.

SMALL PELAGICS

The catch data available on regional databases for small pelagic species are incomplete in all respects, and there are inconsistencies between the three major databases of FAO, WIOFish and StatBase. It is therefore difficult to draw any reliable results or conclusions from them.

Examination of the overall distribution of landings of small pelagics by country as recorded for 2010 in WIOFish (2011) show the highest reported catches from Madagascar at 9,150t followed by KZN at 4,100t, Mozambique at nearly 2,000t and Seychelles at 250t per annum, while the remaining countries do not provide catches in WIOFish (Figure 38). The four taxonomic groups shown on WIOFish (2011) as supporting the highest catches are, in descending order, Carangidae *nei* at approximately 8,000t, *S. japonicus* and Scombridae *nei* at approximately 3,700t and 3,000t respectively, and *T. delagoa* and *R. kanagurta* at less than 500t each (Figure 39).

The highest catches of small pelagic species included in StatBase are those from Tanzania for the rainbow sardine *D. acuta*. These peaked at over 8,000t in 1990 but dropped to between 1,500-3,500t over the next five years after which no more data is available. Catches of Carangidae recorded on StatBase are dominated by records of *D. macarellus* and *Trachurus* spp. from Tanzania between 1990 and 1996 (the full extent of the time-series) and in later years those of Carangidae from Seychelles, which peaked at >2,000t in 2002. Annual catches on StatBase for all other countries were less than 30t per year (Figure 40a).

The total annual catches of small pelagic Scombridae on StatBase ranged from 400 to 800t between 2000 and 2009 but were less than 100t for the remainder of the time series. The major contributors to the total were *R. kanagurta* and *Rastrelliger* spp. from Seychelles and Kenya (Figure 40b). Only Kenya (*Sardinella melanura*) and South Africa recorded catches of Clupeidae, of which *S. melanura* was the higher, with the records starting at 439t in 1990, declining to 112t by 1995 and then varying between approximately 100t and 200t since then (Figure 40c). Catches of *Sardinops* from South Africa were less than 3t throughout the time series. Those records represent only the small portion of total catches of *Sardinops* taken in KwaZulu-Natal, the bulk of the catch is taken in the coastal waters of the south and western parts of South Africa.

The catch/time series reported to FAO are also incomplete and often intermittent. The available information, aggregated by family or, in the case of Clupeoidei *nei,* at Suborder, is shown in Figure 41. These data indicate that catches of Clupeidae have been the highest from the early 1970s onwards, increasing to the late 1990s, albeit with high variability, and now have levelled off on average at 12,000 to 16,000t, declining in the last few years of the series. However, the longer-term trends are masked by high inter-annual variability. Scombridae have been the next most abundant component in the regional catches, increasing from 300t at the start of the 1970s to a peak of over 6,400t in 2005 before declining to less than 1,800t in 2012. Catches of Carangidae, Clupeoidei *nei,* and Engraulidae have all been considerably lower at 1,100t or less.

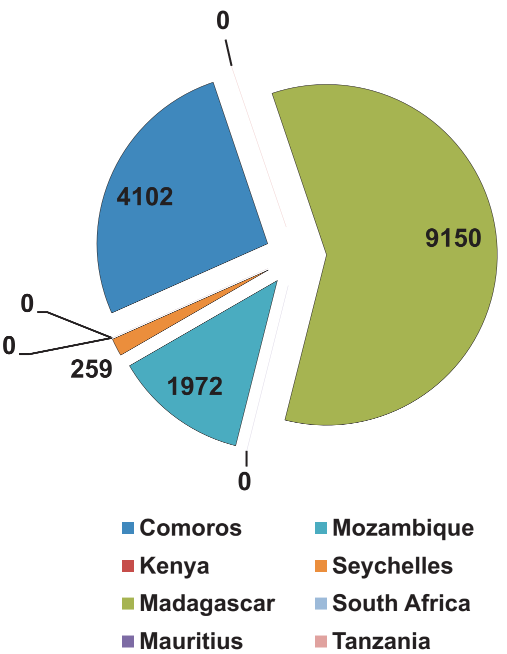


Figure 38. Total annual tonnage of small pelagic species by country as reported on WIOFish.

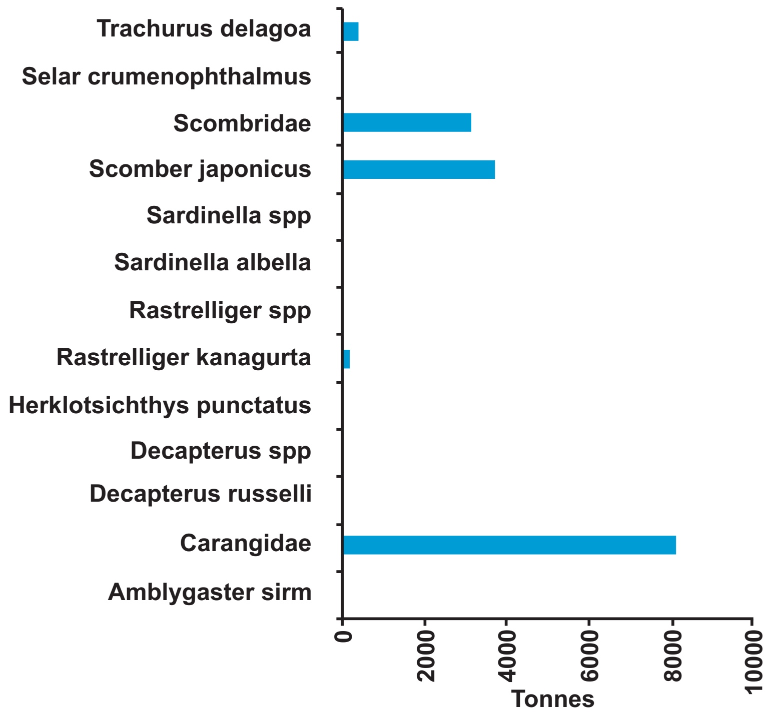


Figure 39. Annual catches of small pelagic taxonomic groups recorded on WIOFish, summed for all the reporting countries.

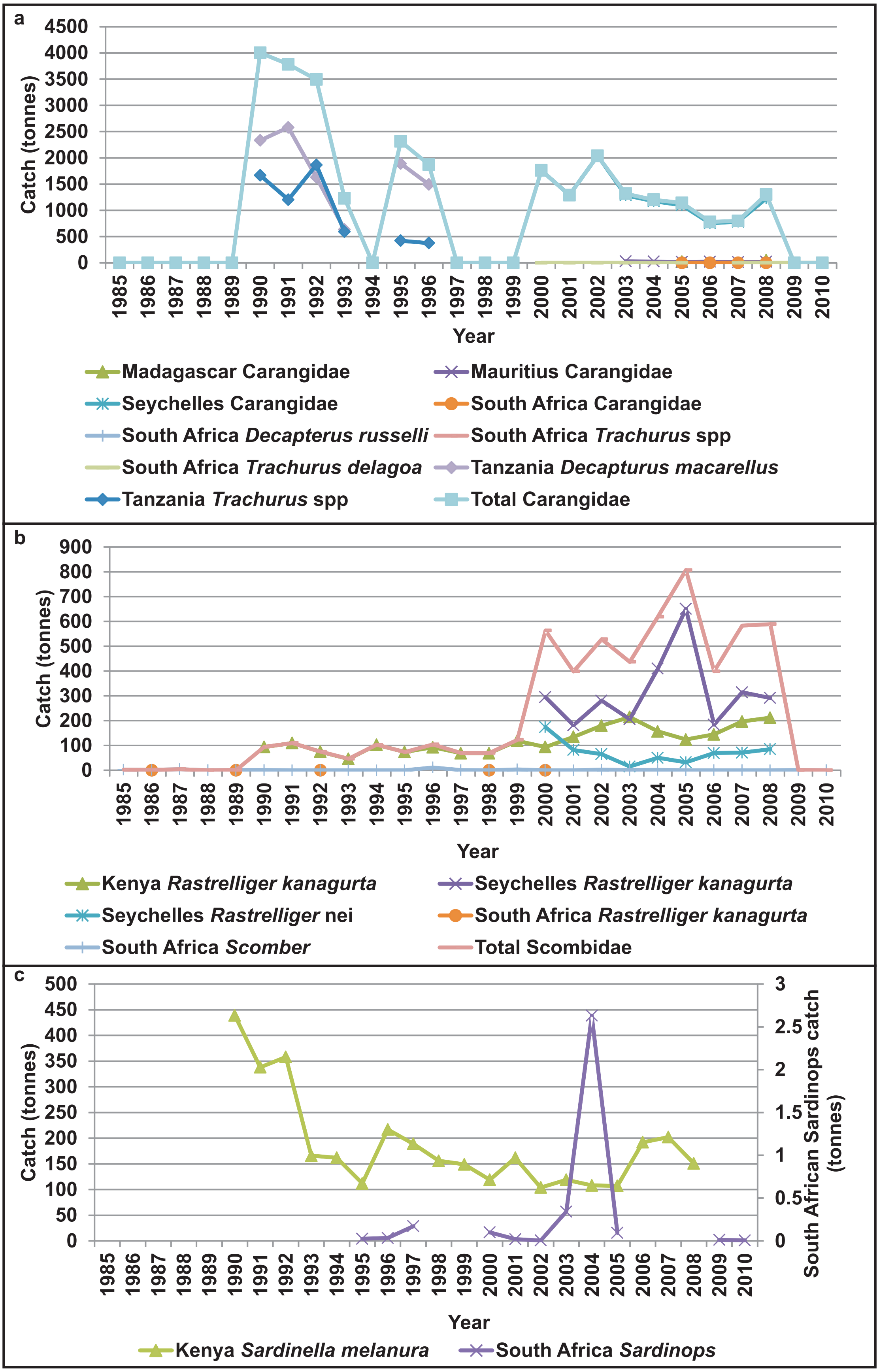


Figure 40 a, b & c. Time series of annual catches of small pelagic species and species groups by country recorded on StatBase. a) Carangidae, b) Scombridae and c) Clupeidae.

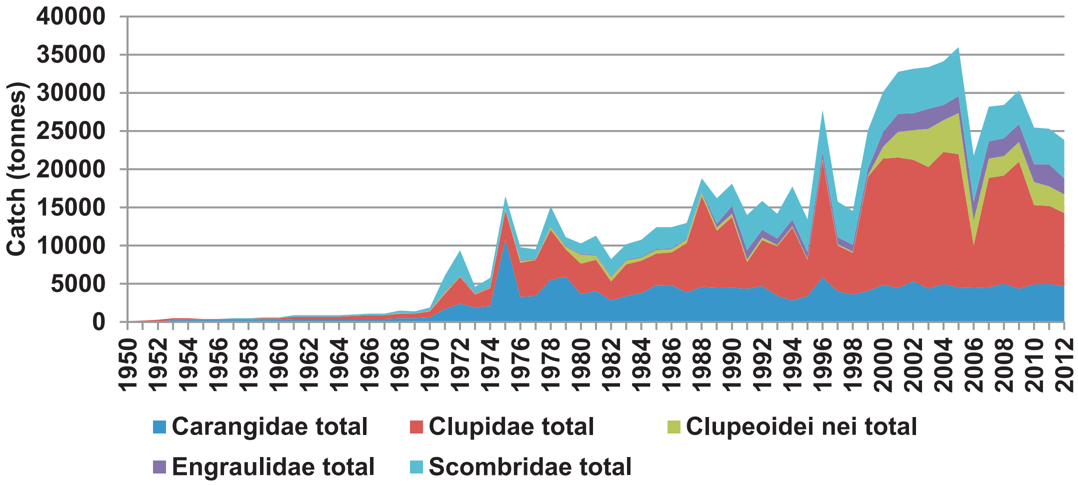


Figure 39. Total landings reported by SWIO countries to FAO of small pelagics grouped by family or higher taxonomic level. *nei* = not elsewhere identified.

CONCLUSIONS

It is clear from the foregoing sections that there are problems with the reliability and coverage of the available regional databases, especially in relation to the medium and small pelagic species. The IOTC records for the SWIO countries, with the exception of Mozambique which only recently joined the Commission, appear to be generally complete and to include comprehensive reporting at the species level. This includes the SWIOFP priority large pelagic species and some of the medium pelagic species. Two other regional databases, StatBase and FAO, clearly do not cover catches of all species, fisheries or years. They are also frequently only aggregated at higher taxonomic levels. Nevertheless, the data reported to FAO provide long time-series for those taxonomic groups reported by countries making it of some value in assessing the nature and trends of those landings. Although WIOFish is not designed to be a statistical database, it does provide useful insight into the diversity of fisheries and their landings, especially in the most recent year.

Drawing primarily on the IOTC and FAO databases, the highest annual catches of large pelagics across the region were skipjack tuna (*K. pelamis*) and yellowfin tuna (*T. albacares*) which were each in the region of 50,000t in 2010, followed by bigeye tuna (*T. obesus*) at approximately 10,000t. All the other large pelagic species reported to IOTC and FAO were considerably lower with 2010 catches of swordfish (*X. gladius*) and Indo-Pacific sailfish (*I. platypterus*) at less than 2,000t and the other species even lower. The trends in catches of these five most abundant species have been of an increase in catches from the early 1980s, apart from *T. obesus*, which only started to increase in the 1990s, tending to stabilise since the turn of the century, albeit with ongoing fluctuations. These species are managed by IOTC and provided countries comply with the requirements of IOTC in terms of monitoring and reporting catches and comply with the relevant IOTC regulations on fishing effort and catches, they should be under a sustainable harvesting regime.

In the case of the medium pelagic species, the IOTC and FAO databases appear to provide the most comprehensive and reliable catch time-series even though still incomplete in important aspects. In the case of the IOTC database, several priority medium pelagic species do not fall within the IOTC mandate and therefore are not included, while the FAO database is variable in the taxonomic detail provided. The StatBase information suggests that Scombridae comprise the highest catches but the information on Carangidae is clearly incomplete. The data from FAO, aggregated across the SWIO countries, gives the highest landings as being *of Scomberomorus* spp. at over 9,000t in 2010, followed by catches of members of the Suborder Scombroidei and of the species *E. Affinis*, also a member of the Scombridae, both at >2 000t. Other species were only recorded at much lower levels and included *A. thazard* & *A. rochei* combined as well as *C. hippurus*. The information on IOTC was similar in terms of species and overall magnitude of catches and, together, these two databases demonstrate the importance of the three Scombrid species: *A. thazard*, *E. affinis* and *S. commerson*. However, attention is drawn to the declining trend in *E. affinis* since the mid-1990s in both the FAO and IOTC datasets, which could reflect over-exploitation. Unfortunately, the sparse information, yet increasing trend in reported catches in some taxonomic groups, suggests increasing fishing effort, making it impossible to determine the status of these species from these data.

A further medium pelagic species that is increasingly important and associated with a greater use of FADs but is not being adequately monitored in landings is *C. hippurus* (Figure 35b). This is not an IOTC species and only appears in catch records from South Africa on the FAO database with catches in recent years at almost 10t. However, it is shown as also being caught in Comoros and Kenya on StatBase and in Mozambique and Tanzania on WIOFish, where the total recorded annual catch adds up to 999t.

It is surprising that individual species of the Carangidae are not more prominent on the FAO database but it is likely that some catches of medium pelagic carangids are included in catches reported collectively as Carangidae, which have been included in the small pelagic category for this report. WIOFish records non-zero landings of *C. fulvoguttatus* and *C. gymnostethus* and *of Caranx* spp. Catches of Carangidae recorded on StatBase are dominated by records of *D. macarellus* and *Trachurus spp.* between 1990 and 1996 (the full extent of the Tanzania time-series on StatBase) and in later years those from Seychelles, which peaked at >2,000t in 2002. Annual catches of Carangidae reported on StatBase for all other countries were <30t per year (Figure 38a). In contrast, the total catches of Scombridae on StatBase varied between 400 and 800t between the years 2000 and 2009, but are recorded at less than 100t for the remainder of the time series. The major contributors to the total small pelagics were the scombrids *R. kanagurta* from Seychelles and Kenya (Figure 35 b).

Only Kenya and South Africa reported catches of Clupeidae to StatBase. Those of Kenya's *S. melanura* are higher, with the records starting at 439t in 1990, declining to 112t by 1995 and then varying between 100t and 200t since then (Figure 40c). Catches of *Sardinops* from KwaZulu-Natal were reported to be less than 3t throughout the time series. This is in sharp contrast to the average of around 400t reflected in national catch records (Fennessy 2014). Nevertheless, this is still only a small portion of the average annual 160,000t taken in the coastal waters of the south and western parts South Africa over the past decade.

While Clupeidae are thus poorly represented on StatBase, catches of small pelagics reported to FAO show them to be the major component, fluctuating around 14,000t in recent years. These are made up mainly of *Sardinella* spp. reported by Tanzania and Comoros. The next largest contribution to the small pelagics comes from the Scombridae, which peaked at over 6,000t in 2006 but has since fallen to <2,000t in 2010. Catches in this family comprise mainly Indian mackerel *R. kanagurta* and catches recorded as *Rastrelliger* spp. from Comoros, Seychelles and Tanzania. Indian mackerel also emerges as an important species in StatBase. *Scomber japonicus* catches of 2t were reported by South Africa for 2009 and 2010. Catches of > 1,000t of unspecified Engraulidae in 2009 and 2010 were reported by Comoros and of 600-700t of Carangidae, mainly by Comoros as Carangidae, with 4t of *Trachurus* spp. reported by South Africa in 2010. StatBase data indicate that *D. macarellus*, reported by Tanzania, is an important carangid species for local fisheries.

Although WIOFish is not intended to be a statistical database and is thus not consistent with data reported to FAO, it does provide useful insight into the nature and relative scale of catches. Thus, while relatively high catches of Scombridae are reported on WIOFish, the highest catches of small pelagics comprise unspecified Carangidae of over 8,000t, mainly from Madagascar and Mozambique, followed by the scombrids, *S. japonicus* at 3,700t by South Africa, *R. kanagurta* and *T. delagoa,* both reportedly contributing less than 400t each.

Based on all three databases, the most important small pelagic species across the region is almost certainly the Indian mackerel *R. kanagurta.* The scombrid, *S. japonicus* may be locally important although it appears to be limited largely to South African catches. Species of *Sardinella* and *Trachurus*, are also important, including the SWIOFP priority species of *D. macarellus, S. albella* and *T. delagoa*. Based on the StatBase data for Tanzania, the mackerel scad *D. macarellus* and rainbow sardine *D. acuta* must also be considered particularly important species in the region.

The FAO data aggregated by family do not give any clear indications of the status of the stocks. Catches of Scombridae declined rapidly from 6,413t in 2005 to 1,783t in 2010, driven largely by a decline in catches of *R. kanagurta* from 5,500t to 1,328t over the same period. It is possible that this decline reflects a rapid fall in abundance of the species but it is also possible that it reflects changes in monitoring and reporting, changes in fishing strategies or environmental changes.

Fisheries independent data (surveys)

The Gap Analysis for pelagic species listed surveys undertaken in the SWIO region, including those by the RV Dr Fridtjof Nansen, the RV Prof. Mesyatsef and surveys undertaken by commercial vessels leased by SWIOFP, for example the F/V Menhadin (SWIOFP 2009). Subsequently, a comprehensive survey of historical data sets from past fisheries research and exploratory cruises in the SWIO region was undertaken by Romanov (2012). He lists a total of 116 surveys, which he ranked as being of High or High/Low interest to SWIOFP and for which fisheries data are available. Of these, two conducted by IRD have their data available in the report; the data of 17 can be found in the NANSIS database; 66 in the YugNIRO[8] Archive and 31 in the YugNIRO Archive/SIOTLLRP databases. All of those in the YugNIRO Archive and YugNIRO Archive/SIOTLLRP databases were evaluated by Romanov as being in critical need of data rescue because the data are on paper and in danger of being lost and requiring investment in database management.

SURVEYS UNDERTAKEN BY THE R/V DR FRIDTJOF NANSEN

Romanov (2012) lists 17 cruises undertaken by the R/V Dr Fridtjof Nansen between the years 1997 and 1990. In addition, three cruises have been undertaken since then, covering northern Mozambique, Mauritius and the southern Mascarene, and West Madagascar. The Annex summarises these surveys, including biomass estimates and relevant biological information of some pelagic species.

SURVEYS UNDERTAKEN BY OTHER VESSELS

Apart from the surveys by the Dr Fridtjof Nansen, the other surveys described by Romanov (2012) as being of high importance, and for which the data should be available, are three surveys undertaken by IRD with the Research Vessel 'Coriolis'. These took place between September 1979 and September 1980 in Seychelles waters, as reported by Romanov (2012).

The first, REVES I, surveyed the Mahé Plateau, Amirantes and southern islands of Seychelles. It was aimed at surveying the small pelagic and semi-demersal fish and undertaking oceanographic studies.

The survey, REVES II, took place in two stages and surveyed small pelagic and semi-demersal fish in the Seychelles waters. The survey obtained estimates of demersal and pelagic fish biomass. That of pelagic fish indicated that the total biomass on the Mahé Plateau was in the region of 45,000t. In addition, the survey obtained a biomass estimate for what are described as neritic species, primarily *Decapterus* spp. of 50,000-65,000t, aggregated at the south and the south-east of the plateau.

The remaining surveys considered by Romanov (2012) to be important were undertaken under the auspices of YugNIRO Archive between 1964 and 1989. As reported in the introduction to this section, those databases are only available on paper and in critical need of data rescue.

DISCUSSION

The surveys that have been undertaken in the SWIO region have contributed to information and of the abundance, taxonomic composition and distribution of the fishery resources of the SWIO countries. In many cases they have provided the most comprehensive assessments of these characteristics available. While the results of the surveys undertaken by YugNIRO are possibly outdated in relation to the current ecological characteristics of the region, it is unfortunate that this extensive set of data is not more readily available. If assembled and synthesised it could provide a valuable overview of the complex fishery community structure of the region.

The more recent and accessible results of the Dr Fridtjof Nansen surveys have inherent potential to provide additional information if all the cruise results could be synthesised, for example in a GIS system that would enable analysis and presentation of the spatial characteristics of the combined areas sampled by the Nansen. This would be a large and time-consuming exercise, beyond the scope of this study.

Given the vast area of the EEZs and high seas of the SWIO area and the limitations of a single research vessel that is also being used in other regions, the spatial and temporal coverage of the Dr Fridtjof Nansen is patchy and nor are the data conducive to analysing trends or assessing the stock status (as opposed to biomass measurements) of resources at national or regional scale. Nevertheless, some useful observations emerge from the summaries in the Annex that help to complement the fishery statistics already reported, especially in relation to small pelagics. An important feature of the Dr Fridtjof Nansen survey results is the relatively high contribution of Clupeidae and Engraulidae to the observed pelagic biomasses, a feature that does not emerge as clearly from the available regional fishery catch databases. The genus *Sardinella*, of which *S. gibbosa* occurs in several reports, are the most commonly listed clupeid recorded in surveys from Madagascar, Mauritius, Seychelles, Mozambique and Tanzania.

Unsurprisingly, carangids and scombrids are also commonly referred to in the survey results and include several of the priority species. For example, *T. delagoa* (Madagascar) and *Decapturus* (Mauritius, Mozambique, Seychelles, Tanzania and Kenya), *S. commerson* (Madagascar, Seychelles, Mozambique, Tanzania and Kenya) and *R. kanagurta* (Seychelles, Mozambique, Tanzania and Kenya). The scombrid *D. acuta*, which was an important component of the catches of Tanzania's artisanal fishery as described earlier, was also encountered in surveys off Mozambique and Tanzania.

8. Southern Scientific Research Institute of Marine Fisheries and Oceanography, Crimea, Russian Federation. http://en.yugniro.in.ua/ (accessed 19 January 2015).

Spatial information on priority species

There is insufficient spatial information across the region as a whole to provide meaningful distribution maps of individual stocks. However, the FAO and IOTC data do allow for useful comparisons of the size of catches by country, split into the three pelagic size groups as shown in Figures 42 and 43.

The FAO data demonstrate some important trends in the magnitude and size composition of national catches (Figure 42). They indicate that the highest total catches in the region come from Seychelles, Madagascar and Tanzania, with Comoros also reporting relatively high catches. In comparison, those from South Africa, Kenya and Mozambique are much smaller. There is insufficient information to determine whether these differences are a result of differing degrees of coverage of actual national landings, genuine differences in the actual landings or a combination of the two. South Africa does not have well developed fisheries along the KwaZulu-Natal coast, but the differences between total catches from Kenya, Tanzania and Mozambique are surprising and are more likely to be a result of sampling coverage than indicators of real differences in catch. The second noticeable feature of these distributions is the greater reliance on large pelagics by the SWIO island countries than by the mainland countries, which show a greater proportion of small and medium pelagics in their catches.

The IOTC data do not include the small pelagics or several priority medium pelagic species. The catches reported to IOTC clearly demonstrate the importance of the large pelagics, and the IOTC medium pelagic species, to the island countries of the region (Figure 43). Seychelles, Madagascar and Comoros show the highest landings and in all three cases, large pelagics make up the bulk of the catches. Landings reported by Mauritius are lower but show the same predominance of large pelagic species. As can be seen from Figure 30a, *K. pelamis* and *T. albacares* make up the bulk of the large pelagic component. Catches reported by the mainland countries are considerably lower and include a higher proportion of the medium pelagic species. Mozambique is a new member of IOTC and its catches were not included in the IOTC database at the time of compiling this chapter.

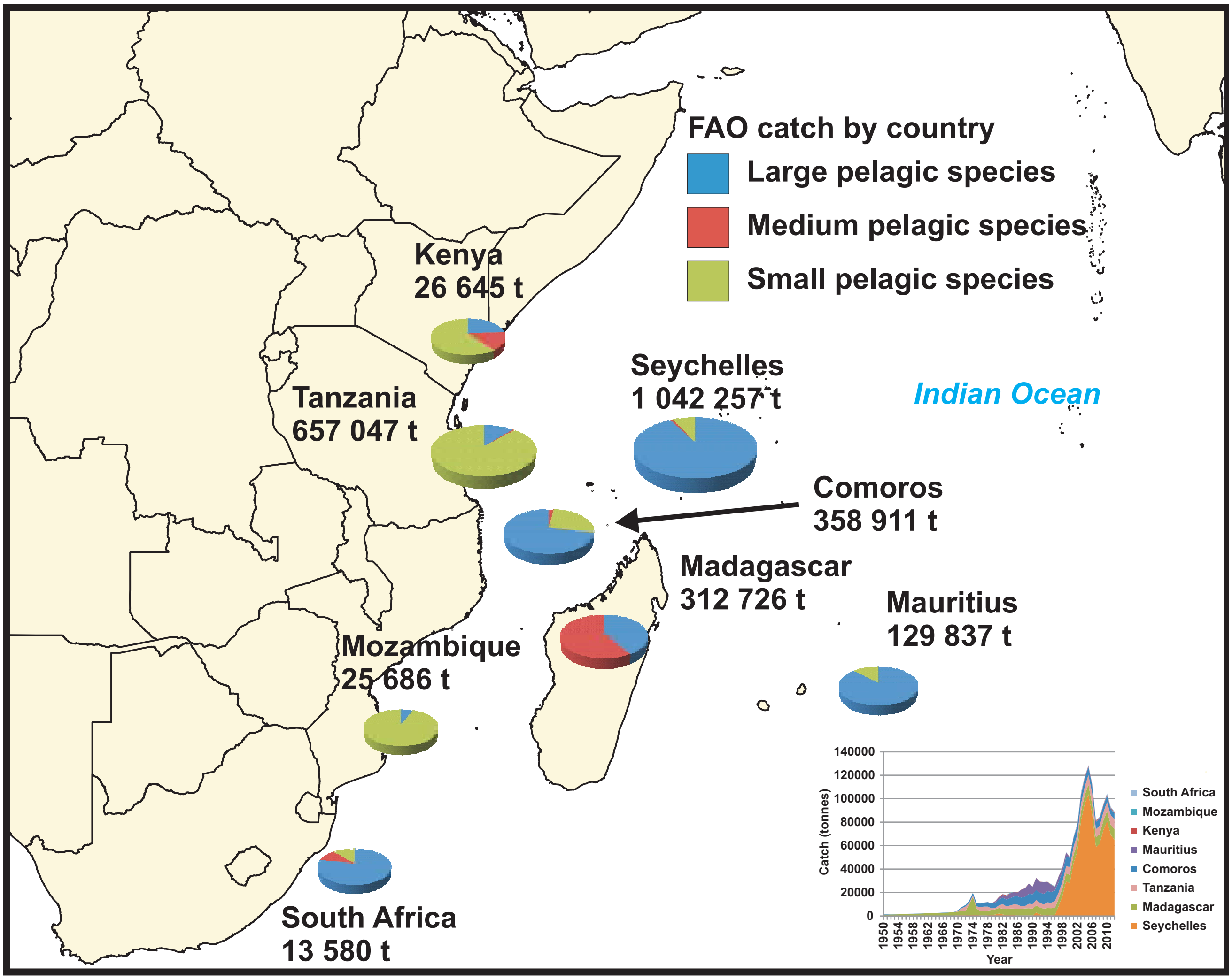


Figure 42. Distribution of catches by country and pelagic category as recorded on the FAO database, catches are aggregated totals from 1950 or earliest year on record for each country to 2012.

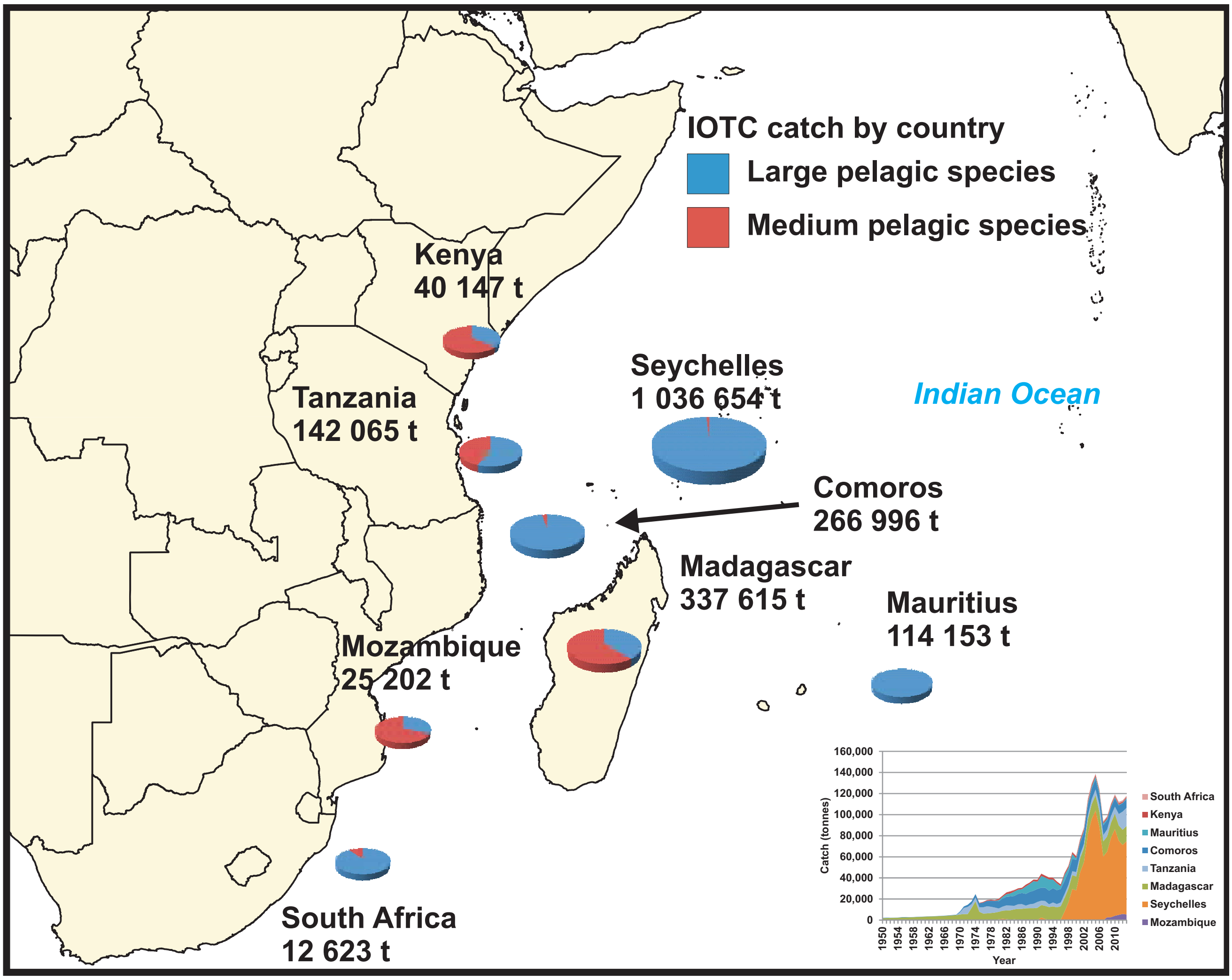


Figure 43. Distribution of catches by country and species size group as recorded on the IOTC database, catches are aggregated totals from earliest year on record for each country.

Biological data on key pelagic species

The Terms of Reference for the study require that the biological data available in databases and in SWIO literature should be explored and estimates should be made of the basic biological parameters of priority species, particularly the small and medium sized pelagic fishes. Examination of the available data revealed that it was inadequate for any analyses of biological features and characteristics, or for stock assessment. Most of the data refer only to catch and do not include any length frequencies or other biological information required for growth analyses. Some of the survey information, particularly from the RV Dr Fridtjof Nansen surveys, includes length frequencies but these are isolated samples and insufficient for determination of growth rates. Such analyses would require a time series of length frequencies drawn from the same population over a period of several years, which the surveys could not provide.

After examination of the information available in SWIO and other literature it was concluded that the best sources of information for biological data are FishBase (2012) and the FAO Aquatic Species Fact Sheets (FAO ASFS, 2012). Drawing mainly from these two sources of information, the biological characteristics of selected species are presented. The medium and small pelagic species selected were those making the larger contributions to catches from the countries while also presenting examples from the major families represented. Two large pelagic species are also included, *I. platypterus* and *Xiphias gladius*, which are important to many countries, including in recreational fisheries. Six medium pelagic species are covered: *E. affinis*, *S. orientalis, E. bipinnulata, C. hippurus, S. commerson* and *A. thazard;* and six small pelagic species: *D. macarellus, D. acuta, R. kanagurta, S. abdella, S. japonicus* and *T. delagoa.*

Status of selected stocks

The important large pelagic species in the region are well monitored by IOTC and, as far as the data allow, are routinely assessed for status and trends. The detailed assessment and species reports can be obtained from the IOTC website at http://www.iotc.org/English/index.php and only a brief overview is presented here. In general, the large pelagic stocks in the western Indian Ocean are in reasonable condition and when assessed under the auspices of IOTC in 2009, the most important commercial species were estimated to be neither overfished nor subject to overfishing, with the exception of albacore (*T. Alalunga),* which was considered to be subject to overfishing. Moreover, while stocks of swordfish in the Indian Ocean as a whole are not overfished, the SWIO resource is considered to have been overfished in the past decade and the biomass to be below the level that would produce MSY (BMSY). In addition, there are several important large pelagic species for which there have been no reliable assessments and the status of which remain uncertain, including *T. tonggol*, *I. platypterus*, *M. nigricans, M. indica* and *T. Audax* (IOTC-SC14 2011, Table 4).

The national reports to the 4th Session of the SWIOFC Scientific Committee in 2010 were used to compile a regional synthesis of stock status. Based on the available information (FAO 2011 refers) and which is assumed to be broadly consistent with the IOTC assessments, the SWIOFC summary suggests that the populations of coastal tunas and related species in the SWIOFP countries are largely under-exploited or moderately exploited with only a few being fully-exploited and two being over-exploited. There are also several species for which the status is unknown. It is important for the SWIOFP countries to recognise that these stocks are all shared and straddling stocks, and cannot be managed as national populations in isolation from the remainder of the biological stock. For those species falling within the IOTC

Table 4. Status of the stocks (IO = Indian Ocean). Large and medium pelagics listed in order in which they appear in Table 5 of IOTC (2011), small pelagics listed in alphabetical order of country in which assessed.

Species	*Country / Region*	*Status*	*Most Recent Data Used in Assessment*	*Source*
Large Pelagics				
Thunnus alalunga	Indian Ocean	Not overfished; Subject to overfishing	2010	IOTC 2011
Thunnus obesus	IO	Not overfished; Not subject to overfishing	2009	IOTC 2011
Katsuwonis pelamis	IO	Not overfished; Not subject to overfishing	2009	IOTC 2011
Thunnus albacares	IO	Not overfished; Not subject to overfishing	2009	IOTC 2011
Xiphias gladius	IO b) SWIO	a) Not overfished; Not subject to overfishing b) Overfished; Not subject to overfishing	2009	IOTC 2011
Makaira indica	IO	Uncertain	2010	IOTC 2011
Makaira mazara	IO	Uncertain	2010	IOTC 2011
Tetrapturus audax	IO	Uncertain	2010	IOTC 2011
Istiophorus platypterus	IO	Uncertain	2010	IOTC 2011
Thunnus tonggol	IO	Uncertain	2010	IOTC 2011
Medium Pelagics				
Auxis rochei	IO	Uncertain	2010	IOTC 2011
Auxis thazard	IO	Uncertain	2010	IOTC 2011
Scomberomorus commerson	IO	Uncertain	2010	IOTC 2011
Scomberomorus commerson	Mozambique	Fully-exploited	2011	Mozambique nat. report SWIOFC Sc. Com. March 2014
Euthynnus affinis	IO	Uncertain	2010	IOTC 2011
Scomberomorus guttatus	IO	Uncertain	2010	IOTC 2011
Small Pelagics				
Sardines	Kenya	Fully exploited	2011	Kenya nat. rep. SWIOFC Sc. Com. March 2014
Decapturus spp.	Mauritius	Under-exploited	2011	Mauritius nat. rep. SWIOFC Sc. Com. Mar. 2014
Small pelagics	Mozambique	Ranging from Low- to Fully-exploited	2011	Mozambique nat. rep. SWIOFC Sc. Com. March 2014
Small pelagics	Tanzania	Moderately-exploited	2011	Tanzania national report to SWIOFC Scientific Committee, Mar. 2014

mandate, that requires acting in accordance with the regulations and decisions of the Commission.

IOTC also provides status reports on some medium pelagic species but has been unable to obtain reliable estimates of status for any of them and the most recent information available refers to their status as being Uncertain (Table 4). Executive Summaries on the status and trends of the following medium pelagic species can be found in IOTC-SC14 (2011): *E. affinis, S. commerson* and *S. guttatus*, as well as *A. thazard* and *A. rochei.* These are SWIOFP priority species with the exceptions of *S. guttatus* and *A. rochei,* The Mozambique national report to SWIOFC reported the status of *S. commerson* to be fully-exploited. No other validated evidence of the status of the priority medium pelagic species could be found.

For the small pelagics, the report to the SWIOFC Scientific Committee (FAO, 2012) provides some information on the likely status of four species groups (Table 4). Under-exploited was *Decapturus* species in Mauritius while Kenya reported that the sardine resources in that country were fully-exploited. Tanzania reported that the small pelagic resource there was moderately exploited and Mozambique estimated that the status of different components of the small pelagic stocks ranged from low-exploitation levels to full-exploitation.

With the exception of the high value large pelagic species assessed by IOTC, there is very little reliable information available on the status of stocks at the national or regional levels.

STATUS OF SELECTED PRIORITY SPECIES AS REPORTED BY IOTC

This section reports on a selection of several important coastal pelagic species and all of the medium pelagic priority species for which information on status and trends is available from IOTC. Further detail on those species and on the others covered by the Commission may be found in IOTC-SC14 (2011).

Xiphias gladius

The swordfish *Xiphias gladius* is reported in WIOFish to be caught in all countries in a total of 16 fisheries. IOTC-SC14 (2011) reports that at the most recent assessment in 2009, the stock was estimated to be not overfished and not subject to overfishing. The catches at that time were below the MSY level. It was also noted that the decrease in longline catch and effort in recent years had lowered the pressure on the Indian Ocean stock as a whole and that the current fishing mortality was not expected to reduce the population to an overfished state. The stock structure of swordfish in the Indian Ocean is not well understood but the southwest region was identified as being of concern because it is thought to be more depleted than the other regions and may have limited mixing with them. This is clearly particularly important for the SWIO countries. The southwest resource is considered to have been overfished in the past decade and the biomass to be below the level that would produce MSY (BMSY). The Commission notes that recent declines in catch and effort brought the fishing mortality rates to levels below FMSY and the resource is not currently overfished.

According to IOTC, swordfish was mainly a by-catch species in industrial longline fisheries prior to the early 1990's and catches increased slightly between 1950 and 1990 as the target species increased. Since 2004, annual catches have been declining steadily as a result of an on-going decline in the fishing effort in the region by Taiwan Province of China longliners. Since 2004 catches have been dominated by the Taiwan PC and EU fleets (Spain, UK, France and Portugal).

The estimated MSY for the whole Indian Ocean is 29,900–34,200t and IOTC warns that annual catches of swordfish should not exceed this estimate. Provided the catch remains substantially below the estimated MSY then management measures are not required but there is a need for continued monitoring and improvements in data collection, reporting and analysis. For the SWIO fraction of the species, the IOTC Scientific Committee recommended that the MSY is estimated at 7,100–9 400t and that catches in the SWIO should be maintained at or below the catch in 2009 (6,678t) until there is a recovery and the biomass exceeds BMSY.

Istiophorus platypterus

The Indo-Pacific sailfish *I. platypterus* is reported on WIOFish to be caught in the Comoros, Kenya, Mauritius, Mozambique, South Africa and Tanzania while, in addition to these countries, Madagascar reported catches to IOTC. IOTC-SC14 reported that there was no quantitative stock assessment available for the species because of a lack of data for several fisheries. As a result, the stock status is uncertain. Some features of the biology, productivity and fisheries of the Indo-Pacific sailfish, together with the lack of relevant data, are a cause for concern. Nevertheless, the decrease in longline catch and effort in recent years has led to reduced pressure on the Indian Ocean stock as a whole but, because of lack of sufficient information, the effect this will have on the resource is unknown. The Scientific Committee recommended that annual catches of the species should be urgently reviewed and that there is a need to improve data collection and reporting.

Indo-Pacific sailfish are caught mainly by gillnets (78%) with remaining catches recorded by troll and hand lines (15%), longlines (7%) or other gears. The minimum average annual catch estimated for the period 2006 to 2010 is around 22,151t. In recent years, the countries attributed with the highest catches of Indo-Pacific sailfish are situated in the Arabian Sea (India, Iran, Pakistan and Sri Lanka). Smaller catches are reported for linefishers in Comoros and Mauritius and by Indonesia longliners. This species is also a popular catch for sport fisheries in all of the SWIO countries.

IOTC reported that catches of Indo-Pacific sailfish increased substantially since the mid-1980's through the development of a gillnet/longline fishery in Sri Lanka and the movement of the Iranian gillnet fishery beyond the country's EEZ and into the high seas. The catches of the species with drifting longlines and other gears have not shown any marked trend in recent years and total catches have been about 5,000t. However, this is considered to be an underestimate because of its low commercial value.

Euthynnus affinis

IOTC-SC14 (2011) reported on the status of *E. affinis* in the IOTC area as a whole. The report states that there was no quantitative stock assessment available for the species in the Indian Ocean and that stock status was uncertain. However, there is cause for considerable concern about the status arising from the lack of data and certain aspects of the fisheries for the species.

The catch estimates for the species available to IOTC were based on small amounts of information and are highly uncertain. The catches for *E. affinis* increased markedly from around 10,000t in the mid-1970's to approximately 50,000t in the mid-1980's and 130,634t in 2009, which was the highest catch recorded for the species. The average annual catch estimated for the period 2006 to 2010 is 122,895t. About 60% of the catches of the species are taken in the East Indian Ocean.

E. affinis is reported on WIOFish as being caught in a total of 11 fisheries in Comoros, Kenya, Madagascar, Mozambique, Seychelles, South Africa and Tanzania. The gear used includes hook and line, ring nets, gillnets, and purse seines. Data from IOTC shows the reported catches from SWIO countries peaked at above 4,000t in 1992 and subsequently dropped, fluctuating between approximately 2,000t and 2,600t since 2000.

IOTC-SC14 (2011) recommends undertaking research on improving indicators, clarifying the stock structure and identifying suitable stock assessment approaches for data poor fisheries such as those for *E. affinis.*

Scomberomorus commerson

IOTC (IOTC -SC14 – 18) reports indicate that no quantitative stock assessment is currently available for this species in the Indian Ocean and stock status is uncertain. Aspects of the fisheries for the species and the lack of data are a cause for considerable concern. The continued increase of annual catches for the species has increased the pressure on the Indian Ocean stock as a whole and the apparent tendency for *S. commerson* individuals to remain in particular localities means that overfishing in these areas could lead to localised depletion.

As with *E. affinis,* the catch estimates for the species were derived from very small amounts of information and therefore are highly uncertain. Catches increased from around 50,000t in the mid-1970s to >100,000t by the mid-1990s. In recent years catches have continued to increase and the highest catches of *S. commerson* were recorded in 2010 at 124,107t. *S. commerson* is reported as being caught in 19 fisheries in all SWIOFP countries apart from Seychelles and Mauritius. It is caught using a number of different gears including seine nets, gill nets, hook and line, traps and others. The total annual catch from all SWIO countries has been over 7,000t for most of this century so far and was highest in 2003 at 7,981t.

IOTC recommends that further work should be undertaken to derive additional stock indicators for the species.

Auxis thazard

IOTC's assessment for this medium pelagic species is very similar to that for *E. affinis* and *S. commerson*; there is currently no quantitative stock assessment but aspects of the fisheries for the species together with the lack of suitable data to use in an assessment are cause for considerable concern. The estimated catches have increased steadily since the late 1970's and had reached >45,000t by the mid-1990s. There has been a considerable increase since 2006 and the average annual catch for the period 2006 to 2010 is estimated at 64,245t with the highest catches on record of 71,023t in 2010. As with *S. commerson*, increasing annual catches for *A. thazard* are adding to the pressure on the Indian Ocean stock but what effect this will have is not known.

WIOFish records only one fishery reporting catches of *A. thazard,* which is in Madagascar and is described as 'Small nets, gill nets, sharks & rays'. Madagascar is also the only country that has reported catches of the species to IOTC. In contrast to the trend for IOTC countries as a whole, catches of the species by SWIO countries appear to have declined in recent years and have been just over 300t since 2007. The maximum catch from these countries reported to IOTC was 1,214t in 1996.

Research emphasis on improving indicators and exploration of stock structure and stock assessment approaches for data poor fisheries are warranted.

Biological profiles of key pelagic species

This section provides an overview of key biological information, life history parameters and distribution of some of the prominent pelagic species.

The information is largely extracted from the FAO species profiles (FAO ASFS, 2012), supplemented with additional information where possible.

LARGE PELAGICS

ISTIOPHORUS PLATYPTERUS

Common name:
– Indo-Pacific sailfish

Primary source of information:
– FAO ASFS, 2012; FishBase, 2012

Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

I. platypterus or Indo-Pacific sailfish is found in the tropical and temperate waters of the Indo-Pacific. In the western Indian Ocean it is found around 45°S and in the eastern Indian Ocean at 35°S. It has entered the Mediterranean Sea via the Red Sea and the Suez Canal. It is a highly migratory oceanic and epipelagic species usually found above the thermocline. The species is most densely distributed in waters close to coasts and islands. It may form shoals of similar sized individuals. In the Indian Ocean, off East Africa, the abundance and distribution of the species reaches a peak when the East African Coastal Current is at its maximum temperature of 20° to 30°C and minimum salinity of 35.2 to 35.3°/oo during the months of the northeast monsoons. The highest biological productivity in the surface waters is also attained at this time, caused by a mixing of waters at the junction of the southward-flowing Somalia Current and the northward-flowing East African Coastal Current.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

No information was available for spawning in the Indian Ocean but spawning seems to take place throughout the year in tropical and subtropical waters of the Pacific with peak spawning occurring in the summer. Eggs shed from a captured female in the Indian Ocean averaged 1.304 mm in diameter. In FishBase the length at maturity recorded in Taiwanese waters is 221 cm (male) and 232 cm (female). According to the FAO ASFS, this species reaches a maximum size > 340 cm in total length and a maxuimum weight of 100 kg. In sport fishing at Malindi, Kenya, the majority of individuals caught ranged from 203 to 254 cm fork length (224 to 279 cm total length) and from 18.1 to 47.2 kg in weight.

GROWTH AND MORTALITY

From FishBase.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
253.0	OT	0.12	-3.92	M		22.0		3.87	Taiwan	eastern waters	No	No
261.0	OT	0.11	-4.21	F		22.0		3.87	Taiwan	eastern waters	No	No
341.0	TL	0.44				22.0		4.71	Japan	East China Sea	No	No

OT = Eye-fork length.

XIPHIAS GLADIUS

Common name:
– Swordfish

Primary source of information:
– FAO ASFS, 2012; FishBase, 2012


Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

The swordfish is a pelagic-oceanic species found in the Atlantic, Indian and Pacific Oceans, including the Mediterranean Sea, the Sea of Marmara, the Black Sea, and the Sea of Azov. It inhabits tropical and temperate and sometimes cold waters and is a highly migratory species. It may also be found in coastal waters. In general swordfish are found in surface waters above 13ºC and have the greatest temperature tolerance of the billfishes, ranging from 5ºC to 27ºC. Swordfish migrate towards cooler water in summer and return to warmer waters in the autumn.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

X. gladius can reach a maximum size of 445 cm total length and about 540 kg in weight. No specific information could be found for the SWIO region but examples of size ranges found elsewhere are given. Very little specific information on spawning in the SWIO area is recorded, although spawning in other regions has been well-documented. Sexual maturity occurs at 5 to 6 years and 150 to 170 cm eye-fork length in the Pacific and Indian Oceans. FishBase gives 221 cm as the length at first maturity, with a range of 156-250 cm. There is conflicting evidence about the size at which males and females reach sexual maturity and whether or not this occurs at smaller sizes in males or females. Swordfish of less than 139 cm eye-fork length may be regarded as immature.

GROWTH AND MORTALITY

Growth records from FishBase – no information on the SWIO region but selected examples from other areas are provided.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
194.4	OT	0.34	-1.22	M		19.0		4.11	Greece	Aegean Sea	No	No
236.0	OT	0.17	-2.10	F		19.0		3.98	Greece	Hellenic Seas	No	No
252.2	OT	0.13	-2.43			19.0		3.93	Turkey	Aegean and Mediterranean Seas	No	No
277.0	FL	0.07	-3.94	M		25.0		3.73	USA	Atlantic coast	No	No
291.2	OT	0.19					140.0	4.21	Algeria	Beni Saf	No	No
302.9	OT	0.07	-4.81	F				3.81	Brazil	Southern region	No	

OT = Eye-fork length.

MEDIUM PELAGICS

EUTHYNNUS AFFINIS

Common name:
– Kawakawa

Photo: Simon Chater

DISTRIBUTION & HABITAT

Kawakawa, *Euthynnus affinis*, is found throughout the warm water areas of the Indo-West Pacific, including oceanic islands and archipelagos. It occurs in epipelagic, neritic habitats at water temperatures between 18 and 29°C. It is found in open waters up to 200m depth but close to shores. Young individuals may be found in bays. It is typically found in multispecies schools of between 100 to over 5,000 individuals of similar size such as small *T. albacares*, *K. pelamis* and *Auxis* sp.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

Sexually mature fish may be encountered throughout the year but there are seasonal spawning peaks that vary from region to region. Recorded peaks in the western Indian Ocean include the period of the NW monsoon, i.e. October/ November to April/May around the Seychelles; and from the middle of the NW monsoon period to the beginning of the SE monsoon, i.e. January to July, off East Africa. Sexual maturity in the Indian Ocean is attained between 50 and 65 cm in the fish's 3rd year. The sex ratio in immature fish is typically about 1:1, while males are numerically dominant in the adult stages. Recorded information on fecundity that applies in the Indian Ocean is approximately 0.21 million eggs per batch, or about 0.79 million per season, for a 1.4 kg female of approximately 48 cm fork length; and about 0.68 million eggs per batch or approximately 2.5 million per season from a female weighing 4.6 kg and of 65 cm fork length.

GROWTH AND MORTALITY

FAO ASFS for this species records the maximum fork length at approximately 100 cm and maximum weight at about 13.6 kg, common to 60 cm. FishBase records two estimates of growth rates from countries in the western Indian Ocean:

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
82.0	FL	0.51				18.0		3.53	South Africa		Yes	No
90.0	FL	0.44			2.24	24.0		3.56	Seychelles		No	No

SARDA ORIENTALIS

Common name:
– Striped bonito

Primary source of information:
– No information was available from FAO ASFS for this species and all information here is taken from FishBase 2012.

Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

The striped bonito, *Sarda orientalis*, is a coastal pelagic-neritic species of the Indo-Pacific, also occurring around some islands, that is typically found in schools with other small tuna species.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

No information was found in FishBase on sex ratios, size at maturity or fecundity. Spawning varies according to the monsoon season.

GROWTH AND MORTALITY

The recorded maximum length for the species is 102 cm fork length and the maximum published weight is 10.7 kg. FishBase reports a common length of 55.0 cm total length. FishBase does not provide any growth rate information from the western Indian Ocean and the only growth parameters listed there are from a study in Japan.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
266.0	OT	0.08	-1.01			15.0		3.72	Japan	Suruga Bay	Yes	No

OT = Eye-fork length.

ELAGATIS BIPINNULATA

Common name:
– Rainbow runner


Photo: JE Randall

DISTRIBUTION & HABITAT

The rainbow runner *Elagatis bipinnulata*, is a circumtropical pelagic species, common throughout the western and eastern Indian Ocean. Typically found at the surface between 0 and 15 m over reefs and especially in open ocean well offshore. It can form schools of considerable size.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

Spawning generally occurring during the summer.

GROWTH AND MORTALITY

The maximum recorded size according to FAO ASFS is 107 cm fork length, but it is reported that it could possibly be up to 120 cm, with a mass of 10.5 kg. It is commonly found up to 80 cm. However, FishBase reports that it can reach a maximum length of 180 cm TL male and weight of 46.2 kg, commonly found up to 90.0 cm TL male/unsexed.

The only growth curve reported in FishBase was from the Philippines:

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
97.5	FL	0.60				28.5		3.76	Philippines	Moro Gulf	No	No

CORYPHAENA HIPPURUS

Common name:
– Dorado

Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

The dorado, *Coryphaena hippurus*, occurs in tropical and subtropical seas worldwide and is generally common in areas with water temperatures of 21° to 30°C. It occurs in the western and eastern Indian Ocean but is possibly absent in the Red Sea and the Gulf. It is an epipelagic species that inhabits open waters but can also be found close to the coast. It forms schools. It is listed as a highly migratory species in Annex I of the 1982 Convention on the Law of the Sea.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

The species spawns pelagic eggs inshore and the larvae are also pelagic. It tends to spawn during the summer months, from June to September.

GROWTH AND MORTALITY

The maximum reported length is 210 cm TL, although 100 cm is more common. Can attain 40.0kg and maximum age of 4 years (FAO ASFS). The only estimated growth curve from the region comes from South Africa.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
156.0	FL	1.04				21.0		4.40	South Africa		Yes	No

SCOMBEROMORUS COMMERSON

Common name:
- King mackerel
- Narrow-barred Spanish mackerel

Primary source of information:
- Taken from FAO ASFS, FishBase 2012
- Govender (1994); Lee (2013)

Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

The narrow-barred Spanish/king mackerel *Scomberomorus commerson*, is widespread throughout the Indo-West Pacific, ranging from South Africa and the Red Sea in the east to Australia and Fiji in the west and northwest to China and Japan. It has also alleged to have entered the Mediterranean Sea through the Suez Canal.

It is an epipelagic, neritic species that includes local permanently resident populations but is also known to undertake extensive longshore migrations. It typically occurs between 10-70 m depths.

This species is distributed from the near-edge of the continental shelf to shallow coastal waters, at times in low salinity and high turbidity. It occurs along reef drop-offs, over shallow or gently sloping reefs and in larger lagoons.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

A principal spawning area lies in southern Mozambique, occurring over a protracted period from September to January (spring-summer). Elsewhere in East Africa spawning lasts from October to July, while that in the waters off Madagascar is from December to February.

The length at first maturity is given as occurring within the range 55-82 cm in FAO ASFS and FishBase reports a range of 55-64 cm from a study in Kenya. Lee (2013) reports that the combined sexes for specimens from KZN and Mozambique mature just below 70cm FL, approaching age 2.

GROWTH AND MORTALITY

Maximum fork length is about 220-240 cm and it is common at lengths of 90-120 cm.

Results of growth studies from Oman, Djibouti and Yemen have estimated growth curves ranging from $L\infty$ of 136.0 and K of 0.21 to $L\infty$ of 230 and K of 0.12. Govender (1994) and Lee (2013) undertook growth studies in the SWIO and reported results as tabulated.

VBGF parameter			Sex	Country/Region	Source
$L\infty$	K	t_0			
156.02	0.15	-3.5	Females	KZN and MOZ	Lee, 2013
149.52	0.14	-3.5	Males	KZN and MOZ	Lee, 2013
173.69	0.11	-4.22	Combined	KZN and MOZ	Lee, 2013
134.3	0.29	-2.99	Combined	KZN	Govender (1994)

In the Lee study, natural mortality ranged between 0.27 and 0.28 $year^{-1}$, with F for the combined regions= 0.21, suggesting tentatively that the fishery is being optimally-exploited with a current SBR at 49% of its unfished level. However, this proved highly variable between regions, indicating possible localised stocks.

AUXIS THAZARD

Common name:
– Frigate tuna


Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

Auxis thazard, the frigate tuna, is a highly migratory species found in the Atlantic, Indian and Pacific Oceans. It is epipelagic in neritic and oceanic waters and feeds on small fish, squids, planktonic crustaceans etc. They also forage for other species of commercial interest and are preyed upon by larger fishes, including other tunas, because of their abundance. This tuna species is restricted to oceanic salinities and has strong schooling behaviour. The optimum temperature range for larvae is between 27º to 27.9ºC but the overall temperature tolerance is at least between 21.6º and 30.5°C, the widest among tuna species studied.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

The spawning season extends from August to April in the southern Indian Ocean while north of the equator it occurs from January to April. In general, fecundity was estimated at about 1.37 million eggs per year in a 44.2 cm long female but in Indian waters it was found to range between approximately 200 000 to 1.06 million eggs per spawning in correlation with size of females. In some places spawning may even extend throughout the year.

Size at first maturity is not reported for the Indian Ocean but is recorded at 29 cm fork length in Japanese waters and about 35 cm around Hawaii.

GROWTH AND MORTALITY

Driftnet records in the Indian Ocean show that maximum fork length is 51 cm, but off Sri Lanka it goes up to 60+ cm. The common size range in catches is between 25 and 40 cm depending on the type of gear used, the season and also region.

Growth records from FishBase; only the most relevant countries selected.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
47.5	FL	0.70				27.0		3.20	Indonesia	Pelabuhan Ratu, West Java	No	No
51.5		0.32	-0.83					2.93			No	
51.5	FL	1.00				27.0		3.42	Indonesia	Pelabuhan Ratu, West Java	No	No
61.6	FL	0.83				12.5		3.50	Sri Lanka	Southwest	No	No

SMALL PELAGICS

DECAPTERUS MACARELLUS

Common name:
– Mackerel shad

Primary source of information:
– No information was available from FAO ASFS for this species and all information here is taken from FishBase 2012.

Photo: Simon Chater

DISTRIBUTION & HABITAT

Decapterus macarellus, commonly called the mackerel shad, is a pelagic-oceanic species found worldwide in sub-tropical waters. In the Indian Ocean it occurs in the Red Sea, Gulf of Aden, Seychelles, Mascarenes, South Africa, and Sri Lanka, but is also widespread in the western Atlantic, eastern Atlantic and eastern Pacific Oceans. This species prefers clear oceanic waters and is frequently found around islands. It is generally caught at depths of 40 to 200 m but can be found near the surface. They are often observed along the reef edges near deep water in fast moving schools. (All the information for this species is taken from FishBase 2012.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

Little information is available on this species. FishBase gives a maximum length of 46 cm for individuals, either male or unsexed, with a common length of 30 cm. It is a species with low vulnerability and a high, minimum population doubling time less than 15 months (K=0.8).

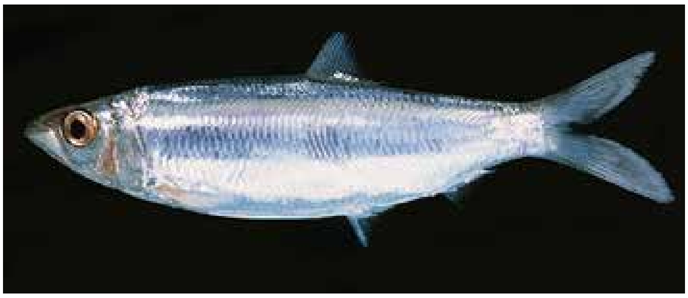
GROWTH AND MORTALITY

Growth records from FishBase.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
19.8	FL	1.00				23.0		2.59	Philippines	Guimaras Strait	No	No
24.3	TL	1.80				22.0		3.03	Philippines	Pujada Bay	No	No
41.2	FL	0.80				27.0		3.13	Sri Lanka	Southwest coast	No	No

DUSSUMIERIA ACUTA

Common name:
– Rainbow sardine



DISTRIBUTION & HABITAT

Dussumieria acuta or rainbow sardine is a pelagic-neritic species found in the Indo-Pacific region, including the Persian Gulf (and perhaps south to Somalia), along the coasts of Pakistan, India and Malaysia to Indonesia (Kalimantan) and the Philippines. It is mainly an inshore species. It closely resembles *D. elopsoides* and some of the information given in both FAO ASFS and FishBase may refer to this species.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

FAO ASFS gives the size of individuals as up to about 20 cm standard length.

It is a highly resilient species with a minimum population doubling time less than 15 months (K=0.8-1.2; tmax=1). Vulnerability is low (14 out of 100).

GROWTH AND MORTALITY

Growth records from FishBase.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
19.4	FL	1.20				28.7		2.65	Philippines	Visayas	No	No
21.0	FL	1.05				28.7		2.67	Philippines	Ragay Gulf	No	No
22.0	FL	0.80				28.7		2.59	Philippines	Guimaras Strait	No	No

RASTRELLIGER KANAGURTA

Common name:
– Indian mackerel

Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

Rastrelliger kanagurta (Indian mackerel) is a pelagic-neritic species found in the Indo-West Pacific from the Red Sea, East Africa, the Seychelles and South Africa to Indonesia, north to the Ryukyu Islands and China, south to Australia, Melanesia and Samoa. The species entered the eastern Mediterranean Sea through the Suez Canal. It is migratory within the oceans, but adults also occur in coastal bays, harbors and deep lagoons, usually in some turbid plankton-rich waters. They form schools by size and occur in areas where surface water temperatures are at least 17°C.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

Information about spawning in the SWIO area was not available but the spawning season around India seems to extend from March through September, with spawning occurring in several batches.

GROWTH AND MORTALITY

Size information for the SWIO area was not available but in Philippine waters length at first maturity is about 23 cm. Maximum fork length is 35 cm, with 25 cm being common.

Growth records are from FishBase. Many records are given in FishBase but information from only a few relevant areas has been given here.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
22.1	FL	0.81				27.2		2.60	Tanzania	Zanzibar	Yes	No
26.3	NG	0.84				25.5		2.76	Mozambique	Sofala Bank	No	No
27.8	TL	0.75	0.13			21.0	20.5	2.76	Mozambique	Sofala Bank	No	No
30.3	TL	0.72				21.0		2.82	South Africa		Yes	No
31.6	NG	0.98				25.0		2.99	Mozambique	Sofala Bank and Boa Paz	No	No
31.7	TL	0.64				27.0		2.81	Seychelles		No	No

Rastrelliger kanagurta is believed to live to at least four years old.

SARDINELLA ALBELLA

Common name:
- White sardinella

Primary source of information:
- No information was available from FAO ASFS for this species and all information here is taken from FishBase 2012.

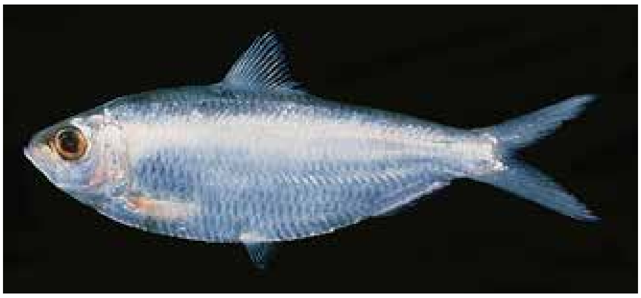


Photo: JE Randall

DISTRIBUTION & HABITAT

Sardinella albella, white sardinella, is a reef-associated species found in the Indo-West Pacific area, from the Red Sea, Persian Gulf, East African coasts, Madagascar eastward to Indonesia and the Arafura Sea, north to Taiwan PC and south to Papua New Guinea. This is a schooling species and occurs in coastal waters.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

No information on this species was found in FAO ASFS but according to FishBase spawning takes place in early and late summer off Sri Lanka. The SWIO region was not specified.

It is a highly resilient species with minimum population doubling time less than 15 months (K=1.10-2.03). Vulnerability is given as 10 of 100.

GROWTH AND MORTALITY

The maximum length is given as 14.0 cm SL male/unsexed and the common length as 10.0 cm SL male/unsexed.

Growth records from FishBase.

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
13.0	TL	1.65				12.5		2.45	India	Gulf of Mannar	No	No
13.3	TL	1.30				12.5		2.36	India	Gulf of Mannar	No	No
13.3	TL	1.44				27.6	9.0	2.41	India	Mandapam	No	No
13.6	TL	1.22				27.6		2.35	India	Mandapam area	No	No
13.8	TL	2.03	-0.01			27.6		2.59	Sri Lanka		No	No
16.8	TL	1.15				28.0		2.51	Tanzania	Dar es Salaam	No	No

SCOMBER JAPONICUS

Common name:
– Chub mackerel

Primary source of information:
– No information was available from FAO ASFS for this species in the Indian Ocean and all information here is taken from FishBase 2012.

Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

Scomber japonicus, chub mackerel, is a coastal pelagic, and sometimes epipelagic to mesopelagic over the continental slope, species found in the warm and temperate transition waters of the Atlantic, Indian, and Pacific Oceans and adjacent seas, although, according to FishBase it is absent from the Indian Ocean apart from South Africa, KZN to Western Cape. Schooling behaviour by size starts at about 3 cm and this species may also form schools with *Sarda chiliensis*, *Trachurus symmetricus* and *Sardinops sagax*. Adults stay near the bottom (to a depth of 250 to 300 m) during the day and go up to the surface at night. It is a migratory species within the oceans and seasonal migrations may be very extended and seem to be temperature related, with those in the northern hemisphere moving further north with increased temperature in summer and those in the southern hemisphere moving further south. The reverse occurs for overwintering and spawning.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

Information on spawning in FAO ASFS is not available for the Indian Ocean but for other regions it most often occurs at water temperatures of 15° to 20°C, resulting in different spawning seasons by regions. Off Peru, spawning occurs from January through May and in September, while off north eastern Japan, it occurs from April to August with a peak in May, but initiating in March further south. Spawning off South Africa occurs in the winter months of June, July and August (FishBase). Eggs are produced in several batches of about 250 to 300 eggs per g of fish with the total number of eggs per female ranging from approximately 100 000 to 400 000.

GROWTH AND MORTALITY

According to the FAO ASFS the maximum fork length is 50 cm, with 30 cm being common (a fish of 47.6 cm fork length weighed 1.1 kg), while FishBase gives a maximum length of 64 cm.

Growth records from FishBase (showing only the relevant country).

Loo (cm)	Length Type	K (1/y)	to (years)	Sex	M (1/y)	Temp° C	Lm	Ø'	Country	Locality	Questionable	Captive
68.0	SL	0.21			0.25	16.7	36.4	2.98	South Africa		No	No

FishBase also reports a maximum age of 18 years.

TRACHURUS DELAGOA

Common name:
– African scad

Primary source of information:
– There is very little information on this particular species, perhaps because of its limited distribution and relatively minor commercial value.

Photo: Rudy van der Elst

DISTRIBUTION & HABITAT

Trachurus delagoa or the African scad is benthopelagic and is found in the western Indian Ocean off Mozambique and South Africa, as well as southern Madagascar and Walters Shoal. It is found in areas with sandy substrate and migrates to the surface at night. Depth range is to 400 m.

REPRODUCTIVE SEASONALITY, SEX RATIOS AND SIZE AT MATURITY

Maximum recorded length is 35 cm. It has low to moderate vulnerability (25 of 100), and high resilience with minimum population doubling time less than 15 months (Preliminary K or Fecundity.)

GROWTH AND MORTALITY

There are no growth records in FishBase or any information in FAO ASFS.

Conclusions and recommendations

The primary aim of this Retrospective Analysis is to assess the status of the principal pelagic species exploited by SWIO countries using a variety of sources of information. Where they were available, national reports (Kenya and Tanzania) and related sources of information were examined but the main sources were the four regional or international databases: WIOFish, StatBase, the FAO database and IOTC. In addition, information reported to the Scientific Committee of the FAO Southwest Indian Ocean Fisheries Commission provided useful information on resource status.

The most important conclusion from this study is that none of these databases provided adequate and reliable information with which to estimate the catches of pelagic species in the SWIO. The IOTC database is probably the most accurate and complete of the four, for those species falling within the IOTC mandate. This is likely to be a consequence of both the high commercial value of the species involved and the mandatory requirements of the Commission, both of which provide strong incentives for the countries to monitor catches carefully. In addition, the commercial nature of much of the fishing activity for the IOTC species means that catches are more likely to be landed in centralised ports where monitoring is easier than in small, dispersed landing sites. Consequently, catches of the IOTC species taken by artisanal fisheries are unlikely to be adequately monitored. StatBase includes reasonably long time series of catches from artisanal fisheries in Kenya and Seychelles, which include IOTC species, but the records from artisanal fisheries in other countries are more sporadic. WIOFish provides a very useful record of the different fisheries in the reporting countries and the species they catch but it is not intended as a statistical database and does not include comprehensive information on the catches of the different fisheries.

The FAO database is intended to provide a full and accurate record of fisheries' catches, as a global information resource, with the responsibility for provision of the data resting with the FAO member countries. It is clear from this report that this database too is incomplete, especially in relation to taxonomic detail of the catches but also in terms of full coverage of national landings.

The overall conclusion therefore is that there is a serious lack of data on pelagic fish catches with which to assess the status of resources as the basis for managing fisheries for optimal and sustainable utilisation. The limitations of the data means that only limited conclusions can be drawn on the state of the pelagic resources in the region. In general, the amount of knowledge available becomes smaller with the size of the pelagic grouping, with the best knowledge being available for large pelagics and the least knowledge for the small pelagics.

The large pelagics fall within the mandate of IOTC and, notwithstanding gaps and uncertainties, there seems to be sufficient knowledge to allow for their sustainable use. The available information from IOTC indicates that there are no stocks in the Indian Ocean at large, that are currently under serious risk of over-exploitation. However, for the SWIO the IOTC raises concern about the overexploited status of *X. gladius* and *T. alalunga*, while Seychelles reported *T. albacares* to be overexploited. Albacore is not yet overfished but is subject to overfishing and a reduction in fishing mortality is needed for that species to avoid a further decline in abundance. The status of the remaining species is uncertain.

The medium pelagic species can be divided into two groups, those being monitored and assessed by IOTC and those that fall outside the current attention of IOTC such as *C. hippurus*, the Carangidae and *S. orientalis.* The knowledge and assumed status of the former group is similar to those of the large pelagic species described above that have not been assessed. Notable is the apparent increased landings reported to IOTC of *S. commerson* and *A. thazard* , both important medium-pelagics, but both unassessed.

The same concerns apply to the small pelagics. The very limited information presented at the SWIOFC Scientific Committee meetings in 2010 and 2012 (FAO, 2011, 2014) indicated that five of the eight fisheries reported on were less than fully-exploited, although this cannot be assumed to be representative.

Clearly, the monitoring of coastal fisheries exploiting small and medium pelagic species needs to be improved to enable, at least, an estimate of trends in key species or other reliable indicators of overall status, as required by the FAO Code of Conduct for Responsible Fisheries which has been adopted by all the SWIOFC countries. It states: "States should ensure that timely, complete and reliable statistics on catch and fishing effort are collected and maintained in accordance with applicable international standards and practices and in sufficient detail to allow sound statistical analysis". Interpreted in accordance with the guidelines of the FAO Strategy for Improving Information on Status and Trends of Capture Fisheries, this is the primary recommendation from the authors of this report.

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Annex:

Summary of data and Information available from selected surveys by the RV Dr Fridtjof Nansen. Information from survey reports of the RV Dr. Fridtjof Nansen 1975-89. CD-ROM. FAO, Rome and for the more recent surveys from preliminary cruise reports "Dr. Fritjof Nansen".

Cruise Title	*Dates of Survey*	*Area Surveyed*	*Biomass Estimates*	*Length Frequencies of Priority Species*
Pelagic Ecosystem Survey SWIOFP/ASCLME / FAO 2009 Cruise 2	25/08/2009 – 03/10/2009	West Madagascar	a) Pelagic-1 (clupeoids: e.g. *Sardinella gibbosa, Etrumeus teres, Herklotsichthys quadrimaculatus*) S. coast: 1,885t; W. coast: – NW. coast: 17,392t b) Pelagic -2 (carangids, scombrids and associated pelagics e.g. *D. macrosoma, T. delagoa, S. japonicus, C. fulvoguttatus, S. commerson*) S. coast: 15,512t; W. coast: – NW. coast: 27,254t	Not included in preliminary report
Pelagic Ecosystem Survey SWIOFP/FAO 2010 Cruise1	06/12/2010 – 21/12/2010	Mauritius and Southern Mascarene	Not available in preliminary report *D. macrosoma* & *S. gibbosa* had highest catch rates	*D. macrosoma, H. quadrimaculatus, S. japonicus*
SWIOFP/ASCLME 2009 Cruise 1	06/08/2009 – 20/08/2009	Northern Mozambique	Pelagic-1 (Clupeidae): 121,500t Pelagic-2 (Carangidae, Sphyraenidae, Trichiuridae and Scombridae): 119,300 t	*C. sexfasciatus, C. malabaricus, D. russelli, S. crumenphthalmus, A. sirm, D. acuta*
Madagascar	June 1983		No biomass estimates. Common species included *Trachurus delagoa, Decapterus macrosoma, Scomber japonicus*	Length frequencies for *Decapterus russelli, D. macrosoma, Trachurus delagoa, Selar crumenphthalmus, Scomber japonicus*
Tanzania 1982-1983	Jun-Jul 1982 Nov-Dec 1982 May 1983	Whole of shelf off Tanzania by acoustic surveys and the trawlable parts of the shelf from the Zanzibar Channel south to the Rufiji delta on each survey	Fish biomass of the fish observed in mid-water over the shelf north of 9°S. June-July 1982 – 101 000t Nov-Dec 1982 – 66 000t May 1983 – 57 000t Most common pelagic species (those in SWIOFP priority list shown in italics): Clupeidae: *Sardinella gibbosa, Pellona ditchela, Dussumieria acuta* Carangidae*: Decapterus russelli, D.kurroides, Atule mate;* Scombridae*: Rastrelliger kanagurta, Scomberomorus commerson and Sphyraenidae*	Nov-Dec 1982: lowest, highest, mean and SD of length frequencies for number of small and medium size pelagic species. May 1983: length frequencies for number of pelagic species including *Sardinall abella, Rastrelliger kanagurta, Decapterus russelli, D macarellus, Selar crumenophthalmus*
Kenya 1980-1983 (4 surveys)	Dec. 1980 Aug. 1982 Dec. 1982 May 1983	4 surveys combined covered all trawlable parts of the Kenya shelf and slope from approx 10m-500m (from 20m for biomass estimates). Shallow, more productive part of shelf was covered in each of the surveys	Biomass observed in midwater. Estimates include small-pelagics and 'semi-demersals'. Dec. 1980 – 22 000t Aug. 1982 – 29 000t Dec. 1982 – 32 000t May 1983 – 18 000t Common pelagic taxonomic groups: Clupeidae, Engraulidae, Carangidae incl. *Decapterus russelli, Scombridae incl. Scomberomorus commerson, Rastrelliger kanagurta* and *Sphyraenidae*	December 1982: lowest, highest, mean and SD of length frequencies for number of small and medium size pelagic species
Seychelles 1978	13-27 July 1978	Mahé Plateau	No biomass estimates. Species recorded include *Euthynnus affinis, Decapterus maruadsi, Decapterus macrosoma, Selar crumenophthalmus, Decapterus, Sardinella* sp., *Rastrelliger kanagurta* and *Auxis thazard*	Length frequencies of demersal species referred to in report but not provided

Mozambique 1977 -1993 (7 surveys)	Aug 77-Jun 78 (4) Oct-Nov 80 (3) Sep 82 (2) May-Jun 83 (1) Apr-May 90 (1) Aug-Sep 90 (1) Nov-Dec 90 (1)	Total shelf Sofala – Maputo Bay Sofala Bank Sofala Bank Sofala -Maputo Bay Sofala Bank Deep-water shrimp Shelf slope 17°S-27°S	<u>Sep 82 Area III – main species</u> *Decapterus* spp., *R. kanagurta*: 94,017t Area IV –main species *Sardinella* spp., Secutor insidiator: biomass 13,740t <u>April-May 1990 Pelagic biomass</u> Angoche to Quelimane – 30,000t Quleimane to Bazaruto – 180,000t Aug-Sep 1990 Angoche to Bazaruto – 127,000t Bazaruto to Boa Paz Bank – 24,000t Of which *S. commerson* contributed estimated 6% and *R. kanagurta* 3%	1977-1978 – *D. macrosoma, C. malabaricus* Oct-Nov 1980 – *D. macrosoma, S. crumenopthalmus, D. acuata, S. abella, Sardinella* spp., *R. kanagurta* Sep 1982 – *D. russelli , D. macrosoma* *April-May 1990 – Decapterus russelli, D. macrosoma, Rastrelliger kanagurta* Aug-Sep 1990 – *D. russelli, C. malabaricus, R. kanagurta*

6.
DEMERSAL FISHERIES

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Previous page: Line-caught seabreams on Mozambique market. Photo by Rudy van der Elst.

6. DEMERSAL FISHERIES

A retrospective analysis of their status in the Southwest Indian Ocean

Sherry Heileman[1], Sean Fennessy[2] and Rudy van der Elst[2]

Abstract

In 2012, the Southwest Indian Ocean Fisheries Project (SWIOFP) conducted a retrospective analysis on the historic and current state of knowledge and fisheries for 23 demersal fish species, from eight families, identified as priority by eight SWIOFP member countries. Considerable data from a variety of sources across the region were reviewed and analysed, including information from trawlers, linefisheries, artisanal fisheries, industrial bycatch and scientific surveys. Notwithstanding their value, temporal and spatial gaps in data for the priority species were found, and in many cases catch statistics were too highly aggregated (spatially, temporally, and taxonomically). Although there was generally inadequate information on the status of stocks in national waters, a considerable body of information does exist that could be used as the basis for studies on biology and population dynamics and for basic stock assessment. Comprehensive assessments have been done for only 12 species (*A. rutilans, L. bohar, L. sanguineus, L. nebulosus, A. virescens, C. nufar, C. puniceus, E. chlorostigma, L. sebae, O. ruber, P. coeruleopunctatus* and *P. filamentosus*). Results indicate demersal fish stocks to have been subjected to heavy fishing pressure with most of the priority species for which stock assessments were carried out found to be fully- or overexploited. However, some signs of recovery under management were noted. Annual catches of 13 key species generally declined, and in some instances, stable or increasing total catch could be due to a shift in fishing grounds following localized stock depletion. While all the countries have some form of management in place, few of the priority species are explicitly covered in these plans, especially considering the transboundary nature of these species. This analysis collates information on key species as a contribution to their improved management through regional collaboration.

Introduction and objectives

Demersal fishes are loosely defined as species associated with the seabed, and are broadly represented by the FAO International Standard Statistical Classification for Aquatic Animals and Plants (ISSCAAP) species categories 31, 32, 33 and 34: flounders, cods and hakes, coastal fishes, miscellaneous demersal species and a proportion of elasmobranchs such as the rays and reef sharks. (FAO 2001a). A great number of species are involved and in the case of the western Indian Ocean (WIO), demersal catches consist of almost 600 species, few of which are adequately studied.

Collectively, these groups represent the largest assemblage of species harvested globally, and also constitute the largest category of reported landings by countries involved in the Southwest Indian Ocean Fisheries Project (SWIOFP) (Fennessy *et al*. 2009). In addition to the formally declared catch records there is a large harvest of demersal species taken by artisanal fisheries that are mostly underreported. Added to the species-diverse complexity of demersal fishes is the virtual absence of species-directed management plans and lack of regional management in the SWIO region, despite the activities of the Southwest Indian Ocean Fisheries Commission (SWIOFC).

In this region, several fishing sectors catch demersal species, including industrial, semi-industrial and small-scale artisanal fisheries. More specifically, these sectors consist of:

- Shallow-water trawling (less than 100m depth) – targeting either demersal fish or crustaceans with a demersal fish bycatch;
- Linefishing – including deep-water dropline/longline (200-400m depth) targeting deepwater snappers and associated species;
- Conventional linefishing, mainly handline, less than 200m depth, targeting a range of reef-associated fishes and predominantly artisanal and recreational.

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Clearly, it was not possible to evaluate all 600 species in this study. Accordingly, a priority species-selection process was undertaken as part of a demersal SWIOFP Gap Analysis (Fennessy *et al.* 2009). This process involved a series of workshops where specialists from eight of the nine SWIOFP member countries provided lists of their key demersal fishes. The French Territory of La Réunion and its scattered islands do not engage in demersal fisheries of any note owing to the lack of any significant expanse of shelf areas suitable for demersal fishing. The selection process generated an initial combined list of 280 species, derived from 26 different fisheries. This list was further reduced by validating species identifications, after which each of the remaining species was scored by the number of fisheries (per country) in which it occurred relatively commonly. Some demersal species that were not currently being caught were also considered. During the scoring process, the appropriateness of the species for SWIOFP was considered, i.e., it should occur in at least two SWIOFP countries, implying that it is possibly a shared resource. Furthermore, if the species only occurred in very shallow water (i.e., had no offshore/large-scale fishery importance and therefore no potential importance to SWIOFP) it was eliminated; however, if the species occurred in both shallow and deeper water, it was included. This led to clarification of whether artisanal/traditional fisheries should be covered in SWIOFP, and it was decided that a species that was caught by both artisanal/traditional fisheries *and* an offshore fishery would qualify for inclusion. Elasmobranchs were considered to warrant special attention that was beyond the scope of this study (see chapter 11 for more information). Similarly, deep-water (> 500m) trawled fishes (orange roughy, cardinals, dories, oreos), which occur outside of national EEZs and are not fished by any of the SWIOFP countries, were excluded, notwithstanding their importance and need for special attention.

This process finally produced a list of 32 prioritised species, which was further reduced to the top-score 23 species in eight families for the purpose of this Retrospective Analysis. Table 1 lists all 32 species together with their predominant fisheries. Species marked with Y in column INCL are those covered in this study. This study aims to document and interpret the historical and current state of knowledge of demersal fisheries, as well as the status of priority species as identified by SWIOFP member countries. Included are trends in catch and effort, biological reference points and stock assessments.

Methodology

This study is based on historic and current data and information available from various sources (including governments of the participating countries, NGOs, academic institutions and private researchers). Accordingly, it involved the identification of available long-term databases on the fishing effort and catches of industrial/semi-industrial fisheries as well as biological data for a selection of shallow-water and deep-water demersal fish species.

COUNTRY VISITS

As many of these databases are held by the governments of SWIOFP member countries, it was necessary to visit some of the countries to enlist support from national fisheries experts, conducted between March and December 2012. Four of the SWIOFP countries were visited: Kenya, Madagascar, Mozambique, and Tanzania, and consultations were held with the SWIOFP Demersal Fisheries focal points, scientists and government officials to obtain an overview of data availability, gather relevant data and information, and to address/clarify particular issues related to this Retrospective Analysis. Communication with the other countries was conducted electronically.

DATA AND INFORMATION SOURCES

Fisheries statistics

Databases[3] containing historical fisheries statistics for demersal species from the following sources were interrogated:

- SWIOFP StatBase, including annual catch, fishing effort, and vessel registries for artisanal, semi-industrial and industrial fisheries, from a variety of gears;
- Western Indian Ocean Fisheries Database – WIOFish, managed by the Oceanographic Research Institute in Durban (www.WIOFish.org);
- FAO Fishstat reflecting catch data submitted by countries to FAO; for South Africa, this included data for the entire country, although only the eastern section of the coastline falls within the SWIOFP area. However, where possible the records for KZN were separated out;
- University of British Columbia Fisheries Centre Sea Around Us Project (www.seaaroundus.org) includes annual catch data obtained from FAO and re-aggregated into standard categories. To circumvent incomplete or inadequate data, catches are re-constructed by the Sea Around Us using an approach developed by Watson et al. (2004). However, reconstructed catches were not available for all SWIOFP countries and for the purpose of this retrospective assessment only nominal catches were used (Jacquet *et al.* 2007, 2010); (note: For Mozambique, Madagascar, Mauritius, and Tanzania reconstructed catches were available from Sea Around Us).

3. See also Capter 1: Introduction.

Table 1. List of priority demersal species with fisheries in which they are mainly caught in the region, the priority score and the number of countries reporting that species as occurring in their catches. Linefishing infers fishing on a semi-industrial scale, although it is recognized that this type of activity is termed small-scale by some countries. INCL indicates species included in this chapter.

Species	INCL	Drop-line	Line-fishing	Long-linew	Fish trawl	Crustacean trawl	Industrial trap	Small-scale	Score	No. of countries
Lethrinus nebulosus	Y	X	X	X			X	X	16	8
Lutjanus bohar	Y	X	X					X	12	7
Epinephelus chlorostigma	Y	X	X				X	X	12	7
Aprion virescens	Y	X	X					X	11	6
Pomadasys kaakan	Y		X			X		X	11	6
Lethrinus mahsena	N		X	X			X	X	10	7
Gymnocranius grandoculis	Y	X	X					X	10	6
Otolithes ruber	Y	X	X			X		X	10	6
Lutjanus sebae	Y	X	X	X			X	X	10	6
Pomadasys maculatum	Y		X			X		X	10	6
Epinephelus morrhua	Y	X	X				X	X	9	6
Trichiurus lepturus	Y					X		X	9	6
Lutjanus sanguineus	Y	X	X	X			X	X	9	5
Pagellus bellottii	N		X		X	X		X	9	3
Pristipomoides filamentosus	Y	X	X					X	8	7
Lethrinus rubrioperculatus	N		X	X				X	8	6
Cheimeirus nufar	Y		X				X	X	8	3
Pristipomoides zonatus	N	X	X					X	7	5
Seriola rivoliana	Y	X	X					X	7	4
Nemipterus bipunctatus	N					X		X	7	4
Etelis carbunculus	Y	X	X					X	6	6
Johnius dorsalis	N					X		X	6	4
Chrysoblephus puniceus	Y		X				X	X	6	2
Etelis coruscans	Y	X	X					X	5	7
Variola albimarginata	N		X					X	5	4
Pristipomoides multidens	Y	X	X						4	3
Apharaeus rutilans	Y	X	X					X	4	3
Polysteganus coeruleopunctatus	Y		X				X		4	2
Argyrosomus japonicus	N		X						4	2
Johnius fuscolineatus	N					X		X	3	7
Argyrops spinifer	N		X				X	X	3	2
Polysteganus baisacci	Y	X	X						2	1

- Reports of historical research and exploratory surveys conducted in the SWIOFP region, including from the Ecosystem Approach to Fisheries (EAF)-Nansen Project (Koranteng *et al*. 2014);
- Data provided to this study directly by the countries.

Generally, the catch data consisted of nominal catches arranged in different categories (which varied by data sources), including species, genus, families, common names and various other groups such as demersal fish, reef-associated, etc. All available datasets were evaluated for their utility, and those deemed appropriate were used for this analysis.

Biological and stock assessment information sources

A comprehensive literature search was carried out for information on the biology and status of the priority species. Major information sources included:

- SWIOFP *EndNote* bibliography;
- Published and grey literature provided by the countries;
- Southwest Indian Ocean Fisheries Commission: Scientific Committee reports;
- Fishbase (www.fishbase.org, Froese and Pauly 2012);
- Internet searches.

Overview of SWIO demersal fisheries

Demersal fisheries occur in most SWIOFP countries, although the French Territory and its scattered islands has little shelf areas to sustain demersal resources. Generally, demersal fisheries involve thousands of fishers with a high level of dependence on these fisheries for food security and employment (Table 2). These fisheries are generally multi-gear and multi-species, although certain species might be dominant depending on season and area, or targeted by certain sub-sectors (e.g. linefishing). As shown in the table, the fisheries can be described as artisanal[4], commercial[5], semi-industrial[6] and industrial[7] (WIOFish 2011), but van der Elst *et al.* (2005) noted the absence of a uniform system of fishery classification in the region. The interpretation of the different terms varies among the countries, which impacts on the submission of fishery statistics and their interpretation (van der Elst *et al.* 2005). For example, while the SWIO demersal fisheries are considered predominantly artisanal, some so-called 'artisanal' fisheries, however, are quite sophisticated. In Mauritius and Seychelles, artisanal hook and line boats may have inboard engines, fish in deep waters, and use power winches. Some of the artisanal vessels in Madagascar, Mauritius, and Seychelles are equipped with echo sounders and Global Positioning Systems (WIOFish 2011). While StatBase refers to industrial handline/pole and line, the term is misleading as, (for example, in South Africa SWIOFP region, KwaZulu-Natal province) these boats are actually small, surf-launched, commercial vessels with outboard motors, fishing with rod and line. Demersal species are also targeted in recreational fisheries throughout the region.

Fisheries management plans specifically targeting priority demersal species covered in this study exist only in Mozambique and South Africa (linefish), although most countries have certain measures and regulations such as license fees, limited entry, catch quotas, size, and gear restrictions, or are currently developing fisheries management plans, for example, under the FAO EAF-Nansen Programme (Koranteng *et al.* 2014).

An overview of the demersal fisheries in each of the SWIOFP countries follows.

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4. Traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for domestic markets. Sometimes licensed and monitored.
5. Fisheries involving fishing groups with formal relationships with small commercial enterprises (for provision of credit, front-end loading of vessels, etc). Crew may have some formal training in navigation, fishing-post-harvest etc. Fishing vessels up to 10m/30hp and may carry ice-boxes, brine tanks and use some technology to locate fish (e.g. GPS, Fishsounders). Includes national domestic and export markets. Often licenced and monitored.
6. Formal fishery, high technology vessels that are port-based, overnight capacity, operates on shelf, vessels are up to 20m, diesel powered, 10 or more fishers employed per vessel.
7. Large commercial enterprises with a fully professional crew including professional captain and engineers. Fishing vessels >30m. Legal requirements for vessel technology. Sophisticated technologies employed in location of fish (including GPS, RADAR, SONAR). Always licensed (within national EEZs) and monitored. (WIOFish 2011).

Table 2. Major fisheries targeting demersal fish in SWIOFP countries.

	Fishery type	***Gear type***	***No. vessels***	***Approx no.fishers***	***Location and depth range***	***SWIOFP priority species***
Comoros	Artisanal, small-scale commercial subsistence	Hook & line/ handline	3,2001[a]	7,5501[b]	Coastal areas, 10- 300m	*E. carbunculus, A. virescens, A. rutilans, L. bohar, L. sebae, E. chlorostigma, E. morrhua, P. kaakan* (WIOFish 2011, FAO/SWIOFP 2012a, FAO/ SWIOFC 2012c.)
Kenya	Artisanal	Hook & line/ handline, (some traps),	4,800 (all- 1990)	12,077-all (2,070 hook & line)	Entire coast, inshore/ offshore, 5-20 m	*L. nebulosus, O.ruber, T.lepturus, L. bohar, L. sanguineus, L. sebae, A. virescens E. carbunculus* (Fulanda *et al.* 2011, WIOFish 2011, StatBase, Maina & Osuka 2014)
	Industrial	Crustacean trawling (bycatch)	3	~50	Malindi-Ungwana Bay, < 50m	*O. ruber, T. lepturus, P. kaakan*
Madagascar	Artisanal, commercial small-scale	Hook & line/ longline	522 (hook & line)	3,000	All coastal fishing zones/dropoffs, 50- 500m	*A. virescens, E. coruscans, E. carbunculus, L. bohar, L. sanguineus, L. sebae, P. filamentosus, P. multidens, E. morrhua, E. chlorostigma, P. kaakan, L. nebulosus, P. coeruleopunctatus, O. ruber, S. rivoliana* (Observer logbook data, WIOFish 2011, FAO/ SWIOFP 2012b)
	Artisanal, commercial small-scale, subsistence	Hook & line, small boats	15,000	30,500	All coastal fishing zones, 2- 50m	
	Industrial	Crustacean trawling (bycatch)	~30	~500	West coast, < 50m	*O. ruber, T. lepturus, P. kaakan*
Mauritius	Artisanal	Hook & line	220	450	Lagoon and outer reef areas, 2- 100 m	*L. nebulosus, A. virescens, L. sanguineus, E. carbunculus, E. coruscans, P. baissaci, E. morrhua* (WIOFish 2011, FAO/SWIOFC 2012c, StatBase)
	Artisanal	Traps, traps & lines	861	1 120	Lagoon, off lagoon, back-reef, 1-15 m	
	Semi-industrial (schooners)	Hook & line/ vertical long line (snappers & groupers)	6	50	Drop offs of Nazareth and Saya de Malha Banks, 100- 300m	
	Semi-industrial, chilled fish	Handline	10 lineboats, 8 carrier ships	80	Nazareth and Albatross banks, 35-50m	
	Shallow banks: industrial – dories & mothership	Hook & line	84 dories, 7 motherships	164	Nazareth and Saya de Malha Banks, 5-35m	
Mozambique	Artisanal	Hook & line	9,214	43,000	Coastline, 5-30m	*C. nufar, C. puniceus, P. coeruleopunctatus, E. coruscans, E. carbunculus, P. filamentosus, P. maculatus, P. kaakan, O. ruber* (WIOFish 2011; IIP 2001; IIP, 2012 unpubl.)
	Semi-industrial	Hook & line, large vessel	31	400	Southern region (23ºS to 26ºS) and Sofala Bank area (17ºS to 21ºS). Reef areas, 15-180m.	
	Semi- + industrial	Crustacean trawling (bycatch)	~100	~ 1,700	Maputo Bay, Sofala Bank, < 50m	*O. ruber, T. lepturus, P. kaakan*

Seychelles	Artisanal	Hook & line, inboard	Unknown	Unknown	Mahé Plateau, 20 -80m	*L. sebae, A. virescens, A. rutilans, L. bohar L. sanguineus, P. filamentosus, E. chlorostigma, E. morhua, L. nebulosus* (MRAG 1996a, WIOFish 2011, FAO/SWIOFC 2012c, StatBase)
	Artisanal	Hook & line, outboard	Unknown	Unknown	Coastal areas, to 80m	
	Artisanal (schooners, with inboard engines, GPS, etc)[b]	Hook & line, dropline, traps	Unknown	Unknown	Mahé Plateau, 30 -350m	
	Artisanal (schooners)[b]	Hook & line, handline	Unknown	Unknown	Around the Mahé plateau and outer islands, 30 -80m	
	Artisanal (schooners, whalers, small boats)	Traps	Unknown	Unknown	Inshore; up to 30 km offshore; 30 -50 m	
South Africa/KwaZulu-Natal (KZN)	Commercial	Hook & line, handline	38	354	Along the KZN coast excluding the St Lucia and Maputaland MPAs, up to 200m	*C. puniceus, C. nufar, L. nebulosus, P. coeruleopunctatus, S. rivoliana, O. ruber, P. kaakan, P. filamentosus, A. virescens, L. sanguineus, E. chlorostigma, T. lepturus, S. rivoliana* (WIOFish 2011, StatBase, FAO/SWIOFC 2012c)
	Recreational	Hook & line, handline	>2,500	>13,500	All along the KZN coast and on offshore reefs, to 200m	
	Industrial	Crustacean trawling (bycatch)	3	50	Thukela Bank, < 50m	*O. ruber, T. lepturus, P. kaakan*
Tanzania	Artisanal, subsistence	Hook & line, handline (incl. shore-based)	8,600	50,312	All along mainland coast & Zanzibar, 1-30m	*L. sebae, E. chlorostigma, E. morrhua* (WIOFish 2011, FAO/SWIOFC 2012c)
	Artisanal, subsistence	Traps	1,576	5,894	All along mainland coast & Zanzibar, 1-30m	

a. All fisheries combined.
b. Referred to as 'artisanal', but vessels are equipped with inboard diesel engines, GPS, echo sounder, etc. and fish in deep waters (WIOFish 2011).

Union of Comoros

Fishing for demersal species in the Comoros is confined to the narrow continental shelf close to shore. Historically, subsistence fishers in canoes fished only on the fringing reefs around the volcanic islands (FAO/SWIOFP 2012a). However, demersal fisheries have now expanded to include artisanal and small-scale commercial operations. This includes the use of motorised craft and different gear types including handlines and traps that may be deployed to depths of 300m. A considerable variety of reef species have been recorded. A preliminary management plan has been developed for demersal fisheries, which will be strengthened by the framework of the EAF-Nansen programme (FAO/SWIOFC 2012a, Koranteng *et al*. 2014).

Kenya

The demersal fisheries of Kenya are predominantly artisanal and exploited by different types of fishing vessels and gear types, including handlines and traps. Demersal species are also taken as bycatch in bottom trawling for shrimp. Fishing is concentrated in the coastal areas as the small artisanal craft are legally restricted to the inshore waters within 3nm from the shore (Fulanda *et al.* 2011). Beyond this area exploitation is done by semi-industrial and industrial vessels. The demersal fish category dominated the country's marine artisanal fish landings, contributing around 47 % of the landings in 2007 and 2008, and 50% in 2010 (Kenya Fisheries Annual Statistical Bulletin 2007, 2008, 2010). Management actions are being considered for the artisanal demersal fishery (FAO/SWIOFC 2012c).

Madagascar

Demersal fish form the basis of traditional artisanal and small-scale commercial fisheries, targeting the full range of exploitable resources in shallow and deep waters down to 500m. Demersal fish are caught mainly by hook and line/longline. Shrimp trawling is extensive, with a substantial bycatch of demersal fish; declining industrial catch rates for shrimp in recent years have resulted in numerous trawlers being converted to target demersal reef fish (Ministry of Environment, Water, Forests & Tourism, unpubl. data). Licences are issued for the demersal fisheries.

Mauritius

Demersal fisheries include the island-based (coastal) artisanal fisheries in the lagoon and outer reef areas, and the semi-industrial and industrial offshore demersal fishery on the banks of the Mascarene Plateau and the Chagos Archipelago. The industrial fishery utilizes dories and motherships. A variety of gears including hooks and lines (the major gear type), traps, nets, and harpoons are used to catch demersal species. The bank fishery is managed by a limited entry and a quota system based on Total Allowable Catch (TAC).

Mozambique

Demersal fish are targeted in the artisanal and semi-industrial hook and line fisheries. These are multispecies fisheries conducted over a wide area and at depths between 5-180m mainly on rocky and coral reef areas. Historically, linefishing was conducted mainly in the southern third of the country where the continental shelf is wider and fisheries are closer to the main markets, but in the past few years, increasing hook and line fishing has been occurring in the north (Fennessy *et al.* 2012). Shrimp trawlers operate over the Sofala Bank and off Maputo, taking substantial quantities of demersal fish as bycatch. A number of priority species are important components of the linefishery. Catch and regular stock assessments of key species in the line fishery are carried out by the Instituto Nacional de Investigaçao Pesquiera (IIP). Fennessy *et al.* (2012) reported a decline from 700 kg/boat day in 1991 to less than 200 kg/day in the line fishery of Mozambique. Van der Elst *et al*. (2000) estimated that landings could have been under-reported by up to 60%, in which case the catch rate has declined by even more than 70%, suggesting collapse of the linefishery south of 21^{O}S. Management of the line fisheries is based on a suite of measures, including licences, TAC, limited entry by sector and geographic zones as well as specific size regulations, daily catch limits, and gear limitations (FAO/SWIOFC 2012c). In 2014, Mozambique adopted a far-reaching Linefish Management Plan based on an ecosystem approach, which is to be implemented over the next five years. (Koranteng *et al*. 2014). The linefish management plan includes a number of fisheries' indicators and reference points: change in total landings more than 20% in past four years; decline in CPUE by more than 50% over historical trends; average size caught less than size at maturity; and spawner biomass per recruit below 25%.

Seychelles

While the fisheries for demersal species are locally described as artisanal, these are indeed sophisticated operations. Demersal fishing is carried out by a variety of vessel types including whalers[8] and schooners[9] (SFA 2012) using mainly handlines and traps, each of which accounts for approximately 75% and 15%, respectively, of the artisanal landings. A new fishery (bottom drop line) was recently introduced and targets the same species as the handline fishery (SFA 2012). The two main demersal fishing grounds are the Mahé and Amirantes Plateaux at depths up to 350m. Other fishing areas include the offshore banks and around the southern group of coralline islands. Artisanal fisheries' catches have remained fairly stable since comprehensive monitoring began in 1985, averaging 4 568t per annum. However, over the period 2008 to 2010 catches dropped significantly by 45%. Piracy and the rising cost of fishing operations may have contributed to this

8. Traditional open decked clinker-constructed vessels 9-12 m long with inboard engines, which are now mostly partially decked and built of fiberglass, with a crew of 6-7 persons. Most whaler-type vessels are equipped with iceboxes and do trips of 3-6 days.
9. Wooden-hull decked vessels usually between 10-15 m and equipped with a 3-4 cylinder diesel inboard engines and an icebox of 2500 to 3000 kg capacity. Schooners do trips averaging 8 days to the edge of the Mahé and Amirantes Plateaux.

decline (SFA 2012). Piracy affected the fisheries for demersal fish in 2009 and is causing displacement of the offshore fleets to inshore areas, where certain line and trap-fish stocks are already overexploited (WIOFish 2011, FAO/SWIOFC 2011b). All demersal fisheries near to centres of population in Seychelles were found to be heavily exploited, including demersal fin-fish caught by traps and lines (Mees *et al.*1998). On the other hand, for the offshore demersal fishery the level of total annual catches indicated that the fishery was only lightly exploited, retaining only about 20% of the potential sustainable yield (Wakeford 2000). Other than a minimum mesh size of 40mm for traps, a ban on spearfishing and the prohibition on the use of demersal trawl nets, there are no other management measures for this fishery (SFA 2012). Seychelles is receiving support under the EAF-Nansen programme for the development of a management plan for the demersal line fisheries (FAO/SWIOFC 2012c).

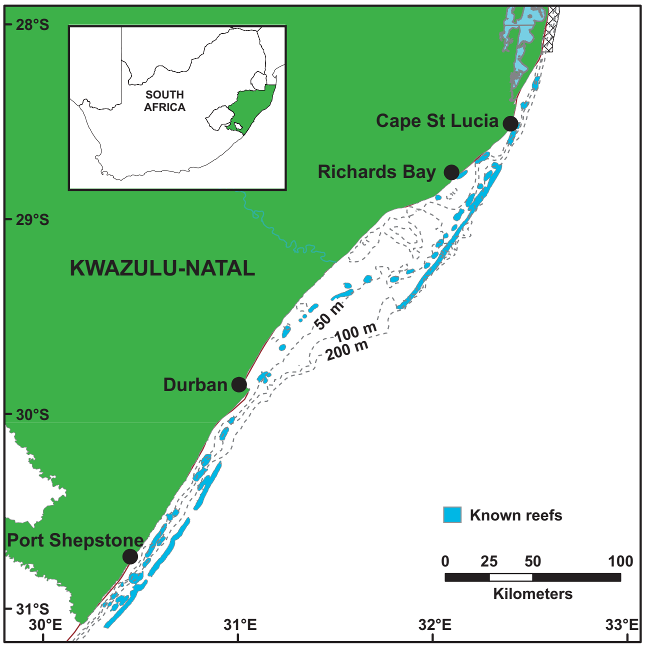
South Africa

Analysis of SWIOFP activities in South Africa is restricted to the KwaZulu-Natal Province (KZN), which falls wholly within the Agulhas Current Large Marine Ecosystem and eastern seaboard of South Africa, up to the 200nm offshore EEZ limit. Demersal species are caught mainly in the commercial and recreational hook and line sub-sectors and as bycatch of crustacean trawling. The linefishery, which is a multi-user, multi-species fishery, operates along the coast in depths up to 200m except in the two marine protected areas (MPA): the iSimangaliso Wetland Park and the Aliwal Shoal MPA, where only pelagic species may be caught. In KZN, the first suite of linefish regulations (i.e. minimum size limits, daily bag limits, closed seasons, closed areas, commercial capping, licenses issued for commercial fishers) was introduced in 1984. These regulations have since been revised and updated. The Linefish Management Plan includes biological reference points (viz. spawner biomass-per-recruit levels: target=25% and threshold=40% of pristine) and stock status indicators (e.g. CPUE <25% of historic value)(Griffiths *et al.*1999), and commercial hook and line effort was substantially reduced. Because of the severe overexploitation in the linefishery, a state of emergency was declared by the fisheries minister in 2000 as a result of which a Linefish Management Protocol was introduced (Griffiths *et al.* 1999). Recent research indicates that some of the key linefish stocks are showing signs of a slow recovery (Mann 2013).

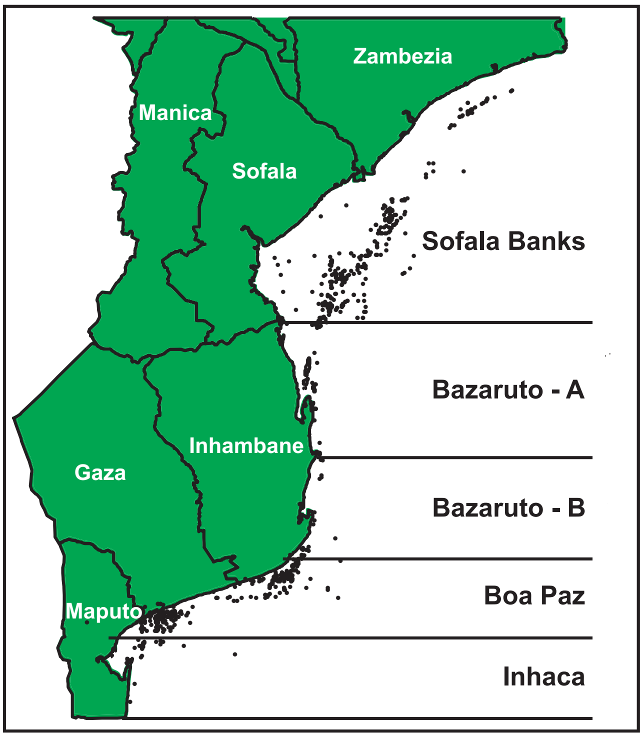
Tanzania

Demersal fish are caught in the subsistence and artisanal sub-sectors, using mainly traditional fishing vessels and a variety of gear types including hook and line/handlines and traps. Fishing is conducted along the entire coast and concentrated close to the shore in depths of <30 m because of the limited range of the fishing vessels. Most of the fish caught in inshore waters by artisanal fishers are demersal species, including Lethrinidae, Serranidae and Lutjanidae (Jiddawi 2003). Trawling for crustaceans takes demersal fish as bycatch. Licences are issued for all types of fishing, including handlines.

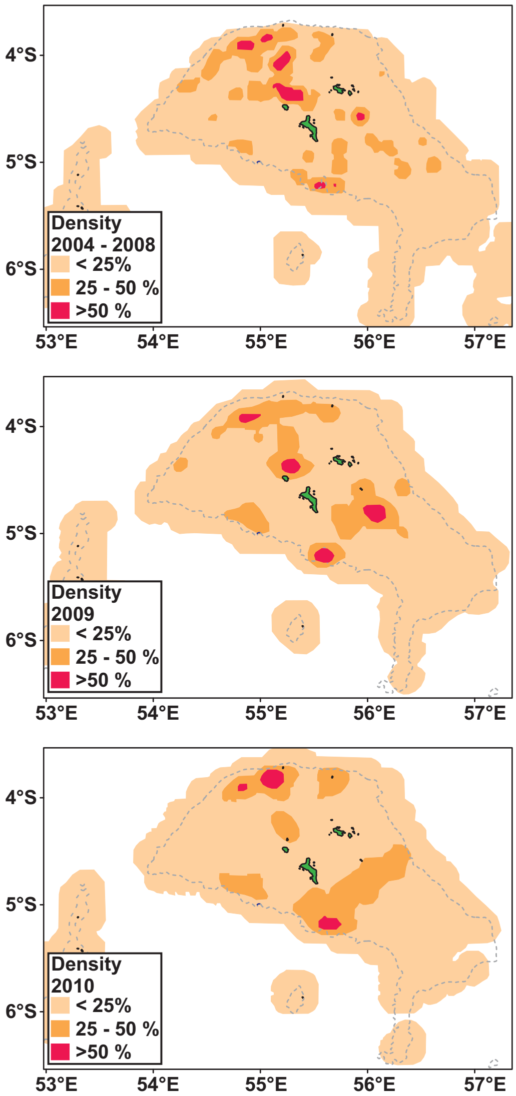
Charts of main demersal fishing areas in selected countries; obtained from various sources as shown. See Chapter 2 for charts of inshore trawling zones.



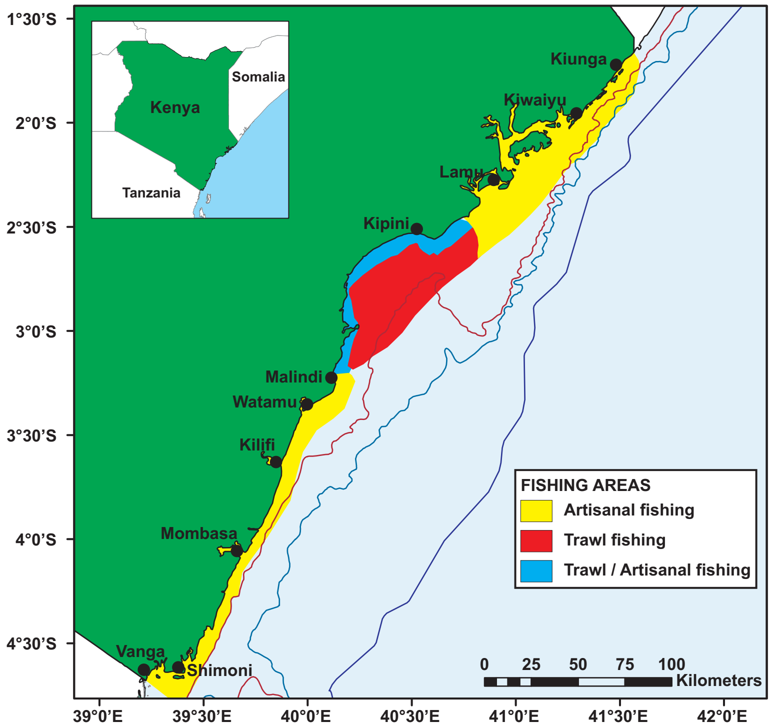
South Africa: KZN reef localities where hook and line fishing is concentrated (Penney *et al.*1999).



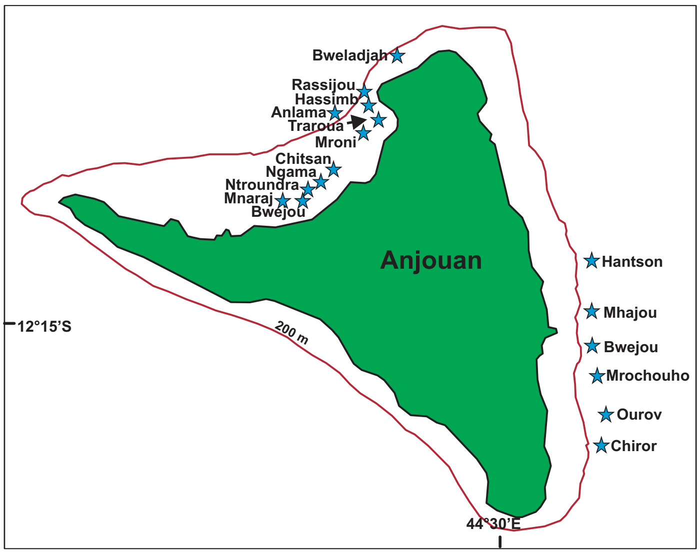
Mozambique: Range of the semi-industrial hook & line fleet operations. Dots indicate actual line fishing effort outings (R. Mutombene, IIP).



Seychelles: Changes in demersal fishing density – 2004-2008, 2009, 2010 (VMS data- SFI).



Kenya: Main fishing zones that include demersal species (P. Ochieng – KMFRI).



Comoros: Main demersal fishing localities around Anjouan (EAF Nansen in FAO/SWIOFP 2012a).

Review of available data and information

A considerable volume of data and information was found on the 23 priority species and their fisheries, spanning a few decades in some cases. However, a number of gaps and inconsistencies were noted.

The following is a generalised evaluation of the available data and information:

CATCH AND EFFORT STATISTICS

i. For most of the countries the StatBase datasets consist of only one or two fisheries sub-sectors, and it was apparent that the catch data did not represent all sub-sectors. Only three of the eight countries reported catch from semi-industrial/industrial fisheries (Madagascar, Mozambique and South Africa), with data from the other five countries coming only from artisanal/coastal fisheries.

ii. Catch statistics for one or several of the priority species were available on StatBase, Fishstat, and the Sea Around Us for 15 of the 23 priority species from five countries (Table 3). Observers' log book data from a small number of vessels were provided by Madagascar, and was used to show the percentage contribution of the priority species in the catch of these vessels;

iii. For all the countries except South Africa, the catch statistics were highly aggregated by general groups, families or genera. The high proportion of the category "marine fishes not elsewhere identified"(nei) was notable in these datasets. As a consequence, the datasets were of use in determining catch trends for only the 15 species shown in Table 1, although they could be used for general annual trends in demersal catches. In most cases, catch data in the literature were also aggregated into various categories (e.g., demersal fish, linefish, etc.), with few priority species specifically mentioned;

iv. Data quality control measures are implemented in only a few of the SWIO countries and there are issues with data collection, including under-reporting, inaccuracies, and Illegal, Uregulated and Unreported (IUU) fishing (FAO/SWIOFC 2008). For example, the Mozambique linefish assessment for the year 2000 revealed that linefish catches reported to the fisheries administration were underestimated by about 32% (IIP 2001). In Madagascar, it was estimated that about 20% of the artisanal catch is consumed by fishers and their families, yet do not appear in official statistics (FAO/SWIOFC 2008);

v. Information on catches and catch rates of priority species was extracted from the literature and where possible, expressed to show catch by gear type and trends in average monthly catches;

vi. Comparison of StatBase and Sea Around Us data on total annual catch of demersal fish for each country showed wide divergence. In some cases the catches varied by several orders of magnitude. Comparison for individual species also showed considerable differences in the level of catch reported. It is possible that StatBase datasets do not cover all sub-sectors. For South Africa, StatBase data cover only the SWIOFP area (i.e. KZN) whereas the Sea Around Us data cover the entire country;

vii. Temporal coverage of the StatBase data varied among the countries, with most countries starting from the year 2000, one from 1985 (South Africa) and two from 1990 (Kenya and Tanzania). Further, the most recent years were not covered for most of the countries, with only four countries (Kenya, Madagascar, Seychelles and South Africa) having coverage up to 2010/2011. Temporal coverage of the Sea Around Us statistics was broader, going back to 1960 for most countries and to 1950 for Mauritius, and extending to 2006 for all except Comoros (data available up to 1975);

viii. StatBase also contains fishing effort data and vessel registries. However, it was possible to relate the effort data to the given catch for only two countries (Seychelles and South Africa). The use of these datasets for determination of CPUE was therefore limited. Furthermore, the unit of effort varies among countries, making it difficult to compare effort or CPUE trends for the same species across the region, which is important for shared stocks;

Table 3. Countries and species for which time series of catch data were available (StatBase, Sea Around Us Project[1], Fishstat[2], SFA[3]).

Kenya	*Mauritius*	*Mozambique*	*Seychelles*	*South Africa (KwaZulu-Natal)*
A.virescens	E. carbunculus	C. puniceus[1]	A. virescens[3]	C. puniceus[1]
	L. nebulosus	C. nufar[1, 2]	E. chlorostigma	C. nufar[1, 2]
		P. coeruleopunctatus	L. bohar	P. coeruleopunctatus
			L. sebae	S. rivoliana
				O. ruber
				P. kaakan
				P. filamentosus
				A. virescens
				L. sanguineus
				E. chlorostigma
				T. lepturus

ix. Inconsistencies in the use of vernacular names were noted. For example, in Madagascar, the same vernacular name was used for more than one species, or different names were used for different sizes of the same species. This creates particular uncertainties if the data are reported only by the vernacular names;

x. GIS data on the fishing grounds were limited. On StatBase, in some cases fishing zones or districts were given by name, which could be either a fish landing site or fishing ground. It is known that GIS data are recorded in observer logbooks, but this was provided for only a few boats in Madagascar. Areas where specific fisheries occur are mentioned briefly on WIOFish, but no GIS data are included. Species (probability of) occurrence maps are available on Fishbase but most of these have not been reviewed and finalized;

xi. Catch and effort data and other fisheries-related parameters were used for comprehensive stock assessments of priority species in Mauritius, Mozambique, Seychelles, and South Africa. For most countries, only trends in total catch or in catch of broad categories including 'demersal fish' are reported in the available literature;

xii. A review of the published and grey literature that was available for this study showed that a considerable volume of information exists which could be used for studies of the biology and population dynamics as well as for basic assessment of stock status, including catch, effort, growth and mortality rates using length-based methods, size at maturity, size at first capture, etc. Where the required data and parameters are available for priority species, these could be used for long term indices for management purposes such as annual catch, catch per unit effort (CPUE), maximum sustainable yield (MSY), yield per recruit (YPR), and spawner (spawning) biomass per recruit (SBPR);

xiii. The findings of this study regarding fisheries data and information in SWIO countries are consistent with those of the first Working Party on Fisheries Data and Statistics held in collaboration with the Kenya Marine Fisheries Research Institute, Mombasa, 24-27 April 2007 (FAO/SWIOFC 2008), and those of van der Elst *et al.*(2005). Similarly, the FAO/ SWIOFC Working Group on Small Pelagics and Demersals (FAO/SWIOFC 2011a) reported on a number of issues regarding the availability of data and stock assessment information in the region as follows: 1. Landings recorded at country level only; 2. Species composition data often not available, countries reporting landings by groups; 3. Fishing effort data are seldom collected, although some have information of the number of fishing vessels registered. Information on vessel configuration such as length, engine power, number of crews and technological assets are rarely reported; 4. Few or no data are collected on fishing gear type that may have a bearing on selectivity, such as mesh size; 5. Basic biological information is not commonly available; 6. Stock assessment information is limited, owing to the limited availability of data and capacity in several of the countries.

RESEARCH SURVEYS

i. Over the past few decades, several research and exploratory surveys have been conducted in the region by national as well as foreign vessels (documented in Romanov 2012). These ranged from multidisciplinary scientific surveys (oceanography, ecology, biodiversity, etc.) to exploratory fishing for commercially important fish stocks. Most of the surveys were carried out using demersal trawls;

ii. Examination of the available fisheries survey reports revealed that all but two (*P. zonatus* and *C. puniceus*) of the priority species were caught (see details in the Annex). In some areas, one or more priority species were important components of the catch. Among those caught in trawl surveys were ten species *(G. grandoculis, E. carbunculus, E. coruscans, L. bohar, L. sanguineus*, *L. sebae*, *P. filamentosus*, *P. multidens*, *E. morrhua*, and *P. coeruleopunctatus*) that usually inhabit reefs and rocky areas, which are generally unsuitable for bottom trawling. From the surveys, it is evident that these species also venture into trawl grounds. The catch rates of benthic trawls might thus not accurately reflect the overall abundance of these species in a given EEZ, but only that on the trawl grounds;

iii. While data from several historical cruises might be lost or unavailable (Romanov 2012), data from many others are available (e.g., from the participating countries and the Norwegian Institute of Marine Research for cruises by RV Dr. Fridtjof Nansen). However, a literature review did not locate any reports in which SWIO cruise data were analyzed further and used in stock assessments, apart from the actual cruise reports and a study of zonation of demersal fishes based on RV Dr. Fridtjof Nansen survey data (Bianchi 1992). In most cases, stock biomass has been calculated for demersal fish as a whole or for fish families, but rarely for individual priority species;

iv. Research cruises have been conducted by the SWIOFP and/or the ASCLME project(s): East Madagascar (2008), Mauritius (2008), Mascarene Plateau (2008), Seychelles Bank (2008), Mozambique Channel (2008-2010), North Mozambique Shelf (2009), West Madagascar (2009), Comoros Gyre (2009) and the seamounts of the Southwest Indian Ocean Ridge (2009). Data from those cruise reports (RV Dr. Fritjof Nansen and others) that were available at the time of this study are included in the species profiles and the Annex.

BIOLOGY AND STOCK ASSESSMENT

Available literature was reviewed for biological information and stock assessments of the priority species. Details on the individual species are given in a dedicated section.

i. There was uneven temporal and spatial coverage and level of detail in the biological information available on the priority demersal species. Comprehensive studies were found for 12 of the 23 species (*A. rutilans, L. bohar, L. sanguineus* and *L. nebulosus*, in addition to the eight species listed below), mainly in Mauritius, Mozambique, Seychelles, and South Africa;

ii. Stock assessments were similarly uneven in coverage. Comprehensive assessments were found for eight priority species (*A. virescens, C. nufar, C. puniceus, E. chlorostigma, L. sebae, O. ruber, P. coeruleopunctatus* and *P. filamentosus*). Overall, assessments have been sporadic and "once-off", except in Mozambique and South Africa where assessments of linefish are periodically carried out. Stock status indices included MSY, CPUE, YPR, and SBPR;

iii. Estimates of age and growth (length based methods and otolith readings) and mortality rates were often reported to be uncertain. This in turn affected the level of confidence in the stock assessments, which require such parameters. Additional studies as well as caution in the use of the results in the management of the stocks in question are required. In other cases, no conclusions could be drawn because of the limited data available or uncertainties in the data;

iv. Assessments have also been done for combined groups of species, for example, demersal fish on the Mauritius Banks (MRAG 1996b), the KwaZulu-Natal (South Africa) line fisheries (Penney *et al.* 1999, Dunlop 2011), and the artisanal fishery of Ungwana Bay, Kenya (Fulanda *et al.* 2011). Studies have also have been carried out for a particular genus, with the species name not given, for example, *Lethrinus* and *Lutjanus* species from Kenya (Fondo 2004). While this is useful for assessment of a particular ecosystem or fishery sub-sector, it is of limited utility for individual species, unless certain assumptions are made regarding the species composition of the catch;

v. Much of the information available is qualitative (e.g., list of species caught) or presented by families (e.g., % composition), rather than quantitative or by species.

Retrospective analysis

TRENDS IN CATCHES

All eight countries sustain demersal fisheries, and as reflected in Table 2, several of the priority species are reported as caught in each country. Total annual catches of demersal fish by country were obtained from StatBase and the Sea Around Us project (Figures 2 and 3). The latter source was selected because standard categories were used for the functional groups (and in some cases the species) reported across the countries, including small and medium demersal fish and reef-associated fish. This allows for regional and intercountry comparisons. Each of the functional groups consisted of various families and species. Only recognizable demersal fish families or priority species in the datasets were included in these demersal catch trends.

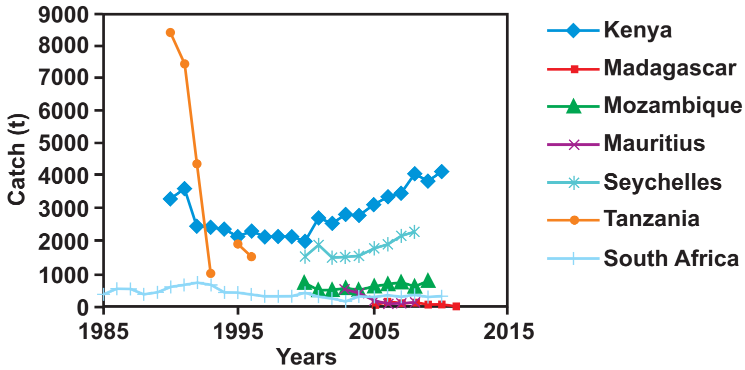


Figure 2. Trends in annual catch of demersal fish in SWIOFP member countries (StatBase data). Comoros is omitted as data for only 1994 are available on StatBase.

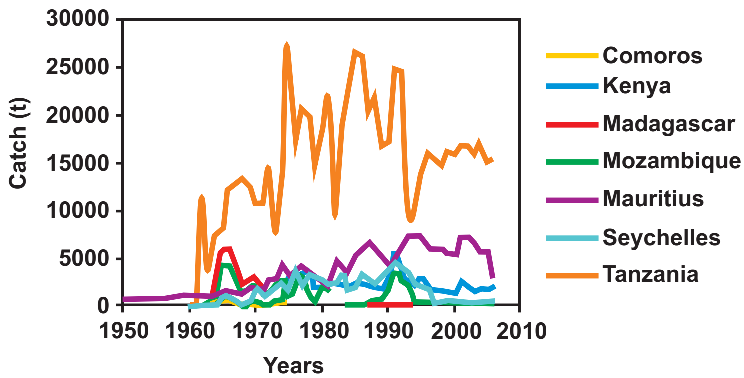


Figure 3. Trend in annual catch of the main groups of demersal fish from the Sea Around Us. Reconstructed catches were used for Mozambique, Madagascar, Mauritius, and Tanzania. South Africa is omitted because the reported catch is for the entire country. (Courtesy R. Watson and D. Pauly).

Comparison of the annual catch from the two sources (note differences in scales of X and Y axes) show the following:

- Temporal coverage: StatBase datasets cover a shorter time period (1985- 2011) while Sea Around Us project datasets cover a wider time period (from 1950/1960 to 2006);
- Trends: Same country shows different trends over the same time period in the two data sources, e.g. for Seychelles;
- Catch level: In some cases, this is higher by several orders of magnitude for the same country and same years. StatBase catch levels were generally lower, which could be due to the fact that for most of the countries, catch data from only certain sub-sectors were included.
- Priority species: In the Sea Around Us data only two of the priority species are reported: *Chrysoblephus,* taken to be predominantly *C. puniceus* for Mozambique but includes several species for South Africa, and *C.nufar* for both Mozambique and South Africa.

Priority species' profiles

Results of this retrospective analysis are presented for each priority species in a standard template. Wherever information was not available the entry has been omitted. Species are arranged by family with common names taken from Fishbase, although vernacular names are commonly used in the individual countries. Catches are reported in tonnes (t), unless indicated otherwise. Distribution of each species is given only for the SWIO region, although the species occurrence may be more widespread. Photographs of the majority of the species came from the collection of Randall (1997) and were downloaded from Fishbase (Froese and Pauly 2012). Other photographs were obtained from the "Guide des Poissons de L'Est de Madagascar" (unpubl.) and are of species caught during experimental fishing in 2003-2004 by the Ministère de l'Agriculture, de l'Elevage et de La Pêche of Madagascar and the Overseas Fishery Cooperation Foundation of Japan (MAEP/OFCF). Species occurrence maps are available on Fishbase (www.fishbase.org).

Basic template:

SPECIES

Common name:
Family:
Distribution & habitat:

FISHERY

Catch trends:
Size at first capture:

BIOLOGY AND POPULATION DYNAMICS

Reproduction:
Length/age at maturity:
Sex ratio:
Age & growth:
Length-weight relationship:
Mortality:

STOCK ASSESSMENTS AND REFERENCE POINTS

Assessment and status:
Reference points or management objectives:

SERIOLA RIVOLIANA

Common name:
- Longfin yellowtail

Family:
- Carangidae

Can attain 160 cm FL (Fishbase)

Photo: MAEP/OFCF, *Guide des Poissons de L'Est de Madagascar*.

DISTRIBUTION & HABITAT

From Kenya south to South Africa (Smith-Vaniz 1984). Reef-associated, depth range 5-160m or more (Lieske & Myers 1994), on outer reef slopes and offshore banks. This species is semi-pelagic, but commonly occurs in drop-line catches in Seychelles.

FISHERY

CATCH TRENDS

Annual catch data for South Africa/KZN show very low catch in 1988 (0.002t), 1991 (0.017t), 1994 (0.004t), and 2003 (0.012t). This species is associated with drifting Fish Aggregating Devices and drop-line catches in Seychelles (Taquet *et al.* 2007).

STOCK ASSESSMENTS AND REFERENCE POINTS

RESEARCH SURVEYS

Caught during surveys by RV Dr. Fridtjof Nansen, with catch rates up to 57.4 kg/hr in Tanzania in 1982 (Iversen *et al.*1984), 10 kg/hr in West Madagascar in 2009 (Torstensen *et al.* 2009) and around 3 kg/hr in Mauritius and Mascarene Plateau in December 2010 (Strømme *et al.* 2010).

POMADASYS KAAKAN

Common name:
- Javelin grunter

Family:
- Haemulidae

Can attain 80cm

Photo: Simon Chater, Oceanographic Research Institute (ORI).

DISTRIBUTION & HABITAT

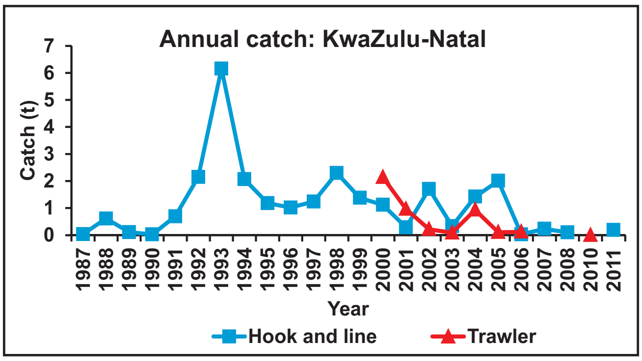
East coast of Africa. Adults in depths <75m over soft sediments (Smith & Heemstra 1986, Fennessy 1992) and larger estuaries (van der Elst 1988). Juveniles in estuaries (van der Elst 1988, Whitfield *et al.* 1989) and shallow inshore waters over soft sediments (Beckley & Fennessy 1996).

FISHERY

CATCH TRENDS

Reported in commercial line fisheries and trawlers in South Africa (StatBase) and occasional incidental bycatch of Thukela Bank shrimp trawlers (Fennessy 1994a). In Tanzania, this species formed over 7% (by number) of shrimp by-catch in 2001 (Bwathondi *et al.* 2002). *P. kaakan* composed 16% of the artisanal hook and line fishery of Mozambique (WIOFish 2011). The following catch trends are based on StatBase dataset.

Most of the catch of *P. kaakan* in KZN was taken with rod and line (66%), and the rest by trawlers. The linefishery catch peaked at over 6t in 1993, followed by a marked decline to less then 3t in the subsequent years. From 2006-2008, the annual catch was negligible (less than one tonne). There is evidence that this 1993 peak in abundance reflected an unusually strong year-class. Annual trawl catches also declined sharply from over 2t in 2001 to less than one tonne in 2006, reflecting low fishing effort and implementation of a closed season for trawling from 2003.



BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

In KZN, spawning occurs in inshore marine areas adjacent to river mouths during winter (van der Elst 1988).

AGE & GROWTH

This species attains a maximum length of 80cm total length (TL) (Fischer *et al.* 1990). Age and growth of *P. kaakan* has not been determined in the SWIOFP region. Age and growth parameters in other regions are available on Fishbase.

STOCK ASSESSMENTS AND REFERENCE POINTS

REFERENCE POINTS AND MANAGEMENT OBJECTIVES

South Africa: Bag limit of 10/person/day for recreational fisheries only (Fennessy & Radebe 2000).

RESEARCH SURVEYS

One of the most common demersal species caught during RV Dr. Fridtjof Nansen surveys on the Tanzanian shelf (Zanzibar and Mafia) in 1982-1983. Caught in small quantities during surveys by RV Mafunzo in this same area in 1986-1988 (MBEGANI Fisheries Development Centre, Tanzania). About 51kg of this species caught (with and without TED) during SWIOFP shallow-water shrimp trawl survey in Tanzania (FV Vega) in 2011 (Mwakosya *et al.* 2011). Also caught during RV Dr. Fridtjof Nansen surveys in Mozambique (Sofala bank) in 1982 and 1990, making up 17-26% of catch by weight of demersal fish (Sætersdal *et al.* 1999) , and in North Mozambique in 2009 (Olsen *et al.* 2011).

POMADASYS MACULATUS

Also referred to as *P. maculatum*

Common name:
- Saddle grunt

Family:
- Haemulidae

Can attain 50cm

Photo: Randall 1997 (from Fishbase, Froese and Pauly 2012).

DISTRIBUTION & HABITAT

Found throughout the Indian Ocean, in coastal waters over sandy bottoms close to reefs, in open bays, trawling grounds, and estuaries; depth range 20-110m (Fischer *et al.* 1990, Randall 1995, FAO 2001b).

FISHERY

CATCH TRENDS

This species is not individually reported in catch statistics of SWIOFP countries (StatBase). It is commonly caught by prawn trawlers and handlines in the small-scale sub-sector.

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

In some areas of the Sofala Bank, Mozambique, fish in spawning condition were found in May-June (Brinca *et al.* 1984). Near Quelimane on the Sofala Bank, most of the individuals caught during 1984 RV Dr. Fridtjof Nansen surveys were between 9-15cm, indicating that this may be a recruitment area (Brinca *et al.* 1984).

LENGTH- WEIGHT RELATIONSHIP

Mozambique (Sofala Bank): Female: W(g)=0.01680 TL$^{?}$(cm)2.992; Male: W(g)=0.0213 TL$^{?}$(cm)2.899. (Brinca *et al.* 1984).

STOCK ASSESSMENTS AND REFERENCE POINTS

RESEARCH SURVEYS

P. maculatus was one of the most important species caught on the Sofala Bank, Mozambique and formed up to 4.2% by weight caught during a Russian survey (Sousa 1982) and 58-67% by weight of all families of demersal fish during RV Dr. Fridtjof Nansen surveys in 1982 and 1990 (Sætersdal *et al* 1999). More than 30 kg/hr were caught in some areas on Sofala bank, Mozambique in 1983 during surveys by RV Dr. Fridtjof Nansen (Brinca *et al.* 1984). About 173 kg of this species was caught (with and without Turtle Excluder Device- TED) during SWIOFP shallow-water prawn trawl survey in Tanzania (FV Vega) in 2011 (Mwakosya *et al.* 2011). Significant quantities caught during SWIOFP surveys (Cruises 1 and 2) with FV Vega off Kenya in 2011 (unpublished data). In West Madagascar during RV Dr. Fridtjof Nansen surveys catch rates were low - below 1 kg/hr in depths less than 30m (Torstensen *et al.* 2009).

GYMNOCRANIUS GRANDOCULIS

Also referred to as *G. robinsoni*

Common name:
- Blue-lined large-eye bream

Family:
- Lethrinidae

Can attain 80cm

Photo: JE Randall (from Fishbase, Froese and Pauly 2012).

DISTRIBUTION & HABITAT

Found throughout East Africa. Reef-associated, non-migratory, at depth range of 20-170m (Pauly *et al.* 1996).

FISHERY

CATCH TRENDS

Caught by lines, including droplines.

SIZE AT FIRST CAPTURE

Length at first capture reported as 14.4cm TL in Kenya; all fish caught by a number of different gear types were juveniles (Mangi & Roberts 2006).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

Reported to form spawning aggregations in the Tanga region, Tanzania (Samoilys *et al.* 2004).

LENGTH/AGE AT MATURITY

TL at maturity reported as 42.4cm TL in Kenya (Mangi & Roberts 2006).

STOCK ASSESSMENTS AND REFERENCE POINTS

RESEARCH SURVEYS

G. grandoculis was caught during research surveys by RV Dr. Fridtjof Nansen in 2009 in West Madagascar (catch rate between 1.3 – 13 kg/hr); and in Mauritius and Mascarene Plateau in December 2010 (catch rate 14.6 kg/hr).

LETHRINUS NEBULOSUS

Common names:
- Spangled emperor,
- Blue emperor
- Scavenger

Family:
- Lethrinidae

Can attain 87cm TL

Photo: Randall 1997 (from Fishbase, Froese and Pauly 2012).

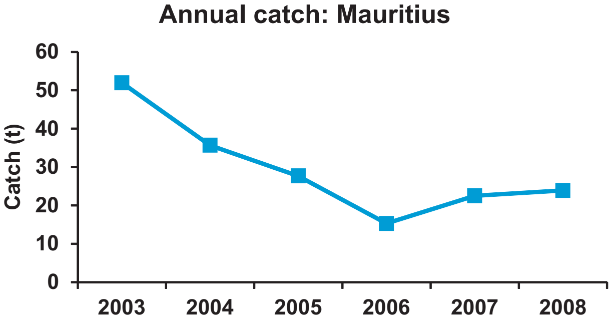
DISTRIBUTION & HABITAT

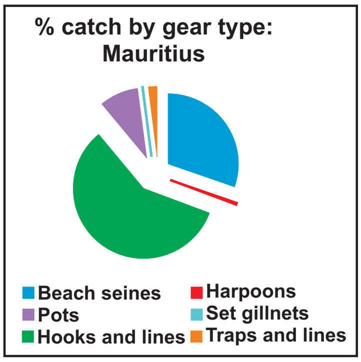
Throughout East Africa, Indian Ocean islands, Mozambique to northern KZN (Mann 2013). Inhabits coral reefs, coralline lagoons, seagrass beds, mangrove systems, and coastal sandy and rocky areas. Adults solitary or in small groups; juveniles form large shoals in shallow, sheltered sandy areas, seagrasses, algae or sponge habitats at various depths.

FISHERY

CATCH TRENDS

An important species in the bank fisheries of Mauritius and Seychelles (MRAG 1996a). In KZN of South Africa, *L. nebulosus* are important in the commercial, recreational and charter boat linefisheries (Dunlop 2011). Increasingly important in KZN as other reef fish species decline (Penney *et al.* 1999, Dunlop 2011). The KZN StatBase dataset lists only the genus *Lethrinus*, most of which are an as-yet undescribed species previously thought to have been *L. nebulosus*, which extends into southern Mozambique, and whose range overlaps with *L. nebulosus sensu stricto* – shown in a SWIOFP genetics study (Gouws *et al*. 2012). Annual catches of *L. nebulosus* are reported for different gear types in the Mauritius lagoon/outer lagoon fishery between 2003-2008 (StatBase). The trend in total annual catch and by gear types are shown in the following figures.





Annual catch in Mauritius declined sharply from >50t in 2003 to <20t in 2006, increasing slightly in the following two years. The catch of lethrinids from the Saya de Malha and Nazareth banks decreased by 23.5% from 2009 to 2010, which may be attributed to a decrease in the number of vessels operating on the banks (FAO 2012, in prep). As shown in the pie chart, in Mauritius most of the catch is taken by hook and line (58%) followed by beach seines (30%), with smaller quantities caught by fish traps and other gears.

In KZN, CPUE (linefish catch per outing) for this species was 0.17 and 1.33 kg (recreational and commercial catch, respectively) in 2008/2009 (Dunlop 2011) compared to 0.01 and 0.77 kg in 1994/1996 (Mann *et al.* 1997). Fishing effort in the commercial line fishery of KZN was reduced through management intervention by about 70% in 2006, and it was suggested that this has increased the catch of *L. nebulosus*, indicating a recovery in the commercial linefishery in KZN. However, such a broad assumption needs to be carefully analysed as other factors might have contributed to this trend, as discussed by Dunlop (2011), and this is further complicated by the discovery of the cryptic species referred to above.

Between 2008-2010, *L. nebulosus* comprised about 2% of the multi-gear industrial catch reported in observer logbooks in Madagascar (unpubl. data).

SIZE AT FIRST CAPTURE

In southern Kenya, length at capture (for a combination of traps, gillnet, beach-seine, handline and speargun) was reported as 7.2cm TL, significantly lower than the size at maturity of 39.75cm (Mangi & Roberts 2006). In Seychelles, length at 50% capture (mainly hook and line) was reported as 47.3cm (MRAG 1996a).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

A protogynous hermaphrodite (Allsop & West 2003). Reported to form spawning aggregations in Seychelles (Robinson *et al.* 2004). Spawning reported to take place in March/April and October/November in East Africa (Nzioka 1979); March, October–November in Seychelles (MRAG 1996a).

LENGTH/AGE AT MATURITY

Size at maturity of 39.75cm TL in southern Kenya (Mangi & Roberts 2006).

SEX RATIO

M:F ratio of 0.62 in Seychelles (MRAG 1996a).

AGE & GROWTH

L_∞= 39.7cm; K= 0.92/yr; growth of 14.6 ± 7.3cm/yr from tagging in coastal Kenya; Lmax= 36.1cm (Kaunda-Arara & Rose 2006). A far larger maximum size of 680-750mm TL was reported from KZN (Mann & Radebe 2000).

LENGTH-WEIGHT RELATIONSHIP

W(g)= 0.03355 FL?(cm)$^{2.84}$ in Seychelles (MRAG 1996a).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

A SWIOFP genetics study showed that *L. nebulosus sensu stricto* can be regarded as a homogenous, widely-connected, panmictic population across the full SWIO (Gouws 2012). MRAG (1996a) examined the effect of density-dependent growth on the yield-effort curve of *L. nebulosus* in the Seychelles using simulation modeling. Assessment of the fishery found that the stocks were lightly exploited and that fishing effort could be increased in the offshore Mahé Plateau and distant banks. Caution was advised, however, as such assessments ignore the potential for localized stock depletion.

RESEARCH SURVEYS

L. nebulosus was caught during research trawl surveys by RV Dr. Fridtjof Nansen in Kenya in 1980, where it was a dominant species in the catch (IMR 1981); in West Madagascar in 2009 with maximum catch rate of 19 kg/hr (Torstensen *et al.* 2009); off Mauritius and on the Mascarene Plateau in 2010 with maximum catch rate of 14.3 kg/hr (Strømme *et al.* 2010).

APHAREUS RUTILANS

Common name:
- Rusty jobfish

Family:
- Lutjanidae

Can attain 110cm FL

Photo: Simon Chater, Oceanographic Research Institute (ORI).

DISTRIBUTION & HABITAT

Widely distributed in the Indian Ocean including, Mozambique, Kenya, Madagascar, Comoros and less commonly in South Africa (Allen 1985, Chave & Mundy 1994). Associated with reefs and rocky bottom areas; depth range 100-330m (Meyers 1999).

FISHERY

CATCH TRENDS

A. rutilans is not itemised in fisheries catches on StatBase. Between 2008-2010 this species composed about 11% of the catch reported in observer logbooks in Madagascar (unpubl. data). On the Mahé Plateau and outer islands of Seychelles, *A. rutilans* is one of the main target species caught by droplines (WIOFish 2011).

SIZE AT FIRST CAPTURE

Size at 50% capture of 39.4cm FL in Seychelles (MRAG 1996a)

BIOLOGY AND POPULATION DYNAMICS

SEX RATIO

M:F ratio of 1.06 in Seychelles (MRAG 1996a).

AGE & GROWTH

Attains a maximum length of 110cm FL (Anderson 1986).

LENGTH-WEIGHT RELATIONSHIP

$W(g)=0.04157FL(cm)^{2.723}$ in Seychelles (MRAG 1996a).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

The rarity or apparent absence in the Comoran deep demersal habitat of several large predators, including *A. rutilans*, may be linked to heavy fishing pressure. (Heemstra *et al.* 2006).

RESEARCH SURVEYS

12 kg/hr caught at one station during surveys in 1982-1983 by RV Dr. Fridtjof Nansen in Tanzania (Iversen *et al.* 1984).

APRION VIRESCENS

Common names:
– Green jobfish; Kaakap

Family:
– Lutjanidae

Attains 112cm TL

Photo: Rudy van der Elst (1988).

DISTRIBUTION & HABITAT

Distributed throughout East Africa. Inhabits open waters of deep lagoons, channels and seaward reefs (Lieske & Myers 1994). Considered benthopelagic (or semi-pelagic), being generally found several metres from the sea bottom (SFA 2012).

FISHERY

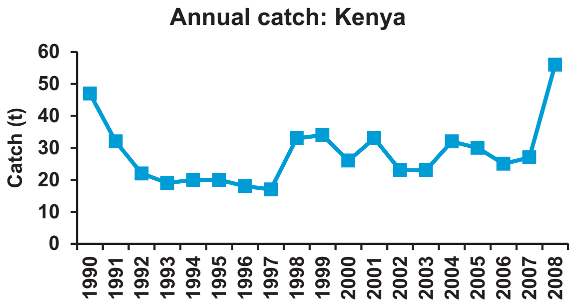
CATCH TRENDS

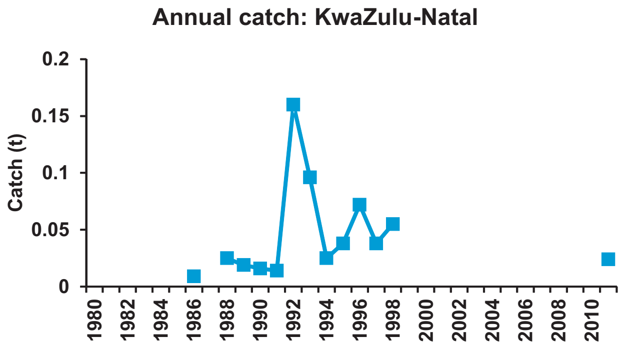
Included in the StatBase artisanal catch statistics of Kenya (1990-2008) and the hook and line fishery of South Africa (1986-1998).

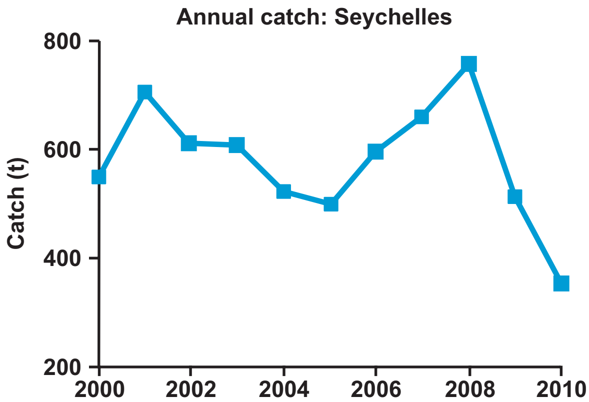
In Kenya, the annual catch declined from 47t in 1990 to 17t in 1997, followed by fluctuations between 1998-2007, before a twofold increase from around 27t in 2007 to 56t in 2008. The annual catch of *A. virescens* (almost entirely by recreationals) was negligible in South Africa, with the highest catch in 1992 of 0.16 t.

Historic records of the Seychelles Fishing Authority and Fishing Development Company indicate that between 1981-1986, the annual catch (gutted weight) taken in the Seychelles bank fishery rose steadily from 37t in 1981 to 60t in 1986. Later records for 2000-2010, indicate considerably higher landings although the annual catch declined from over 750t in 2008 to around 350t in 2010. (SFA 2012).

A. virescens is also a valuable and important component of the catch in Mauritius and the Chagos Archipelago (MRAG 1996a). In Chagos, this species was reported to comprise only 4.88% of the catch (MRAG 1995). It is caught by hook and lines/vertical longlines in Mauritius, and artisanal hook and lines on the Mahé Plateau, where it is also caught with droplines and handlines from schooners (WIOFish 2011). This is among the major species caught in Comoros (FAO/SWIOFP 2012a) as well as in Madagascar (FAO/SWIOFP 2012b), where it formed about 3% of the industrial catch reported in observer logbooks between 2008-2010.







LENGTH AT FIRST CAPTURE

Length at capture (50%) for females of 55cm FL used by MRAG (1996a).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

In East Africa, ripe fish were observed in January and October (Nzioka 1979). A protracted spawning period was reported in Seychelles, with peak spawning from February-May and October-December (MRAG 1996a). A previous study reported spawning in Seychelles from January to April/May with a peak in January (Tarbit 1980).

LENGTH AT MATURITY

Mees (1992a) reported length at maturity of 63cm FL (females) in Seychelles, but overall this species appears to mature at 45cm FL (Pilling *et al.* 1999). In East Africa, van der Elst (1993) reported a length at maturity of 700-750mm TL, and Talbot (1960) 465 and 410mm (SL) for female and male, respectively.

SEX RATIO

Ratio of M:F of 1.24 observed in Seychelles (MRAG 1996a).

AGE & GROWTH

Age and growth of *A. virescens* from Seychelles and Mauritius were determined using length-based methods (Mees 1992a, 1993) and otoliths (MRAG 1996a, Pilling *et al.* 2000):
Females: L_∞=108cm; K=0.14; W_∞=13,100 g; Lmax=112cm TL (Mees 1992a)
Males: L_∞=95cm; K=0.29; W_∞=9,010 g (Mees 1992a)
Unsexed: : L_∞=78cm FL; K=0.35; W_∞=5,082 g (Mees 1992a)
Unsexed: L_∞=95-104cm FL; K=0.32 (Mees 1993)
Unsexed: L_∞=79cm FL; K=0.13 (MRAG 1996a)
Unsexed: L_∞=79cm FL; K= 0.13 (Pilling *et al.* 2000)

An evaluation of age-based and length-based methods for determining growth and total mortality of tropical long-lived species concluded that the former gave more accurate estimates MRAG (1996a). Pilling *et al.* (2000) suggested that mean growth rate and asymptotic length from length-based methods might have been overestimated for this species. Uncertainties arising from the use of length-based assessment methods using both length- and age-based inputs may have led to poor management performance (MRAG 1996a).

Maximum length of 110cm FL reported in South Africa (van der Elst 1981). Maximum age of 27 years (99cm TL) estimated in Seychelles (Pilling *et al.* 1999). The most common size for this species in Seychelles is around 60cm (TL), attaining up to 102cm at a maximum age in excess of 8-9 years (SFA 2012).

LENGTH- WEIGHT RELATIONSHIP

Seychelles: combined sexes: $W(g)=0.031FL?(cm)^{2.79}$ (Pilling *et al.* 1999). South Africa: $W(g)=0.0294FL(cm)^{2.76}$ (van der Elst 1981).

MORTALITY

Total mortality range (Z) was estimated as 1.07-1.28 and M of 0.22-0.76 in Seychelles (MRAG 1996a). Previous estimates in Seychelles were Z= 1.602 and M= 0.496 (Mees 1992a).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

MRAG (1996a) examined the effect of density-dependent growth on the yield-effort curve of *A. virescens* using three different simulation models, and found that density-dependent growth increased the yield available at a given level of fishing mortality. Assessment of the fishery in Seychelles and Chagos Archipelago found that in general the current level of F (F^{curr}) at the time was lower than the reference level of $F_{0.1}$, that is, the stocks were lightly exploited and there was no concern over their status (MRAG 1996a). Caution was advised, however, as such assessments ignore the potential for localized stock depletion. Subsequent stock assessment in Seychelles for the period 2004-2006 and based on (L^{c50}/L^{m50} in conjunction with F/M) revealed overfishing in 2004 and borderline (but not exceeded) in more recent years (FAO/SWIOFC 2012c; SFA 2012). YPR models at a finer spatial scale were recommended.

The long lifespan and slow growth of this species make it highly vulnerable to overfishing (Pilling *et al.* 1999). Low numbers, primarily of small individuals occurring in exploited areas in KZN in contrast to nearby no-take areas suggests that its residency further makes this species vulnerable to exploitation (Floros 2010).

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

This species is not explicitly mentioned in the management plans of the SWIOFP countries, but measures for specific types of fisheries are also pertinent to this species where it is caught, e.g. linefish fishery management plan of South Africa (KZN) and Mozambique; management of shallow water bank fishery of Mauritius; and the draft Fisheries Development Plan 2007-2011 of Seychelles. Reference points and management objectives for this species are not specified in management plans. MRAG (1996a) used a reference point of $F^{0.1}$ to examine the effect of density-dependent growth on the yield-effort curve of this species. Main conclusions are given above (Assessment and status).

RESEARCH SURVEYS

A. virescens was caught during trawl surveys by RV Dr. Fridtjof Nansen in Kenya in 1980, where it was a dominant species in the catch; in east and west Madagascar with catch rates up to 19.5 and 9 kg/hr, respectively (Krakstad *et al.* 2008, Torstensen *et al.* 2009); in the Comoros Gyre with a catch rate of 12 kg/hr (Roman *et al.* 2010); and on the Mauritius/Mascarene Plateau with a catch rate of 10 kg/hr (Strømme *et al.* 2010).

ETELIS CARBUNCULUS

Common name:
– Deep water red snapper

Family:
– Lutjanidae

Attains: 127cm TL

Photo: Simon Chater,
Oceanographic Research Institute (ORI).

DISTRIBUTION & HABITAT

Widely distributed in Indo-Central Pacific region, including, Mozambique, Tanzania, Kenya, Madagascar, Seychelles, Mauritius and Comoros; inhabits rocky areas (Sommer *et al.* 1996) at depth range of 89-485m (Allen 1985, Chave & Mundy 1994). A benthopelagic species (Mundy 2005).

FISHERY

CATCH TRENDS

This species is reported in the catch statistics (StatBase) of Mauritius for 2003 and 2004, with 63t and 72t, respectively. About 99% was caught with hook and line and the rest by traps. *E. carbunculus* is also an important species in Madagascar (FAO 2012b), and was the dominant species (referred to as "vivaneau rouge") during experimental linefishing in Madagascar in 2003-2004, with around 12.5t caught (Ministère de l'Agriculture, de l'Elevage et de La Pêche 2004).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

Two fish caught in February on the north Pemba Banks were ripe (Nzioka 1979).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT & STATUS

E. carbunculus has been assessed as Data Deficient (IUCN Red List 2012). This is a widespread and abundant species, but is fished throughout much of its range where it is now reported to be undergoing some significant localised declines. The rarity or apparent absence in the Comoran deep demersal habitat of several large predators, including *E. carbunculus*, has been attributed to fishing pressure by the Comoran fishers (Heemstra *et al.* 2006).

RESEARCH SURVEYS

Catch rates up to 64 kg/hr were obtained during RV Dr. Fridtjof Nansen surveys in 2009 in West Madagascar (Torstensen *et al.* 2009). Low catch rates were obtained for similar surveys in Mauritius and the Mascarene Plateau in 2010 (Strømme *et al.* 2010).

ETELIS CORUSCANS

Common names:
- Deepwater longtail red snapper

Family:
- Lutjanidae

Attains: 120cm TL

Photo: Simon Chater,
Oceanographic Research Institute (ORI).

DISTRIBUTION & HABITAT

Indo Pacific, including East Africa and SWIO islands but rarely in South Africa; depth range of 90–396m (Allen 1985, Chave & Mundy 1994).

FISHERY

CATCH TRENDS

No catch data were available from any of the SWIOFP countries. An exploratory fishing survey using bottom long-lines for this species was conducted by the Chinese on the Saya de Malha Bank in the Western Indian Ocean (international waters) in 2005 (Liu-xiong *et al.* 2008). This species makes a minimal contribution to commercial linefish catches in KZN, and is seldom identified in logbooks (Oceanographic Research Institute, unpubl. data).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

Biological data from 310 individuals were collected from October 2005 to January 2006 during the survey on the Saya de Malha Bank. Liu-xiong *et al.* (2008) reported that gonad maturity in stages V and VI were dominant with 60.8% of the specimens at the highest level of maturity in stage V.

SEX RATIO

The ratio of males to females on the Saya de Malha Bank was about 2.4:1 (Liu-xiong *et al.* 2008).

LENGTH/ WEIGHT

Saya de Malha Bank: $W(g) = (0.009439)\ FL(cm)^{3.0817}$; the dominant length range was 683-803mm FL (Liu-xiong *et al.* 2008).

STOCK ASSESSMENTS AND REFERENCE POINTS

RESEARCH SURVEYS

This species was caught at one station during RV Dr. Fridtjof Nansen survey in West Madagascar in 2009 (catch rate 107.59 kg/hr).

LUTJANUS BOHAR

Common name:
– Two-spot red snapper

Family:
– Lutjanidae

Attains 74cm

Photo: Oceanographic Research Institute (ORI).

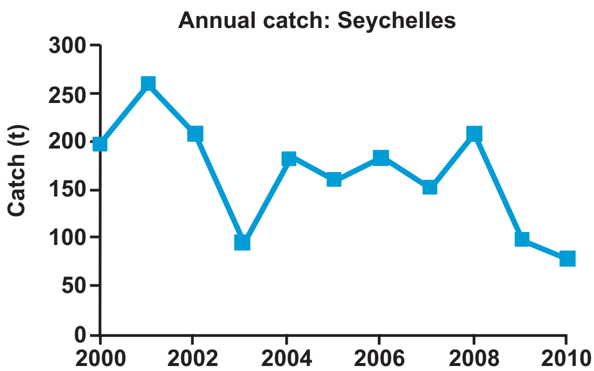
DISTRIBUTION & HABITAT

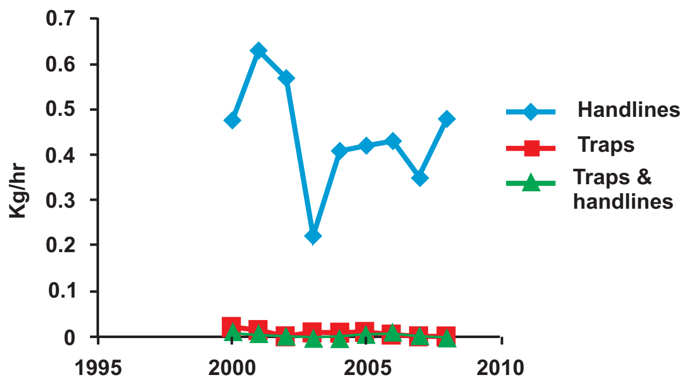
Widespread Indo-Pacific and found throughout East Africa. It is more common around oceanic islands than in continental areas (Fishbase 2012). Inhabits coral reefs, including sheltered lagoons and outer reefs (Sommer *et al.* 1996).

FISHERY

CATCH TRENDS

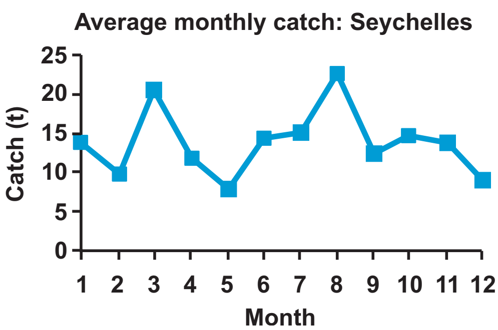
L. bohar is an important species in the SWIO region. In Madagascar, it composed about 2.4% of the industrial catch (diverse gear types) reported in observer logbooks between 2008-2010 (unpubl. data). This species is avoided in Mauritius due to the potential for ciguatera (MRAG 1996b). *L. bohar* is reported in the Seychelles' bank fishery's artisanal catch statistics from 2000-2008 (StatBase). The graphs on the right are based on StatBase datasets (until 2008) and additional catch data provided by Seychelles for 2009 and 2010. The annual catch declined from around 260t in 2001 to 95t in 2003, followed by a general increasing trend, reaching 207t in 2008. It has been suggested that the fluctuation (decrease) in annual catch could be attributed to the occurrence of warm events such as occurred in 1998 and 2003 (FAO/SWIOFC 2011a). Annual catch thereafter declined sharply to around 77t in 2010. Catches during 2000-2010 were generally higher than in the 1980s. Between 1981-1986, the highest catch (gutted weight) was 57t in 1984 and the lowest 20t in 1985 (Seychelles Fishing Authority and Fishing Development Company Statistics).





Over 97% of the catch reported on StatBase was taken by demersal handlines and the rest by traps. CPUE (catch per hour fishing time) for three different gear types (handlines, traps, and combination of traps and lines) in Seychelles are shown below. CPUE showed a similar trend as annual total catch, declining between 2001–2003, followed by a general upward trend and did not attain previous levels as in the early 2000s.

Monthly catch trend in Seychelles shows two peaks- in March and August, which may be related to weather conditions. A similar trend was observed for *L. sebae* in Seychelles where the highest fishing mortality occurred during the calm inter-monsoon months (Grandcourt *et al.* 2008).



LENGTH AT FIRST CAPTURE

In Kenya, length at first capture was reported as 9.6cm TL (for a variety of gear types combined), which is significantly lower than the size at maturity of 42.4cm (Mangi & Roberts 2006).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

L. bohar possibly forms spawning aggregations in Kenya and Seychelles (Robinson *et al.* 2004, Maina *et al.* 2008). A high proportion of ripe fish was observed in October and January/ February in East Africa (Nzioka 1979). In Seychelles, this species was reported to spawn throughout the year with peak spawning activity in March and in October /November (Wheeler and Ommanney 1953).

LENGTH AT MATURITY

In Kenya, this species reportedly attains maturity at a length of 42.4cm (Mangi and Roberts 2006).

SEX RATIO

Sex ratio of 1:1 reported for Seychelles (MRAG 1996a).

AGE & GROWTH

Kenya: L_∞=66cm TL; K=0.27; W_∞=4,875 g (Talbot 1957).
Seychelles: L_∞=66cm TL; K=0.33; W_∞=4,923 g (Wheeler and Ommanney 1953, Munro 1983).
Maximum age of 13 years found in Kenya (Manooch 1987).
Maximum length of 74cm reported in Seychelles (MRAG 1996a).

LENGTH/WEIGHT

Seychelles: $W(g)= 0.01304\ FL(cm)^{3.127}$ (MRAG 1996a).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT & STATUS

In Seychelles, there have been no recent assessments and the status of this species is uncertain. However, there is concern over the stock as high fishing pressure continues in the absence of management measures (SFA 2012).

RESEARCH SURVEYS

L. bohar was one of the most common demersal species caught during surveys by RV Dr. Fridtjof Nansen on the Tanzanian shelf (Zanzibar and Mafia) in 1982-1983, with catch rates up to 212 kg/hr in depths of 24m (Iversen *et al.* 1984), as well as off Kenya in 1980. In West Madagascar, catch rates up to 111 kg/hr were obtained.

LUTJANUS SANGUINEUS

Common name:
- Humphead snapper

Family:
- Lutjanidae

Photo: Rudy van der Elst (1988).

DISTRIBUTION & HABITAT

Distributed from the Red Sea east to the Arabian Sea and south to KwaZulu-Natal, South Africa (Allen 1985). Inhabits coral and rocky reefs to depths of at least 100 m (Sommer *et al.* 1996). Off South Africa shows a preference for slightly silty, turbid areas in the vicinity of shallow, offshore banks (van der Elst 1981). Captured mainly at night on coral banks off Mafia Island (Tanzania) in 9-12m and off Zanzibar to 75m (Lieske & Myers 1994).

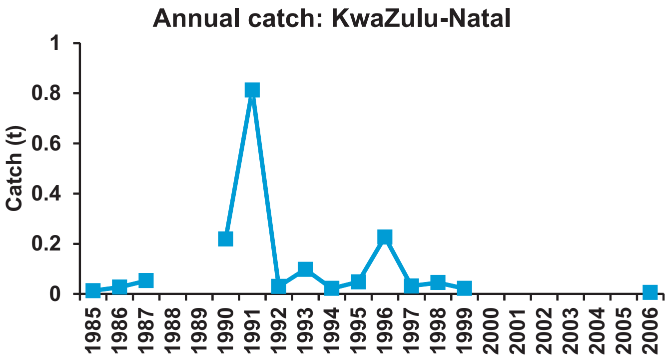
FISHERY

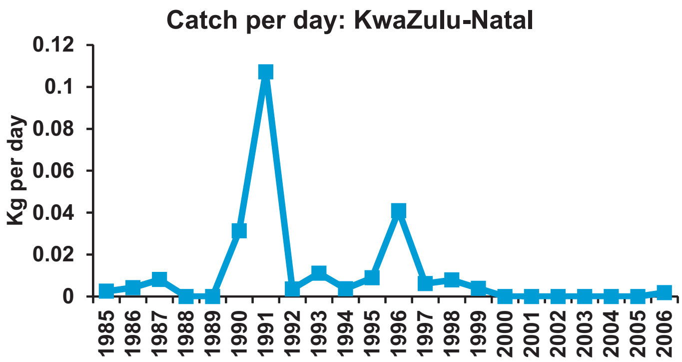
CATCH TRENDS

L. sanguineus is recorded in the linefishery statistics of KwaZulu-Natal (StatBase). Annual catches for the years between 1985-2006 when this species was recorded are presented opposite.

Small quantities of this species were caught in KZN, with annual catch peaking at around 0.8t in 1991 and at 0.23t in 1996. CPUE (catch per day fishing time) trend for the line fishery in KZN reflects the same trend as total annual catch, with a major peak in 1991 and a smaller peak in 1996, declining to almost zero in other years.

L. sanguineus is considered an important species in Madagascar (FAO 2012b), although it comprised only 1.7% of the catch reported in observer logbooks between 2008-2010 (unpubl. data).





BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

Reported to form spawning aggregations in Kenya and Seychelles (Maina *et al.* 2008). Targeting of spawning aggregations by fishers could lead to local extinction of these aggregations, with impact on the stock. In the Mafia Archipelago and North Kenya Banks, peak spawning was reported in October and March (Nzioka 1979) and in South Africa in June and July (van der Elst 1981).

LENGTH AT MATURITY

East Africa: 50-60cm, at 6 years of age (Allen 1985).

AGE & GROWTH

South Africa: Maximum length (Lmax) of 90cm FL reported (van der Elst 1981).

LENGTH-WEIGHT

South Africa:W(g)= 0.0184 FL $cm^{2.92}$ (Torres 1991).

STOCK ASSESSMENTS AND REFERENCE POINTS

RESEARCH SURVEYS

L. sanguineus was caught during research surveys by RV Dr. Fridtjof Nansen and others. In Seychelles, it was one of the dominant species caught in 1978. In Tanzania, up to 39 kg/hr was caught at a depth of 31 m during the 1982-1983 survey. In East and West Madagascar catch rates up to 57 kg/hr and 77 kg/hr, respectively, were obtained in 2009 (Krakstad *et al.* 2008, Torstensen *et al.* 2009).

LUTJANUS SEBAE

Common name:
– Emperor red snapper; "Bourzwa"

Family:
– Lutjanidae

Attains 100cm FL

Photo: Rudy van der Elst (1988).

DISTRIBUTION & HABITAT

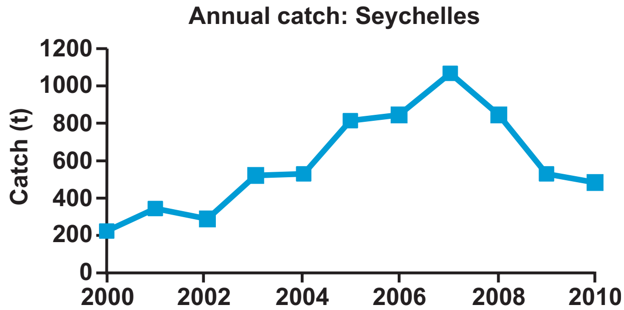
This species is widely distributed along the coasts of the Indian Ocean and its islands (Druzhinin 1970). Juveniles inhabit shallow areas while adults may be found to a depth of 100 m (Allen & Senta 1984).

FISHERY

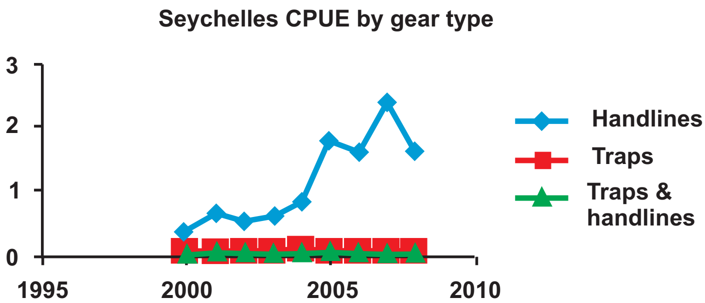
CATCH TRENDS

L. sebae is one of the most important commercially exploited demersal species in Seychelles, where it is caught mainly offshore on the Seychelles Bank by hook and line, although catches are also made with traditional bamboo traps in coastal waters (Grandcourt *et al.* 2008). On the Mahé Plateau *L. sebae* composed 23% of artisanal hook and line catch and about 42% of schooner handline catch between 2006-2010 (WIOFish 2011). Also considered an important species in Madagascar (FAO 2012b) although it comprised only about 1.5% of the catch reported in observer's logbooks between 2008-2010 (unpubl. data). *L. sebae* is avoided in Mauritius because of the potential for ciguatera (MRAG 1996b). On StatBase, this species is reported in the artisanal hook and line catch of Seychelles.

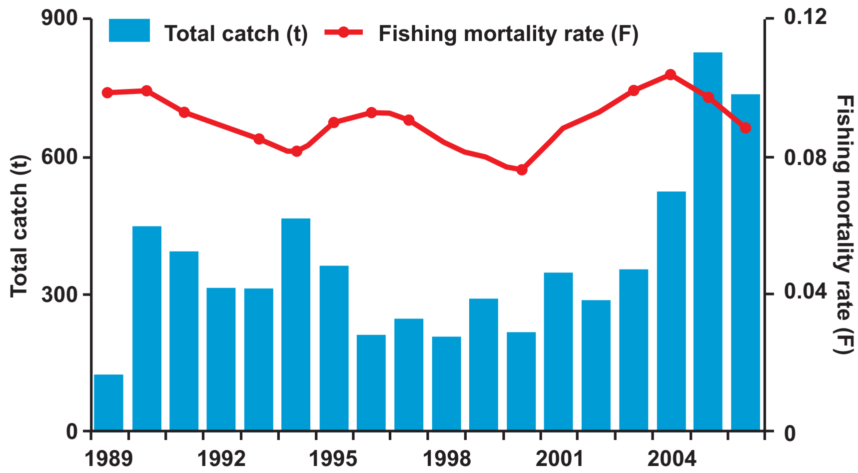
The graphs opposite are based on Seychelles StatBase dataset (until 2008) and additional catch data provided by Seychelles for 2009 and 2010. Mean annual catch of *L. sebae* increased steadily from around 200t in the year 2000 to over 1000t in 2007 (associated with increased targeting by the artisanal fishery), after which it declined sharply to around 485t in 2010. This decline could be attributed to the exploited status of this species in Seychelles (see below). Annual catch in previous years (1984-1986) rose from 107t in 1984 to156t (gutted weight) in 1986 (Seychelles Fishing Authority and Fishing Development Company Statistics). Catch in 1988 was 101.8t (Grandcourt *et al.* 2008).



Around 95% of the catch is taken with handlines, with the rest caught by traps and combination of traps/lines. Catch rate by gear type in Seychelles shows a general steady increase in catch per hour of handlines until 2007, followed by a sharp decline. Catch rates of the other gears were relatively stable, albeit negligible compared to handlines.



There is a distinct seasonal pattern in the Seychelles fishery with most fishing mortality (65%) during the calm inter- monsoon months (Grandcourt *et al.* 2008). Average monthly catch trend (2000-2008) shows two peaks, from February-April and October-December. The decline from May-August could be attributed to inclement weather during this period. The spawning activity of *L. sebae* on the Seychelles Bank peaks during the same periods, February-April and September/October (Lablache & Carrara 1988). This raises the management concern about the potential disruption of reproductive activity associated with the increase in fishing effort during the spawning seasons.



LENGTH AT FIRST CAPTURE

Length at first capture of *L. sebae* was reported as 41cm in Seychelles (Lablache & Carrara 1988). Fish are vulnerable to handlines at a mean size of 39.8cm FL (age 3.1 yrs), which is considerably smaller than the mean size at which first sexual maturity is anticipated (62.0cm FL), resulting in high juvenile retention rates of 51.2% on average (Grandcourt *et al.* 2008). Individuals caught in traps are even smaller than those caught by hook and line (A. Harris, FAO *pers. comm*).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

On the Mahé Plateau, *L. sebae* has two spawning seasons from around February to April (major peak), and September through October, corresponding to the inter-monsoon periods. This species is thought to congregate on shallow coral heads during the spawning season, making it more vulnerable to fishing gear (Lablache & Carrara 1988). Mees (1992) reported spawning peaks in October-November and March-May in Seychelles. Spawning aggregations have also been observed by Robinson *et al.* (2004).

LENGTH/AGE AT MATURITY

In Seychelles, age at maturity of 9 years has been reported for males and females combined (Grandcourt *et al.* 2008); length at maturity of 34.6cm FL recorded for females (Mees 1992).

SEX RATIO

Sex ratio (M:F) of 1.07 in Seychelles (MRAG 1996a).

AGE & GROWTH

Several estimates of growth parameters in Seychelles have been made for *L. sebae*:

K	*L∞ cm FL*	t_0	*Data source; reference*
0.14	78.7	-1.9 yrs	Otoliths; Grandcourt *et al.* 2008
0.18	99.1		LF; MRAG 1996a
0.16	92.9		LF (2-5 yr old cohorts); Mees 1992
0.38	95.1		Males; LF; Mees 1992
0.27	90.0		Females; LF; Mees 1992
0.22	98.0		Bach 1991
0.23	96.0		*LF; Lablache & Carrara 1988

*Length frequency data collected by trawl surveys carried out on the Mahé Plateau by RV Professor Mesyatsev, October 1977 (Birkett 1979); Nauka, February to April 1979 (Azov-Black Sea Research Institute of Marine Fisheries and Oceanography 1979); and in a bilateral project with Germany, March to November 1981 (Steinberg *et al.* 1982 Growth parameters (L∞ and K) determined from otolith readings were lower than those estimated with length based methods.

In Seychelles maximum length of *L.sebae* reported as 91cm TL (male) and in South Africa 100cm FL (unsexed) (Mees 1992, van der Elst 1981). Age range of 1-5 yrs reported in Seychelles by Chauvelon (1990) and 1-28 years by Grandcourt *et al.* (2008).

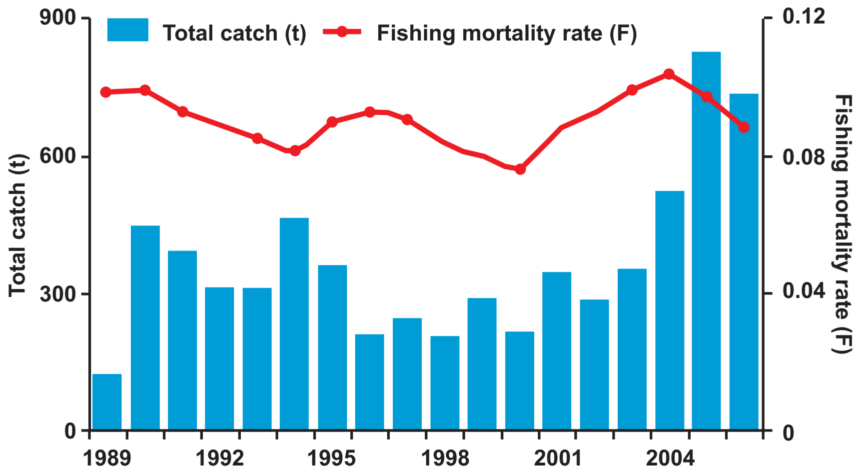
Relatively large size, spawning aggregations, slow growth rate, and high age at maturity make this species highly vulnerable to overfishing.

LENGTH-WEIGHT RELATIONSHIP

Seychelles: $W(g) = 0.019\ FL(cm)^{3.01}$ (Grandcourt *et al.* 2008).

MORTALITY

In Seychelles, a length-converted catch curve gave a total mortality (Z) of 0.73. Natural mortality (M) = 0.48 and fishing mortality (F) = 0.25 (Lablache and Carrara 1988). More recent estimates of natural mortality for *L. sebae* on the Seychelles Bank range from 0.36 (Mees 1992) to 0.12 (Grandcourt *et al.* 2008). Grandcourt *et al.* (2008) estimated annual Z rates from 1977 to 2004 (range 0.18- 0.23) and F rates as depicted in the graph.



Catch and fishing mortality rates from 1989–2006 are shown above; catch trends did not mirror the relative change in estimated fishing mortality rates for the same years (Grandcourt *et al.* 2008). Annual rates of fishing mortality derived from trawl samples for 1977, 1979, and 1981 were lower than those subsequently obtained from the handline fishery.

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

The first stock assessments of *L. sebae* on the Seychelles Bank were made using the swept-area method applied to trawl survey data collected in the 1970s (Birkett 1979; Tarbit 1980; Marchal *et al.* 1981; Kunzel *et al.* 1983) and length cohort analysis by Lablache & Carrara (1988):

Estimated biomass (t/km²)	*Area and Source*
0.18	Edge zon: Kunzel *et al.* 1993
0.09	Central zone: Kunzel *et al.* 1993
0.41	Trawlable area: Tarbit 1980
0.29	Trawlable area: Marchal *et al.* 1981
0.35	Hard bottom offshore banks: Lablache & Carrara 1988

A long-term equilibrium model suggested that if the 1984 level of effort was maintained, the annual yield of *L. sebae* would be around 380t (Lablache & Carrara 1988). However, Grandcourt *et al.* (2008) suggested that the sustainable yields estimated by Lablache & Carrara (1988) should not have exceeded 208t or 8.8% of the adult stock biomass and that the production potential for *L. sebae* was probably overestimated in the past. The optimum fishing mortality rate corresponding to an SBR of 40% of unexploited levels ($F^{40\%}$) ranged from 0.07 to 0.1/ year (Grandcourt *et al.* 2008). The limit fishing mortality rate ($F_{30\%}$) corresponding to an SBR of 30% of unexploited levels ranged from 0.10 to 0.14/ year. F exceeded $F_{40\%}$ in 12 of the 16 years, and exceeded $F_{30\%}$ in 1991 and 2004. The harvest rates (mean for all years) associated with the target and limit biological reference points of 6.6% and 8.8%, respectively, indicate that *L. sebae* has a low production potential.

YPR ranged from 3,393g (1994) to 5,646g (1977) with SBR ranging from 28.0% (2004) to 58.1% (1997) of the unexploited levels. During most years over this period, the fishing mortality rates and consequently the relative SBR approximated the limit reference point, indicating that overall, the resource has been exploited close to threshold levels. YPR and SBR were estimated to increase by 51.8% and 56.2%, respectively, at the existing fishing mortality rate if the selectivity characteristics of the handline fishery were modified so that the mean age at first capture was assumed equal to the mean age at first sexual maturity.

The stock of this species is considered to be fully exploited to overexploited in Seychelles (Grandcourt *et al.* 2008, SFA 2012). The catch in 2007 was more than four times higher than the estimated MSY of 208t and continues to be above MSY, with the fishery requiring urgent management measures (SFA 2012).

REFERENCE POINTS/ MANAGEMENT OBJECTIVES

Grandcourt *et al.* (2008) defined target and limit biological reference points as the instantaneous rates of fishing mortality associated with values of Spawning Biomass/Recruit (SBR) of 40% ($F^{40\%}$) and 30% ($F^{30\%}$) of unexploited levels respectively. Management plans that explicitly address this species have not been developed by any of the countries.

RESEARCH SURVEYS

L. sebae was caught during trawl surveys by RV Dr. Fridtjof Nansen in Seychelles in 1978, where it was one of the dominant species in the catch (IMR 1978b); in West Madagascar in 2009 (catch rates up to 30 kg/hr); and in Mauritius and on the Mascarene Plateau in December 2010 (catch rates up to 60 kg/hr).

PRISTIPOMOIDES FILAMENTOSUS

Common names:
- Crimson jobfish
- Rosy jobfish

Family:
- Lutjanidae

Attains 100cm

Photo: Simon Chater,
Oceanographic Research Intitute (ORI).

DISTRIBUTION & HABITAT

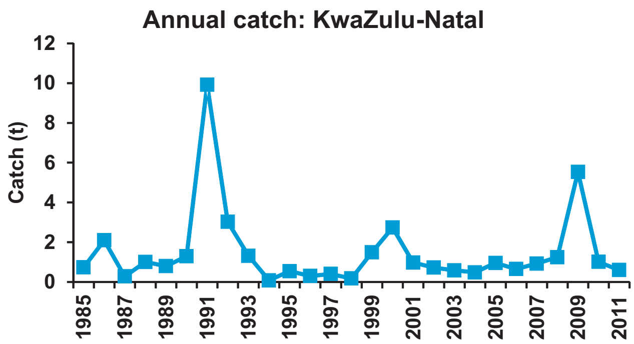
Discontinuous distribution in the western Indian Ocean and recorded from Madagascar, Reunion, east coast of Africa to south of KZN (Heemstra & Heemstra 2004). Found in deep waters from 90 to 360m over rocky bottoms, along the edge of the continental shelf, and around isolated oceanic islands and banks (Randall *et al.* 1997).

FISHERY

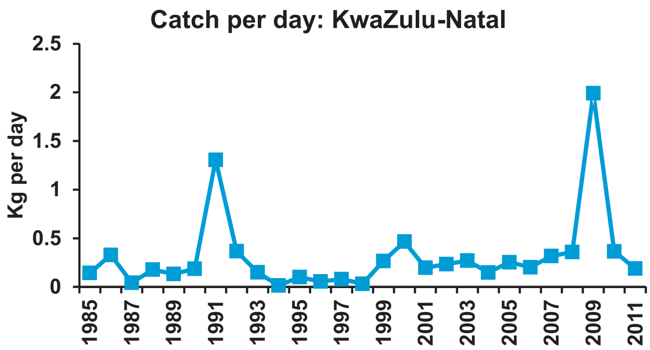
CATCH TRENDS

Annual catch and CPUE (catch per day fishing time) are reported on StatBase for the commercial line fishery of KwaZulu-Natal, South Africa. Trends from 1985-2010 are shown in the following two graphs:

Annual catch of *P. filamentosus* remained below 3t, except in 1991 when it reached nearly 10t and in 2009 when it was 5.5t.



Catch per fishing day shows a similar trend as total catch, with two major peaks, but with the highest CPUE in 2009.



SIZE AT FIRST CAPTURE

Length at capture of 41cm in Seychelles (MRAG 1996a).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

In Seychelles, spawning occurs year-round (Mees 1992), with a major peak on the edge of the Seychelles Bank in February-May and November (Mees 1993). Catch rates of the bank fishery in Seychelles were higher during the calm inter-monsoon periods (April and October), which are also periods of peak reproductive activity for some of the target species (MRAG 1996a).

MATURITY

On the Mahé Plateau, females reach maturity at 36 -38cm FL, and males at 40- 42cm (Mees 1993).

SEX RATIO

On the Mahé Plateau, the sex ratio of this species was reported to be close to unity (Mees 1993).

AGE & GROWTH

Growth parameters of this species from the Mahé Plateau, Seychelles, have been estimated by a number of authors using length based methods and otolith readings:

L∞cm (FL)	*K/yr*	*W∞ (g)*	*t_0/yr*	*Sex*	*Source*
77.6	0.275	6,790		F	Mees 1993 (length)
85.8	0.3	12,200		M	Mees 1993 (length)
81.7	0.2875			M+F	Mees 1993 (length)
75.8	0.244			-	Mees & Rousseau 1997 (length)
77.8	0.36		0.06	F	Hardman-Mountford *et al.* 1998 (otoliths)
85.8	0.33		-0.16	M	Hardman-Mountford *et al.* 1998 (otoliths)
62.3	0.11			-	Pilling *et al.* 1999, 2000 (otoliths)

There were no distinct differences in the growth parameters estimated by length-based methods and from otoliths. However, Pilling *et al.* (2000) found that otoliths were unsuitable for routine aging of this species owing to difficulties in differentiating periodic increments from other increments not related to a regular time scale. On the other hand, use of length-based methods can also produce uncertain results, especially in slow-growing, long-lived species.

Slow growth and relatively high age make it vulnerable to overfishing.

LENGTH-WEIGHT RELATIONSHIP

Mahé Plateau, females: $W(g)= 0.0553\ FL(cm)^{2.693}$; males: $W(g)= 0.0514\ FL(cm)^{2.78}$;
combined: $W(g)= 0.05353\ FL(cm)^{2.7004}$ (Mees 1993).
L^{max} of 89cm TL in Seychelles (Mees 1992).

MORTALITY

Mortality rates on the Mahé Plateau, estimated from length converted catch curve analysis, were Z=0.811, F=0.277 with M=0.534 derived from Pauly's empirical formula. Jones' length cohort analysis gave an estimate of F= 0.294 for the fully exploited part of the stock (Mees 1993).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

Mees (1993) estimated the mean initial biomass density of unexploited populations of *P. filamentosus* on three banks in the Seychelles as 2,987 kg/km^2 and the maximum sustainable yield at 717 kg/km^2/yr. This was equivalent to 24% of the virgin biomass of *P. filamentosus* on the edge of the Seychelles Bank.

An analysis carried out by MRAG (1996a) showed that in Seychelles this species appeared to be most at threat from overfishing. The length at capture was low relative to the length at maturity and fishing mortality was high on the banks south of the Mahé Plateau in 1991 and in the Amirantes in 1994, when fishing by the mothership dory fishing venture was intense.

Grandcourt (2003) used daily catch and effort data to determine the effect of intensive line fishing on the initial virgin biomass of *P. filamentosus* at Saya de Malha Bank on the Mascarene Plateau. Biomass densities of 2,364 kg/km^2 and 1,206 kg/km^2 were reported over a depth range of 55-130m. The potential sustainable yield prior to exploitation was estimated at 567 kg/km^2/yr. The initial virgin biomass available to a line fishery at the north western promontory of Saya de Malha Bank was estimated at 72.6t. The quantity of *P. filamentosus* caught by the mothership-dory fishing operation represented 82% of the initial biomass available to a hook-and-line fishery, equivalent to more than three times the estimated maximum sustainable yield estimated by Mees (1983). Catch rates decreased with time and could not be attributed to changes in location, climatic conditions, fishing depth, fishing method, or bait type. The mode of operation was characteristic of a "hit and run" fishery, where fishing would be conducted at a specific location until catch rates were no longer viable, following which the vessels moved to other fishing grounds. The results demonstrated that intensive line fishing operations have the potential to rapidly deplete demersal fisheries resources. The concentration of the stock in a narrow depth range makes it an easy target, with high potential for overfishing (Mees 1993).

On the Mahé Plateau, yield in the past 10 years has been significantly below MSY and the stocks were overfished in the early 1990s. Reduction in fishing effort was reported in 2009 and 2010, and the stocks are considered to be recovering (SFA 2012).

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

Mees & Rousseau (1997) used MSY and maintaining the spawning stock at 20% of its unfished level, as management targets in their investigation of sensitivity of equilibrium yields of *P. filamentosus* to uncertainties in the input parameter estimates (fishing mortality and length at capture). The simulations indicated that within reasonable effort limits, little benefit could be gained from size regulation, and fishing mortality (effort) regulation was seen to be a more appropriate management option for the hook and line fishery. It was recommended that the fishing mortality not be allowed to exceed F=0.5. Results also indicated that there was little advantage to managing the fishery at MSY.

In Seychelles, the deep water monofilament gill net fishery targeting deep water snappers (mainly *Pristipomoides* spp) is prohibited on the Mahé Plateau and restricted for certain islands of the Amirantes and southern islands. These measures are enforced and only limited mothership-dory operations are practiced on some offshore banks in the southern islands group (SFA 2012).

RESEARCH SURVEYS

P. filamentosus was one of the major species caught during experimental line fishing in northern Mozambique in 1990 on the vessel 'Marie Christine'. This species (referred to as "vivaneau blanc") was also a dominant species captured during experimental line fishing in Madagascar in 2003-2004, with over 4,000 kg caught (Ministère de l'Agriculture, de l'Elevage et de La Pêche 2004). It also made up a substantial part of the trawl catch in depths between 200 -500 m in West Madagascar (catch rate up to 13 kg/hr) during a survey by RV Dr. Fridtjof Nansen (Torstensen *et al.* 2009). Also caught in small quantities during surveys by RV Mafunzo in the Zanzibar and Mafia Channel in 1986-1988 (MBEGANI Fisheries Development Centre, Tanzania). One of the dominant species caught off Kenya during RV Dr. Fridtjof Nansen survey in 1980 and a catch rate of up to 5.5 t/hr of this species (individual weights were 3.5-6.8 kg and lengths 72-85cm) was obtained on the North Kenya Bank in 1983 (Iversen 1984). One of the most common demersal species caught in deep waters during RV Dr. Fridtjof Nansen surveys on the Tanzanian shelf (Zanzibar and Mafia) in 1982-1983 (IMR 1982).

PRISTIPOMOIDES MULTIDENS

Common name:
– Goldbanded jobfish

Family:
– Lutjanidae

Attains 50cm

Photo: Randall 1997 (from Fishbase, Froese and Pauly 2012).

DISTRIBUTION & HABITAT

Found throughout East Africa in depths of 40-245m; schooling behaviour and inhabits areas of hard, rocky and uneven sea floor and steep areas off islands (Parrish 1987, Anderson & Allen 2001).

STOCK ASSESSMENTS AND REFERENCE POINTS

RESEARCH SURVEYS

Caught at one station (17.7 kg/hr) in West Madagascar at depth range of 242-248 m, during RV Dr. Fridtjof Nansen survey in 2009 (Alvheim *et al.* 2009).

PRISTIPOMOIDES ZONATUS

Common name:
– Oblique-banded snapper

Family:
– Lutjanidae

Randall 1997 (from Fishbase, Froese and Pauly 2012).

DISTRIBUTION & HABITAT

Throughout East Africa. Benthopelagic, depth range 70-300m (Anderson & Allen 2001), usually 125-275m (Fry *et al.* 2006). Occurs over rocky bottoms (Sommer *et al.* 1996) of the continental shelf and slope.

OTOLITHES RUBER

Common name:
– Snapper kob

Family:
– Sciaenidae

Attains 80cm

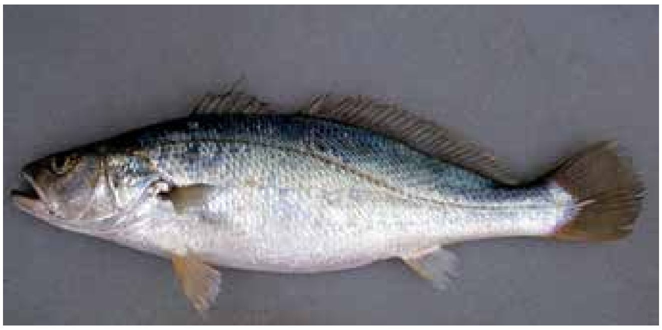


Photo: Simon Chater, Oceanographic Research Institute (ORI).

DISTRIBUTION & HABITAT

Distributed along East Africa and Madagascar in the West Indian Ocean. Found in turbid water over subtidal soft sediments (Fennessy *et al.* 1994); especially found on shrimp trawl grounds in the SWIO region.

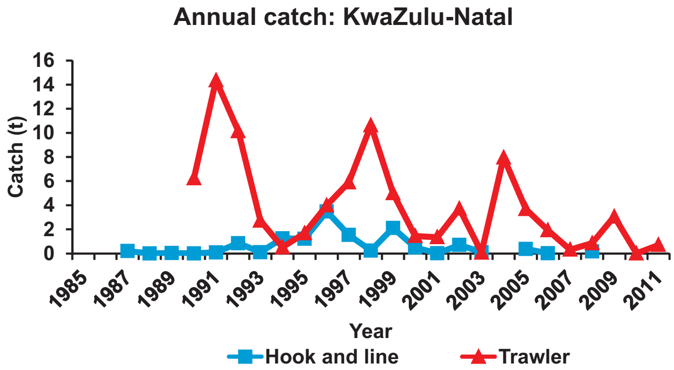
FISHERY

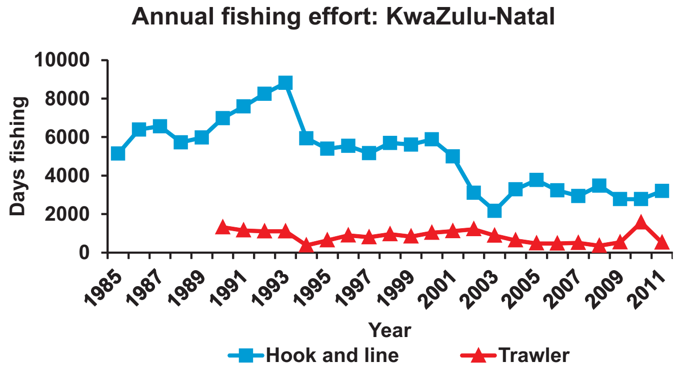
CATCH TRENDS

In South Africa, Mozambique, Tanzania and Kenya, *O. ruber* is an important bycatch species of penaeid shrimp trawlers (Schultz 1992; Fennessy 1994a; Mwatha 2002). This bycatch often consists of juveniles or small individuals that may be discarded at sea (Mwatha 2002, Olbers & Fennessy 2007). On the Thukela Bank of South Africa, this species formed more than 14% (by number) of fish bycatch in the shrimp fishery in 1989-1992 (Fennessy 1994a), while in Tanzania, it was nearly 7% (by number) in 2001 (Bwathondi *et al.* 2002). In Madagascar, *O. ruber* was also one of the major bycatch species of shrimp trawlers (FAO 1994, Randrianarisoa 2007). *O.ruber* is also caught by hook and line, for example in Mozambique, where it comprised 12% of the catch of the artisanal hook and line fishery (WIOFish 2011).

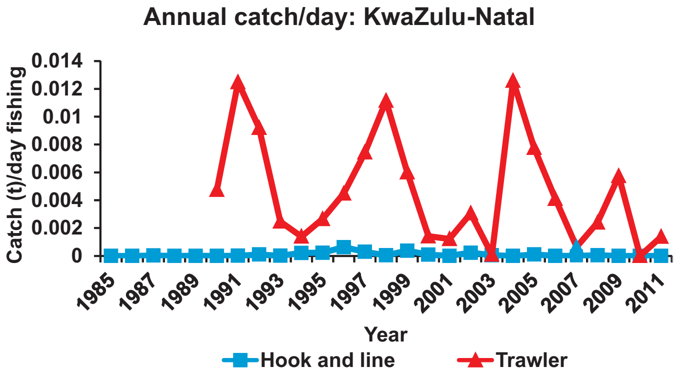
O. ruber is reported in annual landed catches of KZN commercial (bottom trawls) and recreational fisheries (hook and line) from 1987- 2010 (StatBase). Up to 84% of the average annual catch in KZN is taken by bottom trawls as shrimp bycatch. Annual catches between 1987-2010 with lines and bottom trawls are graphed below. Trawl catches are reported from 1990 and showed marked fluctuations with a general downward trend until 2010 owing to changes in fishing effort and restrictions on trawling in 2003. Trawl catches surpassed line catches in almost all years.

Fishing effort (days fishing) of line vessels generally declined from 1994, while trawling effort declined from 1990-1994 and again after 2002. The closed season for trawling was fully implemented around 2003, and currently effort in this fishery is very low.





Annual CPUE (catch per fishing day) of line vessels and trawlers follow a similar trend to that of total annual catches by these two types of gear. Highest CPUE of trawlers occurred in 1991 and 2004; in 2010 this was almost zero. Olbers and Fennessy (2007) reported a steady decline in trawling effort in KZN because of reduced profitability in the fishery (due to several factors), which in combination with measures to lower the level of bycatch, reduced fishing mortality below that estimated for the period 1989-1992.



SIZE AT FIRST CAPTURE

Age = 1 year (trawl catches) in KZN, before age at maturity (Fennessy 1994a, Olbers & Fennessy 2007).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

In KZN, *O. ruber* shows protracted spawning from September to February (Fennessy 2000). Most of the individuals caught in some areas of the Sofala Bank, Mozambique were between 15-22cm, indicating that this might be a recruitment area (Brinca *et al.* 1984).

MATURITY

Length at 50% maturity for females in KZN, South Africa was 237mm TL at age 1.7 years (Fennessy 2000).

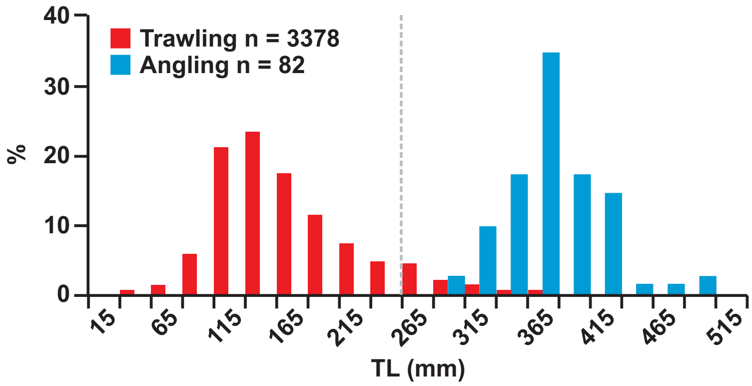
SEX RATIO

In KZN, overall male:female ratio was 1:1.82, with the proportion of females increasing with size (Fennessy 2000). The deviation from a 1:1 sex ratio in the larger size classes suggests sex change, although no evidence was found for this. Size disparity between sexes could also be explained by differential growth and mortality rates, differential migration or spatial sexual segregation.

AGE & GROWTH

Age and growth was determined from otoliths in KZN by Brash and Fennessy (2005). Growth parameters for combined sexes were: L_∞=419mm TL, k= 0.31; t_0=-0.96, with minimum and maximum lengths of 84 and 485mm, respectively. There is evidence for disparity in growth rates for males and females, with females growing faster and also attaining larger sizes (Brash & Fennessy 2005).

In KZN, the mean size of this species increased significantly with greater depths (Fennessy 2000). Boat anglers caught larger individuals of *O. ruber* than the Thukela Bank trawlers, with modal sizes of 365mm TL and 140mm TL, respectively, as shown opposite (from Fennessy 2000). Most trawled individuals on the Thukela Bank were immature, suggesting that this area is a nursery ground (Fennessy 2000).



LENGTH-WEIGHT RELATIONSHIPS

Sofala Bank, Mozambique, females: logW= -1.97185 + 3.00149 logL;
males: logW = -2.117650 + 3.101417 log L (Brinca *et al.* 1984).

KZN: W(g)= 0.00494($TL^{3.13}$)(cm) (Fennessy 2000).

MORTALITY

Mozambique: M=0.7; F=1.25 (Schultz 1992).
KZN: M=0.68; F=0.53; Z=1.2 during 1989-1992 (Olbers & Fennessy 2007).
Although F was lower than M, the fishery was still considered overfished.

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

According to Schultz (1992) *O. ruber* has been overfished by shrimp trawlers in Mozambique. In South Africa, Olbers and Fennessy (2007) found that this species was also overfished during 1989-1992, based on SBPR assessment using the most likely values of M and F – the remaining proportion of SBPR was only 33% of the original unfished level. The overfished status resulted from capture before the fish have had an opportunity to spawn (tc< tm), i.e. recruitment overfishing (Olbers & Fennessy 2007). Studies on trawled fish by a number of authors (e.g. Thompson 1993; Mace 1994) demonstrate the likelihood of recruitment overfishing and stock collapse when SBPR is reduced to 20-30% of the unfished level.

As a result of changes in the shrimp trawl fishery since 1992, viz.: closed season from August to February; increase in codend mesh size from 38mm to at least 50mm – the status of *O. ruber* in KZN appears to have improved (Olbers & Fennessy 2007). This includes an increase in modal length from 150mm TL in 1989-1992 to 200mm TL in 2003-2005. By increasing the age at first capture in the (then) existing SBPR model to 2 years, SBPR increased to 56% of unfished level, so it was concluded that the bigger mesh size increased SBPR to between 33% and 56% of the unfished level (Olbers & Fennessy 2007).

In Madagascar, biomass of this species estimated from trawl data ranged from 0.016 t/km^2 in depths from 15-25 m to 0.093 t/km^2 in depths up to 5m; and from beach seines between 0.04 - 0.08 t/km^2 (Randrianarisoa 2007).

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

In South Africa: SBPR reference point of 40% of pristine level adopted as a threshold level for line-caught fish in South Africa (Olbers & Fennessy 2007), below which stock rebuilding should be undertaken (Griffiths *et al.* 1999).

RESEARCH SURVEYS

O. ruber was one of the most important species caught on the Sofala Bank, Mozambique , with catch rates over 18 kg/hr during a Russian survey (vessel "Pantikapey") of shrimp and demersal fish in 1981 (Sousa 1982); up to 50 kg/hr (with more than 50 kg/hr at one station) in 1983 during surveys by RV Dr. Fridtjof Nansen (Brinca *et al.* 1984), and 58-67% by weight of all families of demersal fish in 1982 and 1990 (Sætersdal *et al.* 1999). Most of the individuals caught in sub-area Quelimane 1 were between 15-22cm, indicating that this might be a recruitment area.

About 160kg was caught during a SWIOFP shallow-water shrimp trawl survey in Tanzania (FV Vega) in 2011 (Mwakosya *et al.* 2011). This species was the second most common in trawl bycatch during surveys by FV Vega in Kenya in 2009, comprising nearly 9% of the catch (without TED). Significant quantities were also caught during SWIOFP surveys (Cruises 1 and 2) with FV Vega off Kenya in 2011 (SWIOFP: unpublished data). Small quantities were caught during surveys by RV Mafunzo in the Zanzibar and Mafia Channel in 1986-1988 (MBEGANI Fisheries Development Centre, Tanzania).

EPINEPHELUS CHLOROSTIGMA

Common name:
– Brown- spotted grouper

Family:
– Serranidae

Attains 73cm

Photo: Rudy van der Elst (1988).

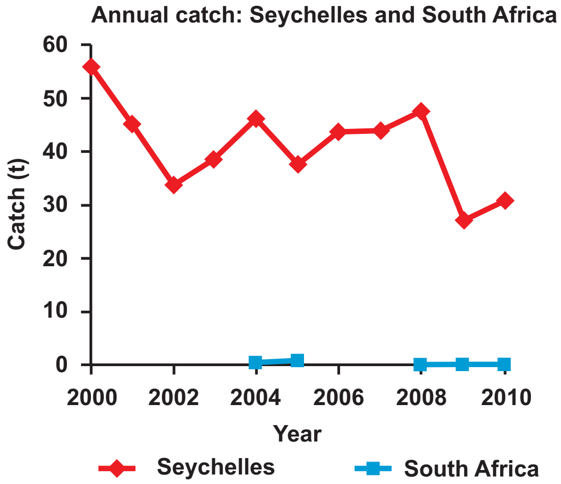
DISTRIBUTION & HABITAT

Distributed from the Red Sea to KwaZulu-Natal in South Africa, over a wide range of habitats such as seagrass beds and outer reef slopes (Fischer *et al.* 1990), depth range 4-300m (Opic *et al.* 1994). Although described as reef-associated and non-migratory (Opic *et al.* 1994), this species has been caught, albeit in small quantities, during demersal trawl surveys in the region, implying that they sometimes venture into soft bottom habitats.

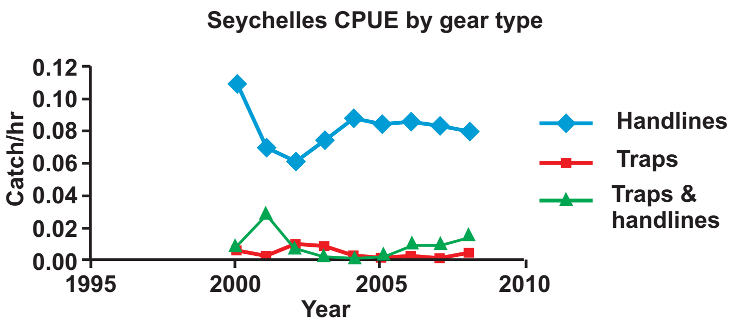
FISHERY

CATCH TRENDS

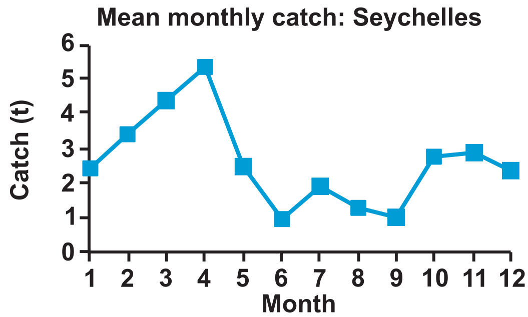
The following are results for Seychelles (StatBase until 2008 and additional catch data for 2009-2010 provided by Seychelles) and South Africa (StatBase), although the latter are probably compromised by misidentification. This species is reported in catches of Seychelles (artisanal handline) and South Africa (commercial linefish), with significantly higher catches in the former. In Seychelles annual catch declined from >50t in 2000 to around 34t in 2002, recovering slightly in subsequent years until 2008, when it declined from around 47t to 27-30t in 2009-2010. This decline may be consistent with the reported overfished status of this species in Seychelles (see below). Catches between 2000-2010 were generally lower than in the 1980s, when they exceeded 100t from 1981-1984. Between 1981-1986, the highest catch (gutted weight) was 164t in 1982 and the lowest 26t in 1985 (Seychelles Fishing Authority and Fishing Development Company Statistics). Annual catch of KZN was negligible: below 0.5t except in 2005 when it was nearly one tonne.



CPUE trends (catch per hour fishing time) in Seychelles show that handline is the dominant gear for this species. CPUE of this gear as well as for traps and lines combined fell sharply between 2001-2003. CPUE of traps also declined from 2002. CPUE of both traps and traps & lines showed a general increase between 2005-2010.



In Seychelles, between 1983-1993, catch rates of *E. chlorostigma* from schooners using handlines showed a progressive decline, which might have been due to a shift in target species, although stock depletion was not discounted (MRAG 1996a). In Seychelles, handlines account for around 88% of the catch, with traps and combination of traps and lines for the rest.



Average monthly catch (2000-2008) in Seychelles is highest from February-April, with a secondary peak in October-December. This is consistent with seasonal trends reported for the late 1980s by Sanders *et al.* (1988).

In Madagascar, *E. chlorostigma* accounted for about 3% of the catch reported in observer logbooks between 2008-2010 (unpubl. data).

LENGTH AT FIRST CAPTURE

Mean length at first capture of 37cm TL (age 5.1 years) reported in Seychelles (Sanders *et al.* 1988), which is close to the length at maturity estimated by Moussac 1986 (see below). In Kenya, length at first capture of 26.4cm TL was reported by Mangi and Roberts (2006). Differences in length at first capture could be attributed to variation in gear type, among other factors.

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

Forms spawning aggregations. A protogynous hermaphrodite, with transition from female to male at 46.4cm TL; not all females transform into males (Moussac 1986, Allsop & West 2003).

In Seychelles (Mahé Plateau) a single prolonged spawning season is suggested from about November - April, with two peaks at the beginning and end of this season when spawning is most likely to occur; related to rising water temperatures (Sanders *et al.* 1988).

SEX RATIO

In Seychelles (Mahé Plateau), the ratio of females:males was about 2.4:1, that is, a higher proportion of females, which could be due to heavy exploitation resulting in depletion of larger (male) fish (Moussac 1986).

MATURITY

In Seychelles, size at maturity of females was recorded at 23cm TL at age 2.5 yrs. (Grandcourt 2002) and 31cm TL (Moussac 1986). Males mature at larger size of 39cm TL (Moussac 1986). Sexual transition also occurs at about these lengths (ages about 4 to 5 years). In Kenya, Mangi and Roberts (2006) estimated length at maturity of 39.75cm for *E. chlorostigma*, which is above the length at first capture (26.4cm TL) reported by these authors.

AGE & GROWTH

Seychelles (St. Anne National Marine Park): Males grow slower and reach a greater size than females. Based on otoliths, growth parameters for males and females, respectively, were:
L_∞: 39.2, 38.4cm FL; K: 0.26, 0.29; t_0:-0.15, -0.14/yr (Grandcourt 2002).

Seychelles, Mahé Plateau: Combined sexes, based on length frequencies of two cohorts (July and January, with latter cohort having larger fish):
L_∞: 62.7 -66.9cm TL; W_∞: 3,330 – 4,070 g; K: 0.19 - 0.167; t_0: -0.29; -0.439/yr (Sanders *et al.* 1988).

An evaluation of age-based and length-based methods for determining growth and total mortality of long-lived species concluded that the former gave more accurate estimates MRAG (1996a). This has implications for assessment results and management.

Seychelles: Lmax: 73cm TL (Mees 1992); 70cm TL (Torres 1991); Tmax: 29 yrs (Grandcourt 2002).

LENGTH/WEIGHT

In Seychelles, three estimates are available for unsexed fish:
W(g)= 0.01490 ($TL^{2.94}$)(cm)
W(g)= 0.00612 ($TL^{3.245}$)(cm)
W(g)= 0.011 ($TL^{3.05}$)(cm)
(Mees 1992; Torres 1991)

MORTALITY RATES

Total mortality (Z) and natural mortality (M) estimated from length-converted catch curves, Seychelles, Mahé Plateau (Sanders *et al.* 1988):
For ages 5 to 8 years:
- Z (1983 & 1984) = 2.09
- Z (1985 & 1986) = 2.20

For older ages:
- Z (1983 & 1984) = 0.16
- Z (1985 & 1986) = 0.29

M = 0.43 (from Pauly's equation).
M= 0.32 (from Richter and Efanov's equation, with mean age of first sexual maturity of 5 years).

For both groups, Z was higher in 1985/1986, and higher for younger age groups.

The growth parameters used in obtaining these estimates were $L\infty$ = 68.4 TL and K = 0.1785; these being the means of the estimates obtained from applying the seasonally oscillating growth model (Sanders *et al.* 1988).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

E. chlorostigma is listed as of Least Concern in IUCN Red List of Threatened Species (IUCN 2012). MRAG (1996a) suggested that the stock of this species on the Mahé Plateau was already showing signs of depletion even in lightly fished locations, and recommended no increase in fishing mortality at the then length at first capture. In Seychelles fishing effort for this species has increased sharply in the last 10 years. A more recent assessment indicated that this fishery for *E. chlorostigma* was fully exploited in Seychelles (SFA 2012).

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

A range of measures and regulations exist in Seychelles for the general management and development of the inshore artisanal fishery. These are discussed and evaluated by Mees *et al.* (1998) and Wakeford (2000). Among the management objectives is re-building of inshore stocks. Estimated biomass ratio (B_{yr}/B_{MSY}) of alternative management options for the inshore and offshore demersal fisheries in Seychelles are presented by Wakeford (2000).

RESEARCH SURVEYS

Low catch rates (<1 kg/hr) were obtained at two stations in West Madagascar during RV Dr. Fridtjof Nansen trawl survey in 2009.

EPINEPHELUS MORRHUA

Common name:
– Comet grouper

Family:
– Serranidae

Attains 90cm

Photo: Randall 1997 (from Fishbase, Froese and Pauly 2012).

DISTRIBUTION & HABITAT

Distributed throughout East Africa; depth range 80-370m (Heemstra & Randall 1993). Although described as reef-associated and non-migratory (Heemstra & Randall 1993), *E. morrhua* has been caught in trawls, implying that they frequent soft bottom habitats and may form loose aggregations (MRAG 1996a). In general, groupers may be less dependent upon hard bottom substrates at depth (Parrish 1987).

FISHERY

CATCH TRENDS

This species comprised around 5% of the hook and line/vertical longline catch of Mauritius between 2007-2011 (WIOFish 2011).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

Likely protogynous mode of reproduction (Heemstra & Randall 1993).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT & STATUS

Listed as of Least Concern in IUCN Red List of Threatened Species (IUCN 2012).

RESEARCH SURVEYS

One of the major species caught during surveys by RV Dr. Fridtjof Nansen in 1980 off Kenya (14kg/hr), in 1983 on the Bank l'Etoile in Madagascar (FAO 1990), and in 2009 in West Madagascar , with catch rates of 3.4-21.7 kg/hr in the latter (Torstensen *et al.* 2009).

CHEIMERIUS NUFAR

Common name:
– Santer seabream

Family:
– Sparidae

Attains 75cm

Photo: Randall 1997 (from Fishbase, Froese & Pauly 2012).

DISTRIBUTION & HABITAT

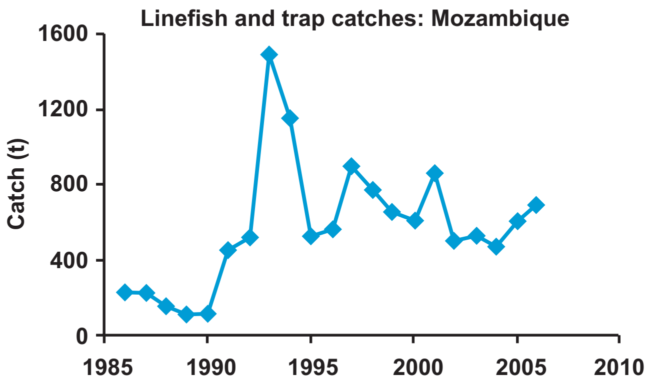
Western Indian Ocean along the entire east coast of Africa (Red Sea south to Mossel Bay, South Africa), Madagascar, and Mauritius (Mann & Radebe 2000b). Found over rocky substrates of coastal waters, at depths up to 100m (Fischer *et al.* 1990).

FISHERY

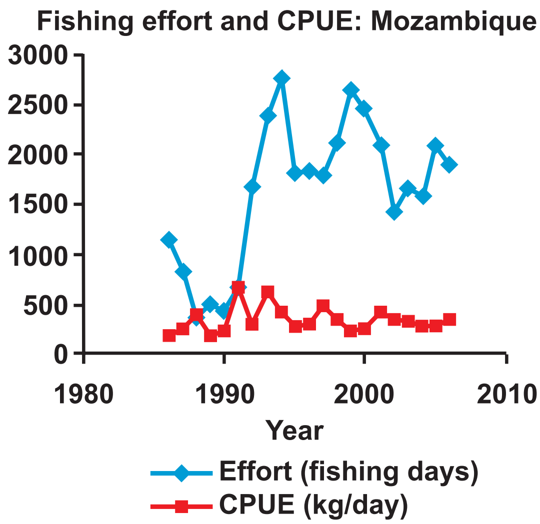
CATCH TRENDS

C. nufar is one of the major species caught in the line fisheries in southern Mozambique, where it is known as "robalo", and in KZN, South Africa. It has been suggested that the stock is shared between the two countries (Mann 2000, 2013).

Catch, fishing effort, and CPUE trends of the Mozambique semi-industrial, industrial line fisheries (1986-2006), and trap fishery (1997-2001) combined are shown in the figures opposite, based on data from Torres and Jakobsen (2007). Fishing effort increased rapidly after the civil war ended, resulting in very high catches in 1993 and 1994. Subsequently, both effort and catches have been considerably lower, with catches mostly in the range 500-600t. Trap fishing was prohibited in 2002. CPUE has been fairly stable since 1994, fluctuating around 400 kg/fishing boat. day. (Torres and Jakobsen 2007)

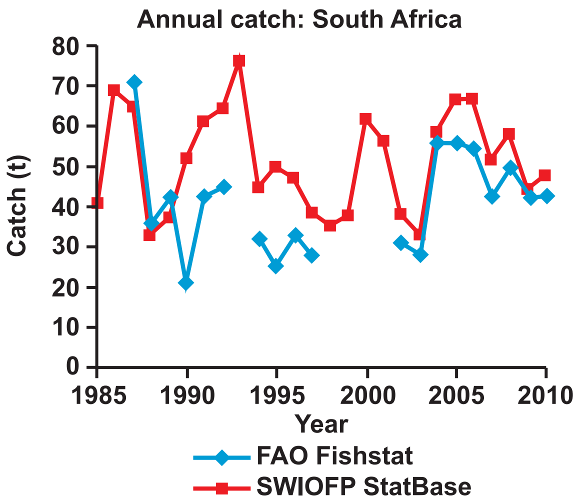


The proportion (by weight) of *C. nufar* in linefish catches of Mozambique progressively declined from 10% (58.20t) in 1996 to 6% (53.55t) in 2001 (Torres 2005) and 4% (29.55t) in 2006 (Torres & Cuco 2007). This reduction may be explained by reduced abundance and/or change of fishing grounds by the linefishing fleet (Torres 2009). The year 2000 linefish assessment in Mozambique, however, suggested that linefish catches reported to the National Directorate of Fisheries Administration were underestimated by about 32% (IIP 2001). Subsequent apparent increases in this proportion may be attributable to discrepancies in sampling protocol (Fennessy *et al.* 2012).



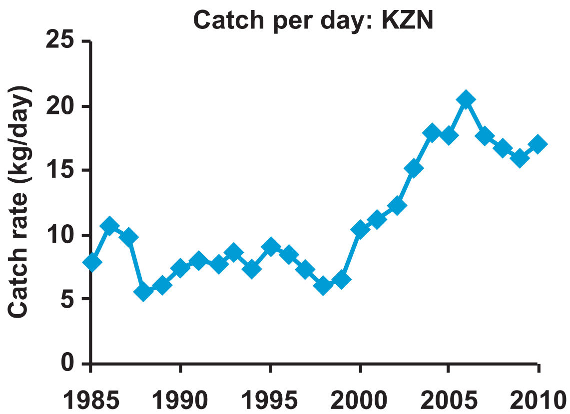
Annual catch of *C. nufar* is reported for South Africa from 1985-2010 on StatBase and on Fishstat from 1987-2010 (Western Indian Ocean):

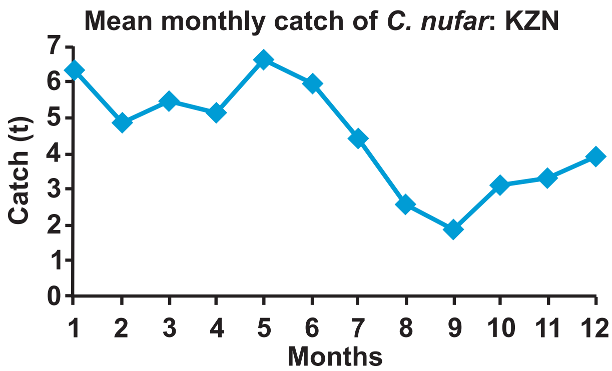
Annual catch in KZN reported on Fishstat is generally lower than that in StatBase, but the trends are similar. Annual catch (StatBase) shows marked fluctuations, with the highest catch during this period taken in 1993 (76t). In recent years (2006-2010), annual catch decreased from 66t to around 48t (a similar decline was observed in southern Mozambique in recent years).



The peak in annual catch in the early 1990s is also evident for *Chrysoblephus puniceus* and *Polysteganus coeruleopunctatus* that are important components of the KZN linefish catches, along with *C. nufar*. According to Penney *et al.* (1999), there had been very progressive and significant increase in commercial and recreational fishing effort in this region which had resulted in the depletion of large endemic reef species, such as *P. undulatus* and *Petrus rupestris*. This in turn led to sequential target switching to smaller sparids such as these three species reported on here.

Catch rates (catch per day fishing time) for the line/handline fishery in KZN generally increased from 1999 to 2006, followed by a declining trend from 2006-2010, reflecting the decrease in total annual catch over this latter period.





Mean monthly catches of *C. nufar* in KZN (shown above) were highest from January-July, and could be related to oceanographic conditions and/or seasonal movement of the stock.

Dunlop (2011) assessed the boat-based linefisheries of KwaZulu-Natal. CPUE of this species in the commercial linefishery of KZN showed a significant increase between 1994/1996 when it was 0.59 kg/outing (Mann *et al.* 1997) and 2008/2009 when it was 10.13 kg (Dunlop 2011). This increase might have been due to underestimation of CPUE during the 1994/1996 survey or other factors (Dunlop 2011). Fishing effort in the commercial line fishery of KZN was reduced by about 70% in 2003-2006, and it was suggested that this has been successful in increasing the overall catch rates (i.e. indicating a recovery of the fishery) of commercial linefishers in KZN. While these results appear encouraging they need to be carefully analyzed as other factors may have contributed to this trend (Dunlop 2011).

SIZE AT FIRST CAPTURE

C. nufar becomes vulnerable to the Mozambique line fishery at about 190-200mm FL (Torres 2009).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

A rudimentary hermaphrodite, but there is uncertainty about protogyny in this species (Coetzee 1983, Garratt 1985a). Spawning reported in most months peaking from June–October in KwaZulu-Natal, South Africa (van der Elst & Adkin 1991; Mann 2013), which is similar to the spawning period in Mozambique (May–October) observed by Torres (2009).

MATURITY

Length at 50% maturity:
Females: 290mm FL (3 yrs); males: 236mm FL (<2 yrs); combined: 258mm FL (2 yrs) (Torres 2009); and 250mm FL for females in KZN (Garratt 1985a,b).

SEX RATIO

Ratio of M:F in Mozambique was 1:1 (Torres 2009) and 1:1.5 (Piotrovsky 1990); KZN= 1:2.5 (Garratt 1985a,b). Possible causes for such variable ratios include differential mortality, growth, and longevity.

AGE & GROWTH

Growth parameters were estimated in Mozambique and South Africa:

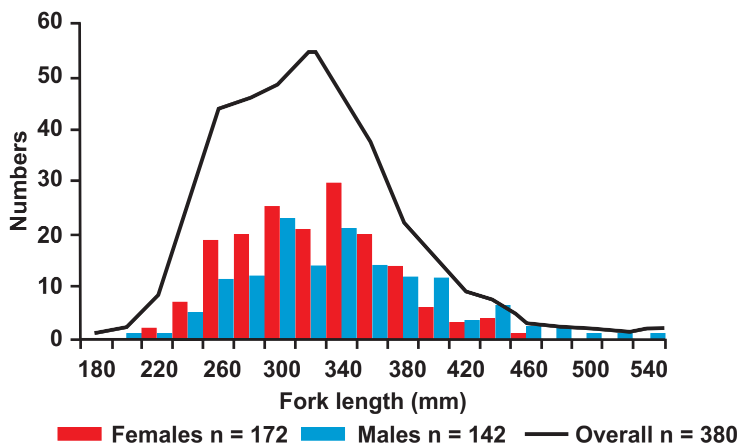
K/yr	*L∞ (TLcm)*	t_0	*Source*
0.06	89.7	-3.28	Torres 2009, otoliths (Moz, combined sexes)
0.17	70.0	-	Timochin 1992, L.Frq. (Moz)
0.065	95.4	-2.62	Coetzee & Baird 1981, otoliths (S.Africa: E. Cape)

Maximum length of 62cm TL (Timochin 1992). Males larger than females (mean fork length of 345.5 ± 64.3mm; compared to 317.6± 49.5mm for females; 324.9 ± 58.4mm for combined sexes), which may be the result of a size-dependent sex transition and impact of exploitation (Torres 2009).

The average sizes reported by three authors show differences probably related to the state of the fishery or the fishing area (depth range, fishing ground):

Size range	*Mean*	*Location and source*
190 -550mm FL	325.65mm TL	Mozambique (Torres 2009, combined sexes)
220 -680mm TL	376mm TL	Mozambique (Piotrovsky 1990)
160 -670mm	302mm	KwaZulu-Natal (Garratt 1985b)

Overall fork length distribution for *C. nufar* in Mozambique: males ranged from 215 to 550mm FL; females from 220 to 460mm (Torres 2009); ages ranged from 2-11 yrs.



LENGTH/WEIGHT

L/W relationship was determine by Torres (2009) in Mozambique:
Females: W(g)= 0.00006 ($FLmm^{2.83}$)
Males: W(g)=0.00007 ($FLmm^{2.80}$)
Combined sexes: W(g)=0.00005 ($FLmm^{2.85}$)
(b was significantly different from 3, indicating allometric growth).

In KZN: W(g)= 0.00024 ($FLmm^{2.571)}$ (Garratt 1984).

MORTALITY

Fennessy *et al.* (2012) estimated natural mortality as 0.19 (close to 0.201 reported by Torres 1991), F of 0.49 and Z of 0.68. Other mortality estimates were: M =0.1; F= 0.55; Z= 0.65 (Torres 2009).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

Comparison of biomass in 2006 with the modelled non-exploited state was 0.16, proved lower than desirable, with mean length as reduced by 27% from the pristine state, which appears to be consistent with the reduction in biomass (Torres & Jakobsen 2007). The 2006 F estimate (0.53) was about twice as high as Fmax (0.26), but this assessment is not considered reliable because of inconsistencies in the model input data (Torres & Jakobsen 2007).

Subsequent YPR and SBR analyses for southern Mozambique suggested that *C. nufar* was exploited at a critical level (Torres 2009). The actual SBR was at 21% of unexploited level – considered to represent recruitment overfishing. The actual fishing effort was considerably higher than that required for maximum sustainable yield (MSY).

More recently, YPR and SPR levels as a proportion of an unexploited population (SBPR/R^o) were used to assess levels of exploitation in Mozambique by Fennessy *et al.* (2012). This study also found *C. nufar* to be over-exploited (SBPR/R^o30%). Overall, levels of confidence in these per-recruit results are low because of the uncertainty in the age estimates and the age-length keys, and other indices such as CPUE, size composition, sex ratio, and catch composition can provide an indication of stock status. Modal lengths have declined substantially from the late 1980s (Piotrovsky 1990) to 2012 (Fennessy *et al*. 2012).

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

Torres & Jakobsen (2007) used Fmax of 0.26 as the reference point for this species, and found that F in 2006 was 0.53. Fennessy *et al.* (2012) proposed a target reference point of SBPR/R^o30% for Mozambique. Increase of age at first capture and reduction of fishing effort will be beneficial for yield and spawner biomass (Torres 2009). Fishing effort is controlled by licenses, controlled fishing zones and catch quotas for the two larger industrial linefishing vessels in Mozambique.

Minimum size limit of 300mm TL and bag limit of 5 per fisher/day for the recreational fishery in KZN.

RESEARCH SURVEYS

C. nufar was one of the major species caught during surveys by RV Dr. Fridtjof Nansen in 1983 on the bank l'Etoile in Madagascar, at depths of 113 m and 124 m (FAO 1990). Also caught during RV Dr. Fridtjof Nansen cruises in East Madagascar (up to 18 kg/hr) and West Madagascar (up to 11 kg/hr) in 2008 and 2009, respectively (Krakstad *et al.* 2008, Torstensen *et al.* 2009).

CHRYSOBLEPHUS PUNICEUS

Common name:
– slinger seabream

Family:
– Sparidae

Attains 60cm FL

Photo: Randall 1997 (from Fishbase, Froese & Pauly 2012).

DISTRIBUTION & HABITAT

Endemic to the southeastern coast of Africa from southern Mozambique to the northern waters of the Transkei (South Africa), and abundant on offshore reefs (Garratt 1984, 1985a). Found at a depths of 10-100 m (Smith & Smith 1986). Tagging results suggested that *C. puniceus* is fairly resident and shows sedentary behaviour (Bullen & Mann 2000). Duncan (2013) estimated gene flow and genetic connectivity between sampling sites throughout Mozambique and South Africa, and found there to be no genetic structuring throughout the species' core distribution, suggesting a single well-mixed stock.

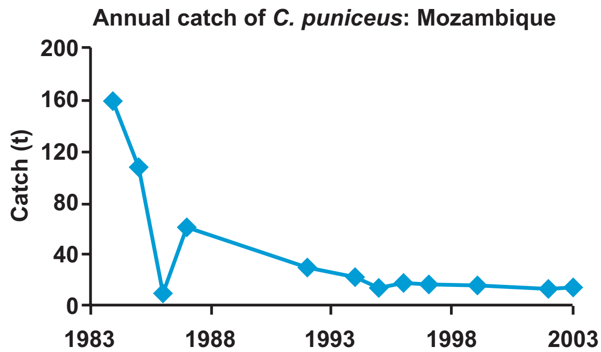
FISHERY

CATCH TRENDS

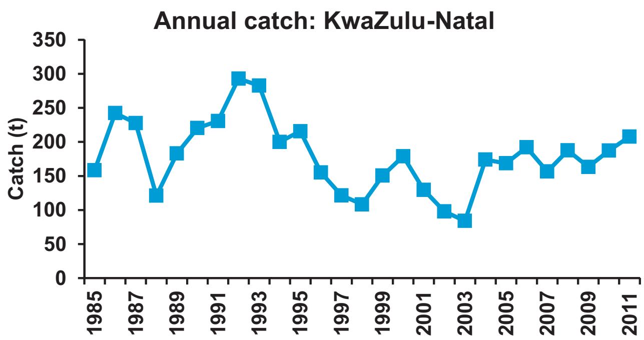
C. puniceus is one of the target species in the line fishery of southern Mozambique and KZN of South Africa. This species composed 16% of the catch of the industrial and semi-industrial hook and line fishery of Mozambique (WIOFISH 2011) and dominates the catch of commercial, recreational, and charter boat fisheries of KZN (Dunlop 2011).

Annual landings of *C. puniceus* in Mozambique were obtained from the Sea Around Us project (Courtesy Reg Watson), which are based on FAO catch statistics. The catch trend is shown in the graph below.

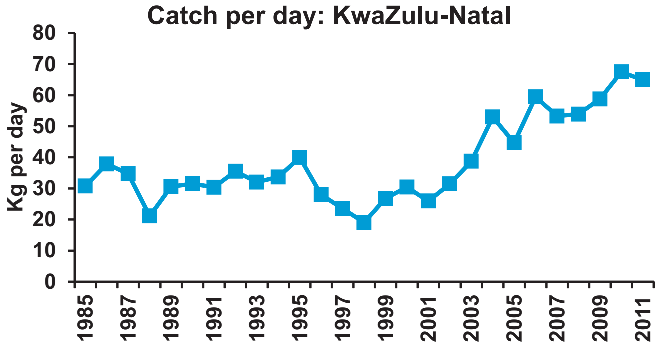
Annual landings in Mozambique dropped sharply from nearly 160t in 1984 to 10t in 1986, and increased to around 60t the following year. Annual landings subsequently showed a progressive decline to 13t in 2003. The proportion of this species in total linefish catches offloaded in Maputo harbour dropped from 47% in 1980 (Piotrovski 1990) to 12% in 1997 (Lichucha 2001). In 2000 and 2007-2009, this species composed 24% and 38% of the catch in southern Mozambique, respectively, based on onboard observer data (van der Elst *et al.*2003, Fennessy *et al.* 2012), but discrepancies in sampling may have affected these figures.



C. puniceus is reported in annual catch statistics of KZN industrial (commercial) fisheries (handline) from 1985-2010 (StatBase), which were used to show the catch and CPUE trends in the graph opposite.



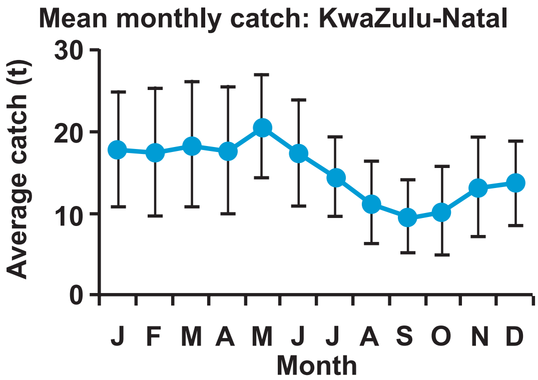
Annual catch peaked at 293t in 1992, followed by a decline to 84t in 2003. Catches increased sharply in 2004 then stabilized between 150-200t in the subsequent years. The peak in annual catch in the early 1990s is also evident for *C. nufar* and *P. coeruleopunctatus* both also important components of the KZN linefishery. Penney *et al.* (1999) concluded that there was a progressive and significant increase in commercial and recreational fishing effort in this region which had resulted in the depletion of large endemic reef species, such as *P. undulatus* and *Petrus rupestris*. This in turn led to sequential target switching to smaller sparids such as these three species reported on here.



In KZN, the catch per boat.day for *C. puniceus* in the commercial line fishery fluctuated between 19-40 kg from 1985 to 1998, followed by a general steady increase to 67 kg in 2010. Catch per outing for this species was 0.66 and 21.37kg for recreational and commercial catch, respectively in 2008/2009 (Dunlop 2011) compared to 0.17 and 5.12 kg in 1994/1996 (Mann *et al.* 1997). The increase in CPUE in more recent years is similar to the trend noted elsewhere in this report. Fishing effort in the commercial line fishery of KZN was reduced through management action by about 70% in 2003-2006, and it was suggested that this has been successful in increasing the overall catch rates (i.e. indicating a recovery of the fishery) of commercial linefishers in KZN. These results are encouraging although other factors might have contributed to this trend (Dunlop 2011).

Mean monthly catches of *C. puniceus* in KZN (shown opposite) over the period 1985-2012 showed moderate seasonality with catches highest from January-July, possibly related to oceanographic conditions and/or seasonal movement of the stock. A similar trend was observed for *C. nufar* in this area.

C. puniceus is reported as an important species in Madagascar (FAO/SWIOFP 2012b). However, this species does not appear to be caught in Madagascar and it is likely being confused with another sparid, perhaps *P. coeruleopunctatus* (S.Fennessy, pers. comm.).



SIZE AT FIRST CAPTURE

In Mozambique, age at first capture was estimated at 2.5 years (around 270- 300mm FL) and 5 years (around 370-400mm FL), based on annual and bi-annual ring deposition, respectively (Lichucha 2001). In KZN, size at first capture was reported as 25cm TL (Govender & Radebe 2000) and age at first capture 1-2 years (Garratt *et al.* 1993), which is less than the age at maturity (see below).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

A protogynous hermaphrodite (Garratt 1986), with sexual transition at 1.5 or 3 years based on one or two opaque bands in otoliths per year, respectively (Lichucha 2001) and in KZN 5 years (Garratt *et al.* 1993). Protracted spawning season with peak in August-October reported in KZN (Garratt 1984) and August-November in Mozambique (Lichucha 2001).

SEX RATIO

In Mozambique, the reported overall sex ratio (M:F) was 1:6.8 (Lichucha 2001) and 1:2.3 (Garratt 1985a), with the proportion of females decreasing with increasing length. This trend is not unexpected in protogynous species. In KZN, Garratt (1985a) observed an overall sex ratio (M:F) of 1:18.1, with females dominant at sizes between 160-369mm FL . Comparison of the population structure of *C. puniceus* from KZN and Mozambique suggested that in KZN the sex ratio has been altered by fishing, which might have affected the reproductive potential of this species (Garratt 1985a).

MATURITY

Mozambique: Age at 50%-maturity attained at 1.5 years, which corresponds to 240mm FL (results based on annual opaque band assumption discarded) (Lichucha 2001). In KZN, maturity reported to occur at 240mm FL at an age of 3 years (Garratt 1984).

AGE & GROWTH

Lichucha (2001) reported two opaque bands deposited in otoliths per year in *C. puniceus* in Mozambique, and presented two sets of corresponding growth parameters, from which the following was selected as the more appropriate: $L\infty$=506mm; k=0.11, 0.33 (females and males, resp.); t^o= -2.66 (F); maximum age of 9 or 18 years, depending on annual or bi-annual ring deposition.

In KZN, growth curves were derived by Garratt *et al.* (1993):
Females: $Lt = 406.1mm\ FL(1-e^{-0.187/yr(t+2.253yrs)})$
Males: $Lt = 406.1mm\ FL(1-e^{-0.187/yr(t-5yrs)})$

This species is relatively long-lived and slow-growing, therefore vulnerable to fishing pressure. The mean size of *C. puniceus* in the catch from southern Mozambique has progressively decreased from 407mm FL between 1987-1989 (Piotrovski 1990) to 311mm in 1996 (van der Elst *et aI.* 1997) and 299mm in 1997 (Lichucha *et aI.* 1998). This could indicate overfishing of the larger individuals in the population, thereby selectively removing protogynous males from the population and creating a skewed sex ratio.

Further confirmation of sex reversal is the marked difference in size of males and females, with males dominating the larger size classes; mean size of male and female was 376.3mm and 292.6mm FL, respectively in Mozambique (Lichucha 2001).

LENGTH-/WEIGHT

Mozambique: (Lichucha 2001).
males: $W(g)= 0.0000599(FLmm)^{2.86}$
females: $W(g)= 0.000116(FLmm)^{2.74}$

South Africa: (Garratt 1984)
males $W(g)= 0.000055(FLmm)^{2.872}$
females $W(g)= 0.000072(FLmm)^{2.82}$

MORTALITY

Mozambique: Lichucha (2001) presented different estimates of M, F and Z based on deposition of one or two opaque bands in otoliths and using different analytical methods, but selected the results based on two bands annually: M=0.27; F=0.41; Z=0.68. More recently, Fennessy *et al.* (2012) reported M of 0.3 based on the work of Punt *et al.* (1993) in KZN.

KZN: Punt *et al. (*1993) reported M = 0.3/yr and F = 0.4/yr.

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

Preliminary assessment in Mozambique revealed that at the existing fishing mortality this fishery was moderately overfished, with the spawning biomass-per-recruit at 37% of its unexploited level with F of 0.41 (Lichucha 2001). YPR analysis showed that the single annual band scenario is less conservative than the double band assessment, which has a bearing on the management approach. Yield-per-recruit analysis of both male and female *C. puniceus* indicated the vulnerability of males to overexploitation at very low fishing mortality rates (Lichucha 2001).

A later assessment in Mozambique by Torres and Jakobsen (2007) found that in 2006, F= 0.35, less than F^{max}= 0.44 (which suggested that this species was being fished at sustainable levels). Comparison of biomass with the modelled non-exploited (pristine) state was 0.37, and mean length was reduced by 15% from pristine state, which appears to be consistent with the reduction in biomass. Similarly, Fennessy *et al.* (2012) reported this species to be lightly exploited, with SBPR/R^o of 78-84% depending on whether one or two growth rings are deposited annually (based on Lichucha 2001). However, this latter analysis was based on the inappropriate application of outdated age-length keys, which affected the model results. Although these authors noted that the model outputs suggested that fishing mortality can be increased 10 times before SBPR drops to an over-exploited level (30 %), they felt this was an extremely unlikely scenario as this species has been fished for many years; the substantial decline in CPUE provides further indication that the species has been overfished (Fennessy *et al.* 2012).

In KZN, the fishing mortality in 1993 was M= 0.4 and SBPR 14-16% (Punt *et al.* 1993). This species was therefore considered to be overexploited in KZN and could collapse at F=0.4 if recruitment is dependent on mature male biomass (Punt *et al.* 1993). Following the publication of detailed status reports on a number of South Africa's key linefish species brought about through implementation of the Linefish Management Plan (Griffiths *et al.* 1999, Mann 2000, Mann 2013), the Minister of the Department of Environmental Affairs and Tourism (DEAT) declared a state of emergency in the linefishery in December 2000 (Government Gazette No. 21949 of December 2000). The notice called for a drastic reduction in the existing level of commercial linefishing effort by about 70% (Dunlop 2011), which came into full effect in 2006. Recent indications are that the species has recovered since the reduction in fishing effort after 2006 (Mann 2013).

As reported by Duncan (2013), *C. puniceus* is represented by a single well-mixed stock throughout Mozambique and South Africa. The transboundary nature of this stock highlights the need for collaborative management between the two countries.

REFERENCE POINTS/ MANAGEMENT OBJECTIVES

In Mozambique, Lichucha (2001) estimated biological reference points as fishing mortality rates at which spawning biomass is reduced to 35% and 50% of its unfished level as well as F^{msy}. Subsequently, Torres and Jakobsen (2007) used F^{max}= 0.44 as the reference point for this species and Fennessy *et al.* (2012) proposed SBPR of 30%. Fishing effort is controlled by licenses (semi-industrial and industrial fleets) and catch quotas for the two industrial linefishing vessels in Mozambique. The linefish management plan for this country includes a number of fisheries indicators and reference points: change in total landings more than 20% in past four years; decline in CPUE by more than 50% over historical trends; average size caught less than size at maturity; and spawner biomass per recruit below 25%. Spawner biomass per recruit level as a proportion of an unexploited population (SBPR/R^o) was used to assess the level of exploitation in Mozambique (Fennessy *et al.* 2012).

In KZN, biological reference points were determined by Punt *et al.* (1993):
F^{SB25}: 0.25/yr; F: 0.17/yr; $F^{0.1}$: 0.08-0.1/yr; F^{MSY}: 0.17/yr. A minimum size limit of 250mm TL is in effect in KZN.

RESEARCH SURVEYS

Reported in the list of species caught during RV Dr. Fridtjof Nansen cruise in north Mozambique in 2009, but catch is recorded as zero (Olsen *et al.* 2011).

POLYSTEGANUS BAISSACI

Common name:
– Frenchman seabream

Family:
– Sparidae

Attains 35 cm TL (Bauchot & Smith 1984).

Photo: Randall 1997 (from Fishbase, Froese & Pauly 2012).

DISTRIBUTION & HABITAT

Western Indian Ocean: known only from Mauritius and Madagascar (Fishbase); depth range 80-100 m (Bauchot & Smith 1984).

FISHERY

CATCH TRENDS

P. baissaci is not reported on StatBase for any of the SWIOFP countries. This species comprised around 24% of the hook and line/vertical longline fishery catch of Mauritius between 2007-2011 (WIOFish 2011).

STOCK ASSESSMENTS AND REFERENCE POINTS

RESEARCH SURVEYS

One of the major species caught during surveys by RV Dr. Fridtjof Nansen in 1983 on the bank l'Etoile in Madagascar, at depths of 113 m and 124 m (FAO 1990).

POLYSTEGANUS COERULEOPUNCTATUS

Common name:
– Blueskin seabream

Family:
– Sparidae

Attains 60cm

Photo: Simon Chater,
Oceanographic Research Institute (ORI).

DISTRIBUTION & HABITAT

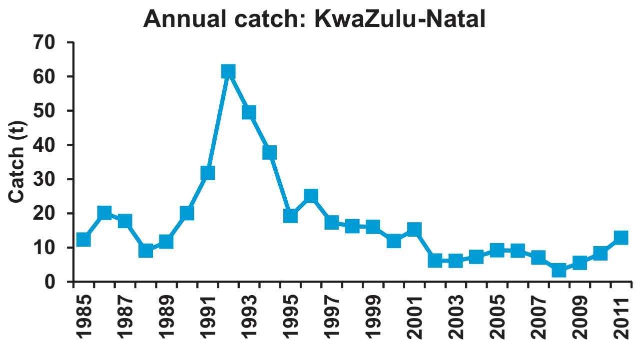
Western Indian Ocean: distributed from the Red Sea to southern KwaZulu-Natal, South Africa, including Madagascar. Occurs mainly in deep waters around reefs (Sommer *et al.* 1996), in depths from 66-405m (Busakhin 1980).

FISHERY

CATCH TRENDS

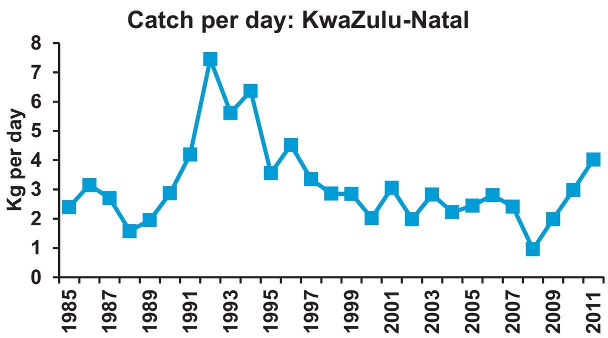
P. coeruleopunctatus is targeted in the line fisheries of Mozambique (referred to as 'cachucho') and KwaZulu-Natal (referred to as 'blueskin' or 'trawl soldier'). It is reported in annual catch statistics of the KZN industrial handline fishery from 1985-2010 (StatBase), which were used to produce the following catch and CPUE trends.

Annual catch of this species rose sharply from round 9t in 1988 to 61t in 1992, followed by a steady decline to under 10t in 2002 with the lowest catch over this period of 3.3t in 2008. The peak in annual catch in the early 1990s is also evident for *C. nufar* and *C. puniceus* that are important components of the KZN linefish catches along with *P. coeruleopunctatus*. As already indicated, the increase of the proportion of blueskin in the KZN linefish catch has been attributed to a shift in fishing effort to deeper reefs as shallow areas have been depleted, as well as depletion of previously abundant larger species of seabream (Penney *et al.* 1999).



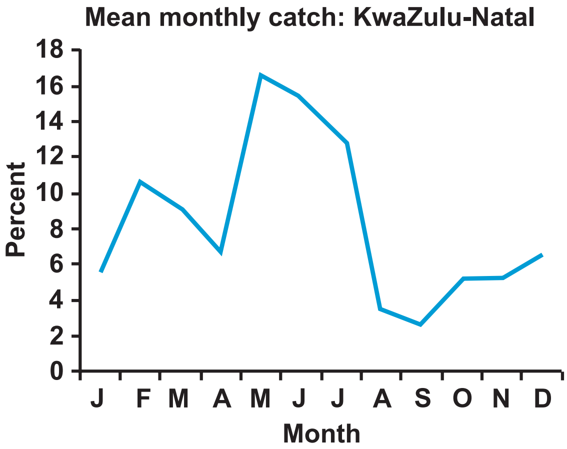
Similarly, in Mozambique, the proportion of *P. coeruleopunctatus* in linefish catch has progressively increased between 1993-2000, which presents circumstantial evidence that the fishery has been operating at increasingly greater depths (IIP 2001), and also further north (Fennessy *et al.* 2012).

Between 1985-2010, catch per day fishing time (boat.day) in the KZN commercial line fishery followed a similar trend as that of total annual catch, peaking at 7.5 kg in 1992 followed by a decline to 0.96 kg in 2008. Similarly, the mean CPUE (catch per boat.day) in the recreational offshore linefishery of *P. coeruleopunctatus* declined from 0.51 kg in 1994-1996 (Mann *et al.* 1997) to 0.21 kg/outing in 2008-2009 (Dunlop 2011).



Monthly catches of this species averaged over the period 1985-2010 in KZN were highest from February-July. A similar trend was observed for *C. nufar* and *C. puniceus* in this area, and is certain to reflect seasonality.

This is an important target species in the linefishery of southern Mozambique and in the earlier trap fishery. In July 1997, permission was granted for two industrial vessels to undertake experimental trap fishing in Mozambique, with the major target being this species. This was seen as a promising and innovative development and in September 2000, the trap fishery was changed from an experimental to a commercial fishery with a number of permit conditions. However, the fishery was terminated in 2001 after inconsistencies in the data submitted by the companies were detected (van der Elst *pers comm*). The percentage of cachucho in the catch decreased substantially from 1997 to 1999 (van der Elst *et al.* 2003).



SIZE AT FIRST CAPTURE

Age 3 in Mozambique (Torres, unpubl. data) at 200mm FL (Fennessy, unpubl).

BIOLOGY AND POPULATION DYNAMICS

REPRODUCTION

This species is thought to be a protogynous hermaphrodite (Fennessy, unpubl).

LENGTH/AGE AT MATURITY

Maturity attained at 2.7 years in Mozambique (Torres, unpubl). Size at maturity of females declined from 227mm FL in 1999-2000 to 176-200mm FL in 2005-2010 (Fennessy *et al.* 2012).

SEX RATIO

M:F ratio of 1:6.6 (Fennessy, unpubl. data). This ratio in the trap fishery of Mozambique was: 1:1.36; 1:2.07; 1:2.5 (for 1997, 1998, 1999, respectively) and the line fishery: 1:1.64 and 1:1.13 (for 1998 and 1999, respectively) (van der Elst *et al.* 2003). In Mozambique, the M:F ratio changed from 1:2.4 in 1999-2000 to 1:3.3 in 2006-2010, which may be an indication of an overexploited status (Fennessy *et al.* 2012).

AGE & GROWTH

Mozambique: L_∞=358mm TL; k=0.2; t_0= -2.24 (Torres, unpubl).

LENGTH/ WEIGHT

Mozambique:
W(g)=0.000303 $(TLmm)^{2.568}$ (Torres, unpubl).
W(g)=0.00001432 $(FLmm)^{3.016}$ (Fennessy 1994b).

MORTALITY

M=0.27 (Torres, unpubl); F=0.25; Z=0.52 (Fennessy *et al.* 2012).

STOCK ASSESSMENTS AND REFERENCE POINTS

ASSESSMENT AND STATUS

In Mozambique, assessment of the linefish fishery is conducted periodically. The 2000 assessment found that the linefish grounds closer to Maputo had been economically overfished and the fishery expanded northwards and to deeper areas (IIP 2001, Fennessy *et al.* 2012). In the 2007 assessment (Torres & Jakobsen 2007), comparison of biomass with the modelled non-exploited state was 0.46, and mean length was reduced by 11% from the pristine state, which appears to be consistent with the reduction in biomass. These authors used F^{max} of 0.3 as the reference point for this species, and found that F in 2006 was 0.15, leading to the conclusion that this species was being sustainably fished (although a number of factors could have introduced bias in the assessment). Considering the uncertainties in the assessments, both the Precautionary Approach to Fisheries Management and the FAO Code of Conduct dictate that no increase in effort should be allowed, and some reduction in effort would improve the economic prospects for individual boats (Torres & Jakobsen 2007). The industrial trap fishery was closed after three years owing to the irreconcilable submission of data as well as a progressively higher proportion of other reef fish species as the trap fishery moved into shallower water following declining catch rates.

A more recent linefish assessment in Mozambique found this species to be optimally exploited (SBPR/R^o 50%) (Fennessy *et al.* 2012). However, confidence level in the per-recruit results is low because of the uncertainty in the age estimates and the age-length keys. Size at maturity of females appears to have declined from 227mm FL in 1999-2000 to 176-200mm FL in 2005-2010, and sex ratio (M:F) changed from 1:2.4 to 1:3.3, which may indicate an overexploited status (Fennessy *et al.* 2012).

REFERENCE POINTS OR MANAGEMENT OBJECTIVES

Torres and Jakobsen (2007) used F^{max} of 0.3 as the reference point for this species. Spawner-biomass-per-recruit levels as a proportion of an unexploited population (SBPR/R^o) were used to assess levels of exploitation in Mozambique, with SBPR/R^o 50% as the reference point (Fennessy *et al.* 2012).

While the fisheries in Mozambique and South Africa are managed by a number of input and output controls, the overriding management objective of this species is to ensure that spawner biomass per recruit does not fall below 25%.

RESEARCH SURVEYS

P. coeruleopunctatus composed 81% by number and 90% by weight during research surveys using traps at selected depths from the vessel “Cassiopeia” in May 1999 in southern Mozambique (Abdula & Lichucha 2000). This species was one of the most commonly caught during RV Dr. Fridtjof Nansen surveys in West Madagascar in 2009, with catch rates up to 59.5 kg/hr in depths of 235-239 m.

TRICHIURUS LEPTURUS

Common name:
– Largehead hairtail

Family:
– Trichiuridae

Attains 200cm

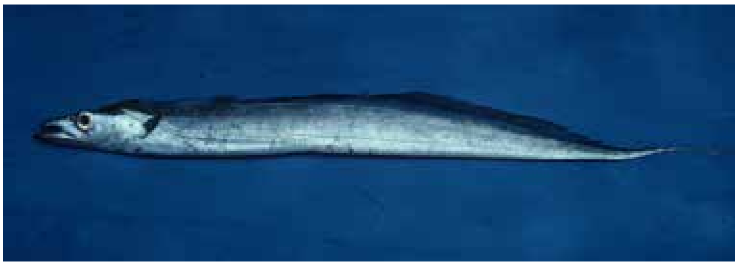


Photo: Rudy van der Elst (1988).

DISTRIBUTION & HABITAT

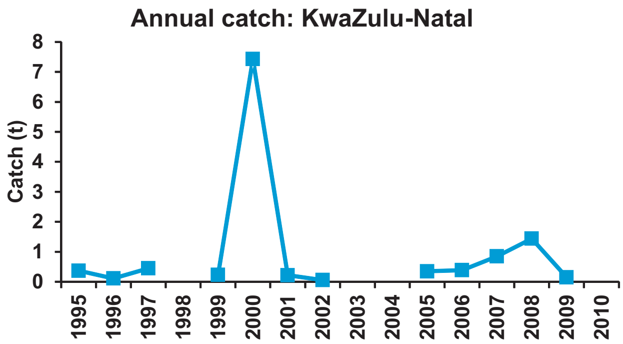
Circumtropical and temperate waters of the world. Generally found over muddy bottoms in shallow coastal waters (Nakamura 1995).

FISHERY

CATCH TRENDS

T. lepturus is commonly caught by shrimp trawls in the SWIO region, and is one of the most abundant species discarded. For example, this species comprised up to 17.7% of the discarded bycatch of trawlers (without TED) during the Malindi-Ungwana Bay survey in Kenya in 2009 (Fulanda *et al.* 2011).

Annual landed bycatch statistics (StatBase) from crustacean trawling are available for KwaZulu-Natal. Annual landed catch remained below 1.5t, except for the year 2000 when it peaked at over 7t. Following a small peak in 2008, it declined to nearly zero in 2009, as effort declined substantially.



BIOLOGY AND POPULATION DYNAMICS

AGE & GROWTH

Growth parameters were estimated from length measurements in India: L_∞= 146.8cm TL; K=0.29/yr; t0=0.249; maximum length= 150cm TL; W_∞= 2,450 g (Torres 1991, Torres & Pauly 1991). Growth parameters estimated from otolith readings for the Western Indian Ocean are available in Al-Nahdi *et al.* (2009).

LENGTH/ WEIGHT

South Africa: $W(g)=0.0002(TLmm)^{3.29}$ (Torres 1991).

STOCK ASSESSMENTS AND REFERENCE POINTS

RESEARCH SURVEYS

Commonly caught during trawl surveys in the SWIO area. On the Sofala Bank, Mozambique, the family Trichiuridae was one of the major components of the catch by weight during a Russian survey in 1981 (Sousa 1982). In West Madagascar, catch rate of *T. lepturus* ranged from 1.0-144.5 kg/hr at depths of 71-328m during RV Dr. Fridtjof Nansen survey in August-October 2009 (Torstensen *et al.* 2009). Also commonly caught during a similar survey in North Mozambique in 2009, with up to 144 kg/hr at one station (Olsen *et al.* 2011). About 496 kg of this species caught (with and without TED) during SWIOFP shallow-water shrimp trawl survey in Tanzania (FV Vega) in 2011 (Mwakosya *et al.* 2011). Significant quantities caught during SWIOFP survey (Cruise 1) with FV Vega off Kenya in 2011.

Summary and conclusions

i. Although several long-term datasets exist for the SWIOFP member countries, only some were made available for this analysis. It was evident that the SWIOFP priority species may dominate the overall landings in several countries' national catch statistics, which were highly aggregated (groups, families, genera, etc), limiting their use in this analysis. There was also considerable temporal and spatial patchiness in the available data, and for some countries the catch data represented only certain sub-sectors (e.g., Mauritius: coastal lagoon fishery; Mozambique and South Africa: semi-industrial and industrial line fisheries; Seychelles: artisanal fishery);

ii. The use of the StatBase fishing effort datasets for determination of CPUE was limited because it was not possible to relate the given catch to fishing effort (data allowed estimation of CPUE for only Seychelles and South Africa). In addition, the unit of effort varied between countries, making it difficult to compare effort or CPUE trends. There is need for effort data to be directly related to the catch and for standardization of fishing effort data within the countries as well as across the region, especially for shared stocks;

iii. The demersal fisheries, particularly the hook and line sector, are described as predominantly small-scale and artisanal in nature, although in certain countries such as Mauritius and Seychelles, 'artisanal' fisheries are sophisticated, with vessels equipped with GPS, echo sounders, etc. The absence of a uniform system for fisheries classification in the region results in variation in the use of the different terms among the countries, which impacts on the submission of fishery statistics and their interpretation (van der Elst *et al*. 2005);

iv. Most of the research surveys were carried out using bottom trawls, although almost all the priority species inhabit rocky bottoms, which are generally unsuitable for trawling. Many species are also benthopelagic and are similarly not well-assessed using trawls. However, several of these species were caught by bottom trawling, indicating that they venture into trawl grounds. While the trawl catches may reflect their abundances on these grounds, they may not reflect the overall abundance in a particular EEZ. Nevertheless, surveys represent an important and valuable source of data and information, including baseline data for monitoring.

v. There was uneven temporal and spatial coverage and level of detail in the biological information and stock assessments available for the priority demersal species. The review noted the existence of data and information that could be used for basic analysis and proxy indicators of stock status as well as for simple biological reference points (e.g. MSY, length at first capture/length at maturity) in the absence of data for more comprehensive stock assessments. However, this was not fully utilized for fisheries assessment and management in most of the countries;

vi. Most of the countries had limited knowledge of the status of the stocks of priority species although a number of studies have been conducted on a few species. Regular stock assessments of priority species are conducted in only a few of the countries, notably Mozambique and South Africa. Other stock assessments found in the literature review have generally been "once-off" or not very comprehensive and in many cases reported as inconclusive because of uncertainties in the input parameters. Further, assessments have been limited to stocks in national waters, with no assessments at a sub-regional or regional level for species that might be shared (e.g. *C. nufar* and *C. puniceus* between Mozambique and South Africa);

vii. The region's demersal fish stocks, especially in nearshore areas, have experienced heavy fishing pressure over the past few decades. Annual catches of 13 species showed a general decline over the period for which data were available (*P. kaakan, L. nebulosus, A. virescens, L. bohar, L. sanguineus, L. sebae, P. filamentosus, O. ruber, E. chlorostigma, C. nufar, C. puniceus, P. coeruleopunctatus* and *T. lepturus*). Annual catch of four species increased following a declining trend, but did not regain previous levels (*P. filamentosus, C. nufar, C. punicues* and *P. coeruleopunctatus*), while that of *A. virescens* in Kenya exceeded previous levels. The corresponding fishing effort data are required to better interpret these trends. In some countries, total catch has been stable or has increased, which could be attributed to a shift to other fishing grounds following localized stock depletion or economic extinction. Aggregating catch statistics (e.g., at the national level) could mask this phenomenon of localized depletion and switching to other areas or species;

viii. Most of the priority species for which stock assessments have been carried out were found to be either overexploited or fully exploited: *A. rutilans* and *E. carbunculus* (Comoros, circumstantial evidence); *E. chlorostigma, L. bohar*, *L. sebae* and *P. filamentosus*, with the latter recovering (Seychelles); *O. ruber* (Mozambique and South Africa, recovering in the latter); *C. nufar* (Mozambique); *C. puniceus* (Mozambique and South Africa); and *P. coeruleopunctatus* (possibly overfished in Mozambique). There was uncertainty in the status of species reported as moderately fished (e.g. *C. puniceus* in Mozambique) due to uncertainties in the input parameters. While some countries did not explicitly include priority species in their catch statistics, they also reported demersal fish stocks as overfished, especially in areas closer to shore;

ix. Increase in catch rates following fishing effort restrictions suggested that populations were possibly recovering (e.g. *C. puniceus* in South Africa following implementation of the Linefish Management Protocol);

x. Nearly all the priority species (especially the lutjanids, sparids and serranids) possess one or more characteristics (slow-growing, long-lived, aggregate to spawn, protogynous mode of reproduction) that make them highly susceptible to overfishing. These features should be taken into account in the management of the fisheries for these species;

xi. Few priority species are explicitly covered in existing or planned fisheries management plans, or have established biological reference points – this is limited to sparids in Mozambique and South Africa and *P. filamentosus* in Seychelles. However, all countries have planned or existing fisheries management plans as well as regulations and measures for their fisheries in general or for certain sub-sectors, for example, the linefish fishery of Mozambique and KZN, South Africa. In these countries, measures are in place for specific priority species;

xii. Most of the priority species show a wide geographic distribution in the SWIO region and certain stocks may be shared between countries. However, in general, little information exists on the transboundary nature of the priority species, and assessments and management (where these exist) are carried out within the national context, even where species are thought to be transboundary. The extent to which the stocks are shared needs to be verified and taken into account in their assessment and management, which should be done jointly between the countries in question if the stocks are indeed shared or transboundary.

Recommendations

A number of issues identified should be addressed by the member countries in partnership with the SWIO Fisheries Commission, as tabulated on the following page (not prioritized). It is recognized that because of limited human and financial resources and other factors some of these recommendations might not be seen as currently feasible. Nevertheless, it is hoped that by highlighting the issues and proposing options to address them, this analysis would assist the SWIO countries to improve fisheries data collection and analysis and in turn, the management of their demersal fisheries in the longer term. The appropriate recommendations could be implemented incrementally depending on availability of resources.

Many of these recommendations have already been proposed elsewhere, for example, by the FAO/SWIOFC Working Group on Small Pelagics and Demersals (FAO/SWIOFC 2011a).

Issue	*Recommendations*
Aggregation of catch and effort data by groups or families, with limited differentiation by species for most of the countries and apparent uncertainties in species identification. This makes these data sets of limited use for stock assessment and management of the individual species.	i. Collect and report catch statistics by species (with focus on key species) and not aggregate statistics at higher levels. ii. Uncertainties in species identification should be addressed and a standard regional demersal species identification guide made available such as the FAO species guides issued for the West Indian Ocean. iii. SWIOFP invested extensively in observer programmes. These should be implemented and expanded.
Limited spatial differentiation in catch and fishing effort data, with most data aggregated at the national level. Data at smaller scales are required to understand spatial differences in stock status.	iv. Collect and report catch and corresponding fishing effort at the appropriate spatial scale (e.g. by fishing areas) and by gear types. Define the spatial extent of fishing grounds and collect geo-spatial data with catch and effort data where possible, particularly for the most important commercial species.
Available information is often lost when captured into the databases because they were not adequately designed for capture.	v. Professionally-designed databases that will allow for the capture of comprehensive information, preferably regionally relevant. vi. Implement appropriate data quality control measures where these are lacking.
Interpretation of catch trends requires corresponding effort data, yet often fishing effort data cannot be directly related to the given catch. Furthermore, effort is not standardized and is recorded using different units.	vii. Collect fishing effort data along with the corresponding catch data, in order to relate the given catch to the level of fishing effort. viii. Develop standardized measures within country of fishing effort across fishing sub-sectors and gears that target priority species. For confirmed transboundary species, fishing effort data should also be harmonized and standardized among the countries.
Ambiguity in fisheries' sector classification in the countries, which presents a number of issues regarding collection of statistics and interpretation. It was apparent that the available StatBase datasets represented only certain sub-sectors such as artisanal or semi-industrial/ industrial, and did not reflect total national catch. Furthermore, under-reporting of catch was noted in previous studies.	ix. Develop a standardized classification system for the demersal fisheries sub-sectors throughout the region. x. Develop or strengthen mechanisms to collect data for all major sub-sectors and ensure that such data are made available by sub- sector, gear, fishing area, etc. xi. Develop approaches to estimate as far as possible, total catch from the major sub-sectors, and standardize these approaches across countries that share the stocks in question.
Inadequate knowledge about the status of the stocks of priority species in most of the countries. Existence of a considerable body of data and information that has not yet been analyzed or used in assessment and management of SWIO demersal fisheries. This includes data from current fisheries as well as historical and recent surveys in the region including many sporadic or "once-off" studies.	xii. Make greater use of simple reference points, for example, change in total landings more than 20% in past four years, decline in CPUE by more than 50% over historical trends, average size caught less than size at maturity. xiii. Undertake an assessment of unprocessed data and develop a protocol to capture and process information, with student support where possible.
Several of the species show a wide geographic distribution and may be shared between countries but there is limited information on stock identity and spatial and temporal distribution of such demersal stocks.	xiv. Determine stock identity and spatial and temporal distribution of the priority species using population genetic studies. xv. Strengthen collaboration between the countries concerned, including collection and sharing of data, joint assessment and management, etc.
Overexploitation of demersal species, including priority species, appears to be widespread in the region. Yet, these species are rarely explicitly considered in existing or planned fisheries management regimes. Several of the priority species are highly vulnerable to high fishing pressure because of their life history strategies.	xvi. Management plans and regulations should explicitly consider the priority species and the major fisheries that target them, rather than covering broad species categories and fishing sectors.

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Annex:

Summary of results of selected fisheries surveys in SWIO countries (showing year, vessel, reference, catch rate or total catch, depth and number of stations at which priority species were caught. Blank cells indicate that the species was not caught or data not available.)

	Mozambique/1978a; Dr. Fridtjof Nansen (IMR 1978)			**Mozambique, Sofala Bank/1981; Pantikapey (Sousa 1982)**			**Mozambique, Sofala Bank /1983; Dr. Fridtjof Nansen (Brinca *et al*. 1984)**		
Species	*Total catch kg*	*Depth range m (depth max catch)*	*No. stations*	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*
A. rutilans									
A. virescens									
C. nufar	4	45	1						
C. puniceus									
E. chlorostigma	5	90	1						
E. morrhua									
E. carbunculus									
E. coruscans									
G. grandoculis									
L. nebulosus									
L. bohar	4-34	19-55 (20)	3						
L. sanguineus							21	31	1
L. sebae							12	37	1
O. ruber	49-176	10-50 (10)	2	1-19	11-30	NA	14-79	10-15 (15)	5
P. baisacci									
P. coeruleopunctatus									
P. kaakan									
P. maculatus				1-12	11->30 (>30)	NA	4-164	6-37 (6)	6
P. filamentosus									
P. multidens									
P. zonatus									
S. rivoliana									
T. lepturus	57-627	10-35 (35)	2				11-101	7-19 (19)	11

	North Mozambique/2009; Dr. Fridtjof Nansen (Olsen *et al*. 2011; SWIOFP/ASCLME)			North Mozambique/ 1990; Marie-Christine (Paula e Silva *et al*. 1990)			Mozambique/1999; Cassiopeia (Abdula and Lichucha 2000)		
Species	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*	*Catch kg/ day (gutted weight)*	*Depth range m (depth max catch)*	*No. stations*	*Catch*	*Depth range m (depth max catch)*	*No. stations*
A. rutilans									
A. virescens				14-795	110-150	-			
C. nufar							93 kg caught (1.9% by number and 2.4% by weight of total catch	-	-
C. puniceus									
E. chlorostigma									
E. morrhua							34 kg caught (0.5% by number and 1.6% by weight of total catch)	-	-
E. carbunculus									
E. coruscans									
G. grandoculis									
L. nebulosus									
L. bohar				3- 3,891	-	-			
L. sanguineus									
L. sebae									
O. ruber									
P. baisacci									
P. coeruleopunctatus							3,570 kg caught (81% by number and 90% by weight of total catch)		
P. kaakan									
P. maculatus									
P. filamentosus				1-491	-	-			
P. multidens									
P. zonatus									
S. rivoliana									
T. lepturus	<1-145	10- >100	18						

	East Madagascar/2008; Dr. Fridtjof Nansen (Krakstad *et al*. 2008; ASCLME)			West Madagascar/2009; Dr. Fridtjof Nansen (Alvheim *et al*. 2009; Torstensen *et al*. 2009; SWIOFP/ASCLME)			Mauritius and Southern Mascarene/2010; Dr. Fridtjof Nansen (Strømme *et al*. 2010; SWIOFP)		
Species	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*
A. rutilans									
A. virescens	19	69	1	9	71	1	10	60	1
C. nufar	18	40	1	2-11	40-45 (45)	2			
C. puniceus									
E. chlorostigma									
E. morrhua				3-22	82-119 (107)	3			
E. carbunculus									
E. coruscans				108	234-288	1			
G. grandoculis				1-13	45-73 (73)	3			
L. nebulosus				19	45	1			
L. bohar				111	71	1			
L. sanguineus	57	69	1	16-77	28-32 (32)	3			
L. sebae				20-30	53-82 (82)	2	60	60	1
O. ruber									
P. baisacci									
P. coeruleopunctatus				1-59	82-324 (239)	7			
P. kaakan									
P. maculatus									
P. filamentosus				2-12	71-119 (119)	3			
P. multidens				18	242	1			
P. zonatus									
S. rivoliana				10	73	1	3	60	1
T. lepturus				1-144	202-324 (324)				

	Tanzania/1982; Dr. Fridtjof Nansen (IMR 1982)			**Tanzania/1982-1983; Dr. Fridtjof Nansen (Iversen *et al*. 1984)**			**Tanzania/2011; FV Vega (Mwakosya *et al*. 2011)**		
Species	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*
A. rutilans				12	182	1			
A. virescens	15	51	1	15-389	28-57 (28)	4			
C. nufar									
C. puniceus									
E. chlorostigma									
E. morrhua									
E. carbunculus	34	212	1	43	212	1			
E. coruscans									
G. grandoculis									
L. nebulosus	28	60	1	7-40	25-60 (46)	3			
L. bohar	13-212	10-48 (24)	5	5-212	5-48 (24)	7			
L. sanguineus	18-39	31-44 (31)	2	18-39	31-44 (31)	2			
L. sebae									
O. ruber							160	-	-
P. baisacci									
P. coeruleopunctatus									
P. kaakan							51	-	-
P. maculatus							173	-	-
P. filamentosus				4-1183	140-182 (140)	3			
P. multidens									
P. zonatus									
S. rivoliana				3-57	127-140 (140)	2			
T. lepturus	<1-10	50-320 (320)	3	1-52	13-320 (16)	5	496	-	-

	Kenya/1980; Dr. Fridtjof Nansen (IMR 1981)			Kenya/1983; Dr. Fridtjof Nansen (IMR 1983)			Kenya/2011; FV Vega cruises I and II (SWIOFP, unpubl)		
Species	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*	*Total catch kg*	*Depth range m (depth max catch)*	*No. stations*	*Catch kg/hr (approx)*	*Depth range m (depth max catch)*	*No. stations*
A. rutilans									
A. virescens	3-12	77-102 (78)	3	24	86	1			
C. nufar				11	160	1			
C. puniceus									
E. chlorostigma									
E. morrhua	13	150	1	14	160	1			
E. carbunculus									
E. coruscans									
G. grandoculis									
L. nebulosus	11	77	1				<1	10-18	3
L. bohar	4	78	1	16	86	1			
L. sanguineus							<1	14-39	2
L. sebae									
O. ruber							<1-294	4-39 (16)	46
P. baisacci									
P. coeruleopunctatus									
P. kaakan									
P. maculatus							<1-27	6-46 (11)	42
P. filamentosus				5,540	162	1			
P. multidens									
P. zonatus									
S. rivoliana				14	160	1			
T. lepturus				61-168	25-45 (45)	2	2-89	5-42 (16)	15

	Comoros Gyre/2009; Dr. Fridtjof Nansen (Roman *et al*. 2010; SWIOFP/ASCLME)		
Species	*Catch rate kg/hr*	*Depth range m (depth max catch)*	*No. stations*
A. rutilans			
A. virescens	12	90	1
C. nufar			
C. puniceus			
E. chlorostigma			
E. morrhua			
E. carbunculus			
E. coruscans			
G. grandoculis			
L. nebulosus			
L. bohar			
L. sanguineus			
L. sebae			
O. ruber			
P. baisacci			
P. coeruleopunctatus			
P. kaakan			
P. maculatus			
P. filamentosus			
P. multidens			
P. zonatus			
S. rivoliana			
T. lepturus			

7.
FISHERIES' BYCATCH

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Previous page: Catch of a deep-water crustacean trawler off Durban, South Africa. Photo by Sean Fennessy.

7. FISHERIES' BYCATCH

An updated assessment of the status in the Southwest Indian Ocean

Sean Fennessy[1] and Bernadine Everett[1]

Abstract

Bycatch is a complex issue; designating an organism as bycatch relies on value judgements by fishers of what part of their catch is not desirable because it is low in value, too small for consumption, sub-legal in size, unpalatable or toxic. It is generally assumed that small-scale fisheries have little to no bycatch, whereas industrial-type fisheries have large amounts. However, the designation of an organism as bycatch can change in both the short and long term, as markets, legislation and personal circumstances vary. Information on bycatch is lacking for most fisheries in the southwest Indian Ocean. Based on an analysis of the bycatch elements in the WIOFish database, this chapter presents a summary of stakeholders' assessments of the amount of bycatch and the scale of the bycatch problem for the various fisheries in their respective countries, based on their experience. The results verify that recreational, subsistence, artisanal and small-scale fisheries are considered to have limited bycatch issues, while more sophisticated fisheries are more problematic. Fishing with nets, in particular, scored highly. It is apparent that improved monitoring of many of the southwest Indian Ocean fisheries is required to improve the understanding of bycatch in order to facilitate management.

Introduction

The term "bycatch" implies that there are some parts of the catch which are incidental and less desirable than others, with the corollary that there is targeting of more desirable species. In this sense, all fisheries are capable of producing bycatch. However, bycatch is a complex issue, largely because the definition of bycatch is not straightforward, often relying on value judgements of what constitutes non-target catch, particularly in the extreme case of fisheries in which there do not appear to be specific targets (Davies *et al*. 2009). The term "desirable" itself implies a value judgement, with species being variably designated as bycatch if they are low in value, too small for consumption, sub-legal in size, unpalatable or toxic. In high-value, technologically sophisticated, industrial-scale fisheries, the distinction between target and bycatch species is much more marked than for subsistence fisheries, and the level of bycatch could be predicted to be higher in the former type; but even in industrial fisheries, what is considered bycatch can change over very short time scales, even during a fishing trip – for example, as the latest market prices become available, or as freezers fill up. The bycatch can be split into retained and discarded components, and the proportion of each is similarly variable depending on numerous factors. Over a longer time period, discarded bycatch species can become retained bycatch, and ultimately even become targets themselves as catches of favoured species decline ("today's bycatch is tomorrow's target"). In less-sophisticated fisheries, a higher proportion (if not all) bycatch is retained, as economies of scale do not apply as much. For example, artisanal fisheries are considered to have negligible discards (Kelleher 2005).

Approach

Despite considerable fishing effort on a variety of resources in the SWIO (van der Elst *et al*. 2005, van der Elst *et al*. 2009), there is little formally published information on bycatch or discards (see for example the relative paucity of records from the SWIO in Wallace *et al*. 2009), other than that presented in a review issue of the WIO Journal of Marine Science (issue 7(2) of 2008), which mainly focussed on bycatch of larger fauna such as marine mammals and turtles. For the purposes of this Retrospective Analysis, the WIOFish database (www.wiofish.org) was examined (2013) to qualitatively assess the level and extent of the bycatch problem for all marine harvesting activities known to occur in the SWIO, as assessed by stakeholders from fisheries research institutions and management agencies in the region. The scores allocated

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were based on the individuals' experience with the fishery concerned, ranging from their being aware of the bycatch from the literature, to having had hands-on sampling experience, to having been involved with data analysis. Their inputs to the database were provided during annual workshops held throughout the region commencing in the early 2000s, with increasing numbers of SWIO countries participating over time. The database is being regularly updated as new information becomes available, and should be consulted in the first instance for additional information; specific individuals listed therein should be consulted to provide additional input on a particular fishery.

For this analysis of the eight participating SWIOFP countries (Tanzania, Mozambique, Seychelles, South Africa, Comoros, Kenya, Madagascar, Mauritius), fisheries which are current or which are known to have ceased operation in the last five years were included in the scoring assessment; fisheries which are illegal but which are known or believed to persist were also included. In this regard, it should be noted that, for Madagascar and Comoros which were only recently included in the database, only information on currently operating fisheries was available.

Although there are 10 recognized fishery types listed on the database (Table 1), there is a huge number of harvesting types listed on the database, and because it was necessary to obtain a measure of the participants' perceived nature of the bycatch associated with a particular type of harvesting, listed fisheries were re-classified into one of 34 aggregated harvesting types based on the type of gear being used or activity being undertaken i.e. all activities with a similar mode of operation, regardless of country or fishery type (artisanal, small-scale commercial, industrial, etc) were combined. Means of the bycatch scores (Table 2) for each aggregated harvesting type were then plotted to examine relative scores. If a gear/activity had a zero score (i.e. no information available) from a particular country for either bycatch level or bycatch problem, that score was excluded, as a zero score would have distorted the average score; these are listed separately. A brief description of the aggregated harvesting type is provided under the Comments (if the name of the fishery is insufficiently explanatory), together with information on the target and bycatch species if provided by workshop participants, and/or from published literature.

Table 1: WIOFish definitions of fishery types.

Artisanal	Traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for national domestic markets. Sometimes licensed and monitored.
Subsistence	A fishery where the fish caught are shared and consumed directly by the families and kin of the fishers rather than being bought by middle-(wo) men and sold at the next larger market.
Small-scale commercial	Fisheries involving fishing groups with formal relationships with small commercial enterprises (for provision of credit, front-end loading of vessels etc). Crew may have some formal training in navigation, fishing-post-harvest etc. Fishing vessels up to 10m/30hp and may carry ice-boxes, brine tanks and use some technology to locate fish (e.g. GPS, Fishsounders). Includes national domestic and export markets. Often licenced and monitored.
Semi-industrial	Formal fishery, high technology vessels that are port based, overnight capacity, operates on shelf, vessels are up to 20m, diesel powered, 10 or more fishers employed per vessel.
Industrial	Large commercial enterprises with a fully professional crew including professional captain and engineers. Fishing vessels >30m. Legal requirements for vessel technology. Sophisticated technologies employed in location of fish (including GPS, RADAR, SONAR). Always licensed (within national EEZs) and monitored
Foreign fleet	Rights granted by WIO countries but catches are landed in countries other than the rights issuing country.
Sport	Recreational fishing offered as a professionally organised activity involving vessel charter and/or the use of fishing guides, includes big game fishing. Often tourist based.
Recreational	Fisheries targeted by non-fishers (local and tourists) as a leisure (not for profit) activity. May use range of technology from simple handlines to fully-motorised craft with GPS, RADAR, SONAR and professional crew.
Tournament fishing	Recreational fishing undertaken by organised groups, either voluntarily or as a sponsored marketing activity or as a "charity" event
Other	Various activities e.g. experimental fishing, research, specimen collecting

Table 2: Measures used by WIOFish workshop participants to assign scores to the level of bycatch and the extent of the bycatch problem in various fisheries in their respective countries.

		Score	*Explanation of score*
Bycatch level: the proportion of the total catch that is considered bycatch (i.e. how much of the catch is bycatch)	Bycatch problem: the extent to which the bycatch is acknowledged to be a problem	0	Unknown/no data
		1	Nil, None, No problem 0%
		2	Low 25%
		3	Average/medium 50%
		4	High 75%
		5	Comprehensive 100%

Results

A plot of the average bycatch scores for each of the 10 WIOFish fishery types is presented in Figure 1, showing generally low bycatch scores but with higher scores for industrial-type fisheries. A plot of the average score for each aggregated harvesting type is presented in Figure 2, followed by a synopsis of information for each aggregated harvesting type. Predictably, the average scores for the level of bycatch and the extent of the problem correspond closely for all harvesting types, as a large amount of bycatch (i.e. a high level) would imply a larger problem in a particular fishery, and vice versa. Most (24) of the 34 aggregated harvesting types were assessed as having no bycatch or were assigned very low bycatch scores, 8 had low-medium scores, while 2 (dynamite and trawl) scored highly. Most of the 8 fisheries with low-medium scores showed considerable variability in their scores, reflected in the high standard deviations, indicating that there was inconsistency in the assessment of the bycatch issue for these activities.

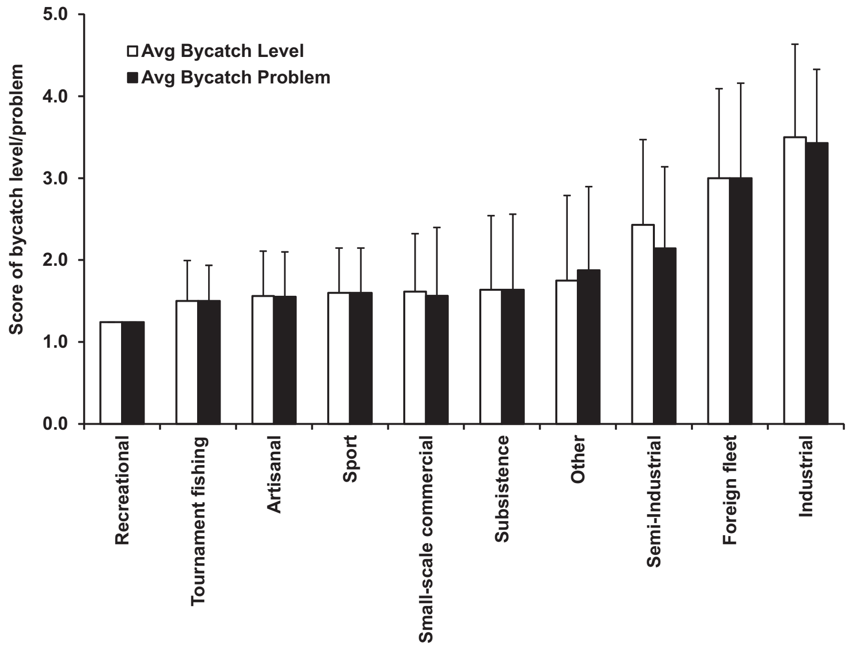
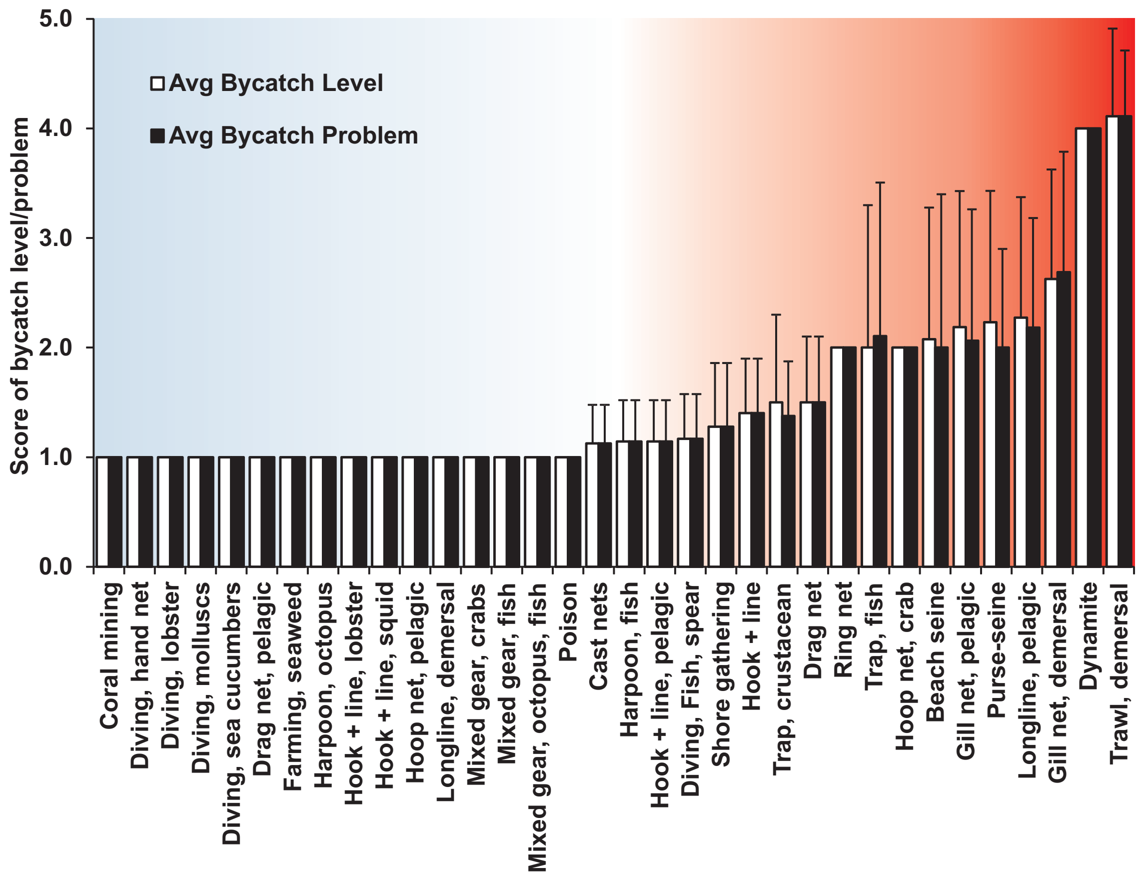


Figure 1: Average (+ 1 STD) fisheries' bycatch scores for WIOFish fishery types based on assessments provided by participants from eight SWIOFP countries.

Figure 2: Average (+ 1 STD) fisheries' bycatch scores for aggregated harvesting types based on assessments provided by participants from eight SWIOFP countries.



FISHERIES TYPES

Aggregated harvesting type: Coral mining
WIOFish fishery name: Other, coral mining
WIOFish Fishery types: Subsistence
Countries reporting this harvesting: Tanzania
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Although still apparently ongoing in Tanzania, it is also known to have occurred in Kenya, Madagascar and Comoros (Salm 1983). Not strictly a bycatch problem, as harvesting involves breaking off pieces of dead coral reef or pieces of live coral i.e. targets the coral itself; there may be limited loss of associated epifauna such as littorinids and limpets on dead coral, or sponges and ascidians on live coral. Needless to say, the removal of live coral seriously compromises this habitat (Dulvy *et al*. 1995) and the species which rely on it.

Aggregated harvesting type: Diving, hand net
WIOFish fishery name: Diving, hand/hoop net, ornamental fish
WIOFish Fishery types: Recreational, small-scale commercial, other
Countries reporting this harvesting: South Africa, Kenya, Tanzania, Mauritius
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Likely to be more widespread than reported, but bycatch levels are insignificant owing to specific targeting of ornamental reef fishes by divers.

Aggregated harvesting type: Diving, molluscs
WIOFish fishery name: Diving, gathering, ornamental shells/oysters; Diving, speargun, octopus
WIOFish Fishery types: Recreational, artisanal, small-scale commercial
Countries reporting this harvesting: South Africa, Kenya
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
A mixture of target species, but since selectivity is highly focussed, bycatch is largely not a problem, aside from the removal of oyster-associated epifauna such as algae and micro- invertebrates, but this is insignificant.

Aggregated harvesting type: Diving, sea cucumbers
WIOFish fishery name: Diving, gathering, sea cucumber
WIOFish Fishery types: Artisanal, small-scale commercial
Countries reporting this harvesting: Seychelles, Tanzania, Madagascar, Mozambique, Kenya
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
A widespread activity in the SWIOFP region (Conand & Muthiga 2007), with adverse impacts associated with processing of the product; however, because there is specific hand-selection of the cucumbers (mainly *Holothuria* spp) by divers, bycatch levels are negligible, limited to the pearlfish (Family Carapidae) which reside inside the cucumbers.

Catch from a subsistence, pelagic drag net, with low levels of bycatch, most of which will be consumed. (Photo: Sean Fennessy)

Aggregated harvesting type: Drag net, pelagic
WIOFish fishery name: Small nets, mosquito nets, herring
WIOFish Fishery types: Artisanal
Countries reporting this harvesting: Comoros
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Harvesting involves young fishers using small nets to specifically target shoals of the herring *Spratelloides delicatulus* in shallow lagoons and reportedly there is no bycatch.

Aggregated harvesting type: Farming, seaweed
WIOFish fishery name: Shore gathering, seaweed, culture
WIOFish Fishery types: Small-scale commercial
Countries reporting this harvesting: Tanzania
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Small pieces of *Eucheuma* and/or related alga are attached to a network of twine in shallow lagoons and are harvested once sufficient growth is attained. Appears to be restricted to Tanzania, particularly Zanzibar, and Kenya in the SWIOFP region (e.g. Ronnback *et al.* 2002). Associated epiphytic fauna (amphipods, isopods, molluscs) are probably removed when the seaweed is harvested, but given the artificial nature of the “habitat”, the nature of the associated species and likely amounts of “bycatch”, the bycatch problem is assessed as very low.

Aggregated harvesting type: Harpoon, octopus
WIOFish fishery name: Harpoon, by hand, octopus
WIOFish Fishery types: Artisanal
Countries reporting this harvesting: Madagascar
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Fishers wade in the coastal lagoon, and spear octopus *Octopus* sp. on sight; the fishery is illegal, but is still practiced. Known to take place in other WIO countries. No bycatch is associated with this activity.

Aggregated harvesting type: Hook & line, shore, lobster
WIOFish fishery name: Hook & line, shore, lobster (rec, sub)
WIOFish Fishery types: Recreational, subsistence
Countries reporting this harvesting: South Africa
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Subsistence fishers use a pole and fixed line with a baited hook at night from the shore to catch lobsters *Panulirus homarus* (Steyn *et al*. 2008); levels of bycatch are not known but are considered low, and comprise juvenile (sub-legal size) lobsters. Recreational shore fishers catch lobsters incidentally while targeting fish with hook and line. Overall the low bycatch scores are justified.

Aggregated harvesting type: Hook and line, squid
WIOFish fishery name: Hook & line, small boat & motor, squid
WIOFish Fishery types: Artisanal
Countries reporting this harvesting: Seychelles
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Fishers on small boats use artificial lures (squid jigs) to target squid *Loligo* spp; owing to the nature of the fishing activity, there is no bycatch.

Aggregated harvesting type: Hoop net, pelagic
WIOFish fishery name: Small nets, hand/hoop net, squid & glassies
WIOFish Fishery types: Recreational
Countries reporting this harvesting: South Africa
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Fishers use gas lamps at night in estuaries to attract bait species (mainly squid *Loligo* spp) which are collected using a lifted hoop net. The squid are the more desirable targets, but glassies *Ambassis* spp are also used as bait at times; if not needed they are returned to the water alive, so there is no bycatch problem.

Aggregated harvesting type: Longline, demersal
WIOFish fishery name: Hook & line, longline, artisanal
WIOFish Fishery types: Artisanal
Countries reporting this harvesting: Madagascar, Mozambique
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Likely to occur in other SWIOFP countries. In Mozambique, boat fishers deploying demersal longlines in moderately deep water (< 100m) report a variety of targeted demersal fishes and elasmobranchs. Although the bycatch scores are here assessed as low, the non-selective nature of the gear means that a wide range of species is probably caught, and there is limited information on the scale of participation, so the bycatch score could be higher. Monitoring recommended.

Aggregated harvesting type: Mixed gear, crabs
WIOFish fishery name: Mixed gears, mangroves, crabs
WIOFish Fishery types: Artisanal, subsistence (although semi-industrial is also listed, this should probably rather be small-scale commercial)
Countries reporting this harvesting: Madagascar
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Fishers operate from boats and on foot in estuaries to collect mangrove crabs *Scylla serrata* using a variety of gear including hook and line, lift nets and traps. Bycatch levels will vary according to gear type but are likely to be very low given the specific targeting of crabs; bycatch probably includes eels (Family Anguillidae) when bait is used.

Aggregated harvesting type: Mixed gear, fish
WIOFish fishery name: Mixed gears, traps and lines, artisanal
WIOFish Fishery types: Artisanal
Countries reporting this harvesting: Mauritius
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Fishers on small boats access a variety of inshore areas using hook and line and baited traps with quite large mesh size, catching a considerable variety of reef fish species. It is not apparent what the bycatch levels are, but given the non-selective nature of the gear and the habitat being fished, they are unlikely to be as low as the previous fishery. Monitoring recommended.

Aggregated harvesting type: Mixed gear, octopus, fish
WIOFish fishery name: Mixed gears, harpoon and line, artisanal
WIOFish Fishery types: Artisanal
Countries reporting this harvesting: Mauritius
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Fishers on foot in shallow waters target octopus with a harpoon and also target shore fishes (*Siganus sutor* and *Scarus* spp.) with basic hook and line gear. Bycatch levels are likely to be very low, probably limited to undesirable fish (toxic, too small) caught by hook and line, so not problematic.

Aggregated harvesting type: Poison
WIOFish fishery name: Other, poison, fish; Other, research, poisons
WIOFish Fishery types: Subsistence, Other
Countries reporting this harvesting: Comoros, South Africa
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
In Comoros, subsistence harvesters introduce juice from crushed *Tephrosia* plants into shallow pools to anaesthetise fish which are then collected. The fishes which are reported to be targeted are diverse, including serranids, scarids and saurids, and it is likely that many others are also caught by this method. It is not apparent whether all affected fishes

are collected or whether fishes which are not collected recover from the effects. However, the level of participation is probably low, so bycatch is not a substantial problem. For research purposes in South Africa, poisons such as rotenone are introduced into the water, killing fishes which are collected. In the process, fishes surplus to requirements are also killed, as are invertebrates. The effects are not reversible, but there is no information on the extent of this activity, and it is likely to occur in other SWIOFP countries than reported.

Aggregated harvesting type: Diving, lobster
WIOFish fishery name: Diving, lobster
WIOFish Fishery types: Artisanal, recreational, subsistence, small-scale commercial
Countries reporting this harvesting: Seychelles, South Africa, Tanzania
Average bycatch level score: 1
Average bycatch problem score: 1
Comments:
Individuals diving and collecting lobster *Panulirus* spp. This activity is frequently practiced simultaneously while hunting fish using a spear, so, although widespread in the SWIOFP region, some countries have probably included it in the Diving, fish, spear activity. In any event, the bycatch is negligible as the organisms are visually targeted and selected. Likely to occur in other WIO countries.

Aggregated harvesting type: Cast nets
WIOFish fishery name: Small nets, cast nets, fish/shrimps/squid
WIOFish Fishery types: Artisanal, Small-scale commercial, Subsistence, Recreational
Countries reporting this harvesting: Comoros, South Africa, Seychelles, Madagascar, Tanzania, Kenya
Average bycatch level score: 1.1
Average bycatch problem score: 1.1
Comments:
Widespread activity. Harvesting using a small net usually thrown over observed shoals of small pelagic fish, squid or prawns (*Penaeus* spp) in shallow water over soft sediments. Levels of bycatch are not documented, and although the gear is small the level of participation in this activity is high and consequently bycatch may be considerable in turbid waters where cast-netting is done "blind", particularly where prawns are targeted. The main problem may lie in impacts on fry and juveniles in nursery areas. Monitoring recommended.

Aggregated harvesting type: Harpoon, fish
WIOFish fishery name: Shore gathering, spear, fish; Harpoon, small boat, rays
WIOFish Fishery types: Artisanal, subsistence
Countries reporting this harvesting: South Africa, Comoros, Seychelles, Kenya, Tanzania, Kenya, Tanzania
Average bycatch level score: 1.1
Average bycatch problem score: 1.1
Comments:
Practiced by individuals in several shallow (<20 m) habitats including estuaries, involves visual identification of a wide variety of fishes, either by diving from shore or boat, or while wading; as with spearfishing, the bycatch is not an issue.

Pelagic gamefish are targeted by hook and line recreational fishers, with low levels of bycatch (Photo: Rob Kyle)

Aggregated harvesting type: Hook and line, pelagic
WIOFish fishery name: Hook and line (specifying trolling, gamefish)
WIOFish Fishery types: Artisanal, small-scale commercial, sport, recreational, tournament
Countries reporting this harvesting: Seychelles, Comoros, Tanzania, Kenya
Average bycatch level score: 1.1
Average bycatch problem score: 1.1
Comments:
Despite the wide variety of fishery types, incorporating a wide range in levels of sophistication of vessels and gear, the type of gear (lures) and the method of deployment (trolling in epipelagic coastal waters) means that targeted pelagic species are virtually always caught (unless the lure is allowed to sink to the bottom), so bycatch levels are considered low and not problematic.

Aggregated harvesting type: Diving, fish, spear
WIOFish fishery name: Diving, speargun, fish
WIOFish Fishery types: Artisanal, subsistence, recreational, tournament
Countries reporting this harvesting: Mozambique, Tanzania, Kenya, South Africa, Comoros
Average bycatch level score: 1.2
Average bycatch problem score: 1.2
Comments:
Highly selective shooting of targeted fish by divers, no by-catch associated with this fishery.

Aggregated harvesting type: Shore gathering
WIOFish fishery name: Shore gathering (numerous activities)
WIOFish Fishery types: Artisanal, subsistence, small-scale commercial, other
Countries reporting this harvesting: All
Average bycatch level score: 1.3
Average bycatch problem score: 1.3
Comments:
Many (69 fisheries on the WIOFish database use this name) activities of this type are listed, all involving the collection of a wide variety of marine and estuarine invertebrates, as

well as mangrove wood and turtle eggs. Sometimes simple implements are used. The activity is generally selective unless blade-like implements are used to remove patches of sessile organisms, so bycatch is probably low, and would include small amounts of epiphytic organisms (algae, small molluscs) and juveniles of target organisms such as oysters and mussels.

Aggregated harvesting type: Hook and line

WIOFish fishery name: Hook and line (numerous varieties)
WIOFish Fishery types: Artisanal, subsistence, small-scale commercial, semi-industrial, industrial, sport, recreational, tournament, other
Countries reporting this harvesting: All
Average bycatch level score: 1.4
Average bycatch problem score: 1.2
<u>Comments</u>:
A huge variety (59 fisheries with this name listed on the WIOFish database, excluding those which target pelagics) of hook and line gears are used to fish on or very close to reefs for a very wide range of demersal species throughout the region (e.g. Robinson & Shroff 2004, Penney *et al.* 1993, Jehangeer 2006). Participants range from subsistence individuals with hand lines to industrial vessels with large numbers of crew and quite sophisticated gear (GPS). There is no formal information available on bycatch levels or what are considered target species – rather, targeting is inferred from the landed catch composition. In many fisheries (except perhaps for recreational fisheries), undesirable bycatch species (e.g. ciguatoxic "red" fish species (Hamilton *et al.*2002), or sub-legal sized individuals in fisheries which have minimum legal size limits) are used as bait, or discarded. Even if they are discarded, their survival is not assured, particularly when caught at depth, due to barotrauma. Given the non-selective nature of the gear, and particularly for fisheries which have high effort and/or catch levels, on-board monitoring is recommended in order to properly assess the situation.

Aggregated harvesting type: Trap, crustacean

WIOFish fishery name: Artisanal, subsistence, small-scale commercial, industrial, other (experimental)
WIOFish Fishery types: Traps, offshore, crabs; Traps, industrial, pots, lobsters; Traps, cage nets, crustaceans
Countries reporting this harvesting: Kenya, Madagascar, Comoros, Mozambique, Seychelles, South Africa
Average bycatch level score: 1.5
Average bycatch problem score: 1.4
<u>Comments</u>:
A variety of traps/pots deployed in inshore waters or deep (> 100m) water, targeting lobsters *Panulirus* spp and *Palinurus delagoae* respectively (Sousa 2001, Groeneveld & Cockcroft 1998). No published information is available on bycatches in shallow water traps. In deep water traps, slipper lobsters *Scyllarides elizabethae* and crabs *Chaceon macpherson* are commonly caught as bycatch, and are retained, while unwanted crabs such as *Pleistacantha ori*, and negligible numbers of fish, are discarded (Groeneveld *et al.* 1995). Lost traps which continue ghost fishing contribute to bycatch, but this is not quantified. Monitoring recommended.

Aggregated harvesting type: Drag net

WIOFish fishery name: Small nets, mosquito nets, fish; Small nets, drag net, fish/shrimps
WIOFish Fishery types: Artisanal, subsistence, recreational
Countries reporting this harvesting: Madagascar, Tanzania, South Africa
Average bycatch level score: 1.5
Average bycatch problem score: 1.5
<u>Comments</u>:
Despite being illegal in countries reporting this activity, it persists and occurs in other SWIOFP countries as well. A small-meshed net (sometimes shade cloth or mosquito mesh is used), dragged by one or two people on soft substrata in shallow inshore waters, including estuaries, for a variety of fishes and or prawns *Penaeus* spp. The small mesh size means tiny fishes and prawns are caught, and which may be discarded. No information is available on the extent of this, the activity could well warrant a higher bycatch score. Monitoring recommended.

Aggregated harvesting type: Hoop net crab

WIOFish fishery name: Small nets, hoop net, kona crab
WIOFish Fishery types: Artisanal
Countries reporting this harvesting: Seychelles
Average bycatch level score: 2
Average bycatch problem score: 2
<u>Comments</u>:
Several hundred baited hoop (tangle) nets on a longline are set offshore in water 30-80m depth for spanner crabs *Ranina ranina*; bycatch information is limited, discards include gravid females and sub-legal individuals which are returned to the water, although survival is low (Boulle 1995).

Aggregated harvesting type: Ring net

WIOFish fishery name: Large nets, ring nets, fish; Small nets, surrounding net (zuwio); Small nets, boat drag & seine (kavogo, kigumi)
WIOFish Fishery types: Small-scale commercial, artisanal, subsistence
Countries reporting this harvesting: Kenya, Tanzania
Average bycatch level score: 2
Average bycatch problem score: 2
<u>Comments</u>:
An encircling type of gillnet, very variable in size, deployed from a boat, in variable water depth. Fish are herded towards the net using a variety of methods. For very large ring nets, a large boat with ~30 crew deploys the net around shoals of fish in water up to 30 m in depth; SCUBA divers often assist with this process. The net is able to be set on/close to reef, particularly when divers are used, as they help to prevent snagging. Recent information (KMFRI and TAFIRI, unpublished) for the very large ring net gear indicates that a large variety and substantial quantities of fishes, including many demersal reef fishes, are caught this way. Larger, valuable fishes are the target, but many other species are caught; it is not apparent to what extent these are retained or discarded. There are numerous participants in this type of fishery, particularly for users of smaller gear. On-board monitoring recommended.

Aggregated harvesting type: Traps, fish

WIOFish fishery name: Traps, fence/staked/basket traps,
WIOFish Fishery types: Artisanal, Small-scale commercial, Subsistence
Countries reporting this harvesting: Tanzania, Mozambique, Seychelles, South Africa, Comoros, Kenya, Madagascar
Average bycatch level score: 2
Average bycatch problem score: 2.1
Comments:
A variety of forms, ranging from traps with a guiding fence in shallow water (including estuaries (e.g. James *et al.* 2008) and intertidal areas), to simple woven basket traps deployed from canoes, to traps constructed from artificial materials and deployed from large (>20m) vessels in relatively deep (<~50m) water (e.g. Robinson *et al*. 2004). Sometimes baited. Information on the nature of bycatch/discards is not readily available – there is considerable variation in the scores of the level and extent of the problem (Figure 2) – monitoring recommended.

Aggregated harvesting type: Beach seine

WIOFish fishery name: Small/large nets, beach/estuarine seine, fish
WIOFish Fishery types: Artisanal, subsistence, small-scale commercial
Countries reporting this harvesting: Tanzania, Mozambique, Seychelles, South Africa, Comoros, Kenya, Madagascar
Average bycatch level score: 2.1
Average bycatch problem score: 2
Comments:
A seine net of variable size, one end of which is anchored on the shore and then the other is paid out into the water, either by wading or from a boat, and both ends of the net are then retrieved by hand on the shore. Deployed on soft substrata (including sea grass beds) and on reef flats with low profile, in relatively shallow inshore areas (including estuaries). A wide variety of fishes and invertebrates is caught (McClanahan & Mangi 2001) although at times there is targeting e.g. of pelagic fishes (Mualeque & Santos 2011). Mosquito mesh is sometimes used to line the cod-end, which can lead to large catches of larvae (e.g. in Mozambique, larval shrimp *Penaeus* spp – A. Nataniel, Escola Superior de Ciências Marinhas e Costeiras, Quelimane, Mozambique, unpubl. data). Seine nets are extensively used throughout the SWIOFP region, often illegally, and have been shown to result in overfishing (e.g. McClanahan *et al.* 2008, Kamakuru *et al.* 2005). Information on bycatch/discards is not readily available (probably because of the illegality of this type of harvesting in several countries), and there is considerable variation in the scores for bycatch level and extent of the problem (Figure 2) – monitoring recommended.

Aggregated harvesting type: Gillnet, pelagic

WIOFish fishery name: Gillnets/surrounding/surface/drift, pelagics/sharks/rays/fish/estuarine fish
WIOFish Fishery types: Artisanal, subsistence, small-scale commercial, other
Countries reporting this harvesting: Tanzania, Mozambique, Seychelles, South Africa, Comoros, Kenya, Madagascar
Average bycatch level score: 2.2
Average bycatch problem score: 2.1
Comments:
Gillnets with variably sized mesh depending on the reported WIOFish targets, which range from small pelagic fishes (e.g. *Rastrelliger kanagurta*, *Hilsa kelee,* Belonidae) to larger scombrids such as *Scomberomorus commerson* and *Thunnus albacares*, or elasmobranchs *Carcharhinus* spp. Often set at night, the net may be anchored in shallow water, or simply allowed to drift in deeper water; it may even be used as a type of purse seine if it is set around a shoal of fish. Very widely used in the SWIOFP region. Numerous non-fish fauna are caught e.g. dolphins *Tursiops aduncus*, *Stenella longirostris* and dugongs *Dugong dugon* (see Kiszka *et al*. 2008), turtles *Chelonia mydas* and *Eretmochelys imbricata* (Bourjea *et al*. 2008), and, for some fisheries, a variety of non-target elasmobranchs (Dudley & Cliff 1993, Kiszka & Muir 2007). This activity supposedly only occurs in shelf water; banned since 1994, open ocean drift gillnets were responsible for a wide variety of bycatch such as elasmobranchs (Bonfil 1994), and this activity may still occur in the SWIOFP region. The nature and level of the bycatch varies from fishery to fishery, hence the variance associated with the average scores (Figure 2). A higher bycatch score is warranted given the threatened nature of some of the non-fish bycatch. Monitoring recommended.

Aggregated harvesting type: Purse seine

WIOFish fishery name: Small nets, lamp, fish; Industrial nets, purse seine, tuna; Small nets, purse seine, small pelagics
WIOFish Fishery types: Artisanal, Small-scale commercial, Subsistence, Foreign fleet, Industrial, Other
Countries reporting this harvesting: Tanzania, Mozambique, Seychelles, South Africa, Comoros, Kenya, Madagascar
Average bycatch level score: 2.2
Average bycatch problem score: 2.0
Comments:
A wide range of gear sizes and vessel sophistication. Small-scale fishers in small boats in shallow inshore areas target small pelagic fish such *Sardinella* spp, *Rastrelliger kanagurta* and *Sphyraena* spp (sometimes using lamps at night to attract fish), which are encircled, and the net is then lifted and closed off, and the catch is scooped up with hand nets. Industrial vessels operate in oceanic waters, either targeting free-swimming shoals of large yellowfin tuna *Thunnus albacares* or shoals of skipjack tuna *Katsuwonis pelamis* and small yellowfin tuna associated with flotsam or FADs. In small-scale fisheries, several other pelagic fish species are probably caught, and could be considered bycatch, but most are probably retained for consumption; small inedible

species are likely to be discarded but levels of this are probably negligible. In the industrial fishery, discard rates in the Indian Ocean are around 5%, and comprise a variety of pelagic fishes such as small individuals of target species and other tunas, dorado *Coryphaena hippurus*, rainbow runner *Elagatis bipinnulatus* and billfishes Istiophoridae as well as several shark species (Kelleher 2005, Amande *et al*. 2008, Romanov 2008). Monitoring recommended.

Aggregated harvesting type: Longline, pelagic

WIOFish fishery name: Hook & line, longline, pelagic, surface, swordfish & tuna, sharks
WIOFish Fishery types: Artisanal, subsistence, small-scale commercial, semi-industrial, industrial, foreign fleet
Countries reporting this harvesting: Tanzania, Mozambique, Seychelles, South Africa, Comoros, Kenya, Madagascar, South Africa
Average bycatch level score: 2.3
Average bycatch problem score: 2.2
<u>*Comments:*</u>
Essentially a buoyed long line with numerous branch lines with baited hooks; increasing levels of longline length, gear sophistication and vessel size from artisanal to industrial; small-scale operations take place in much shallower inshore waters for a range of scombrids, billfishes and carangids, while industrial fishing (by foreign (legal and illegal) and/or local fleets) occurs in oceanic waters (EEZ and high seas), where the targets are mainly yellowfin and bigeye tunas (*T. obesus*), swordfish *Xiphias gladius* and sharks. Bycatch scores for the less sophisticated fisheries are lower than those for the industrial fisheries, which is reflected in the variability around the average scores (Figure 2). Discard rates for industrial longline fisheries are high (~22%), but vary regionally and by fleet e.g. in the Seychelles the rate is around 10% (Kelleher 2005). Blue sharks *Prionace glauca* and mako sharks *Isurus oxyrhinchus* comprise most of the bycatch in the industrial fishery for swordfish, and are retained by at least some fleets; however, some fleets persist in removing only the fins and discarding the carcasses (Garcia-Cortez *et al*. 2006, Le Manache 2012). Other species making considerable contribution to the bycatch (depending on the target species) are pomfrets *Brama brama*, escolar *Lepidocybium flavobrunneum* and dorado *Coryphaena hippurus*, as well as several billfish species (Brothers *et al.* 1999, Lewison *et al.* 2004a, Bourne *et al.* 2008, Huang & Liu 2010). Monitoring recommended.

Aggregated harvesting type: Gillnet, demersal

WIOFish fishery name: Bottom gillnet - sharks/rays/fish/crustaceans
WIOFish Fishery types: Artisanal, subsistence, small-scale commercial
Countries reporting this harvesting: Kenya, Tanzania, Madagascar, Seychelles, Comoros, Mozambique, Mauritius
Average bycatch level score: 2.2
Average bycatch problem score: 2.2
<u>*Comments:*</u>
Gillnets which are anchored to the sea bed, at a variety of depths, with increasing mesh and gear size as the size of the target species increases (up to 30cm mesh if sharks are targeted). Smaller gillnets may be used as encircling nets in shallower waters by small-scale fishers, with fish being chased towards the net before it is closed off. Although not reported in WIOFish, perhaps because it is an IUU activity, there are also foreign vessels using set demersal gillnets in deep water for sharks to extract shark liver oil (e.g. Le Manach *et al.* 2011). A wide variety of fishes and sharks is caught in demersal gillnets used by small-scale fishers (Laroche & Ramananarivo 1995, McClanahhan & Mungi 2004), and some countries report targeting of prawns *Penaeus* spp in estuaries using these nets. Demersal gillnets can have a significant bycatch of turtles and dolphins (Obura *et al.* 2002, Silva 2006), although demersal gillnets have lower catches of these than pelagic gillnets (Kiszka *et al*. 2008).

Aggregated harvesting type: Dynamite

WIOFish fishery name: Other, dynamite, fish
WIOFish Fishery types: Artisanal, subsistence
Countries reporting this harvesting: Tanzania
Average bycatch level score: 4
Average bycatch problem score: 4
<u>*Comments:*</u>
Explosives are detonated by small-scale fishers in the vicinity of coral reefs to kill fish, some of which float to the surface and are then collected. However, many fish sink and are therefore lost, and can be considered as bycatch; invertebrates in the reef are also killed and are not collected (Guard & Masaiganah 1997), and considerable physical damage is inflicted on the reefs themselves and the sessile epifauna and flora (Wells 2009).

Aggregated harvesting type: Trawl, demersal

WIOFish fishery name: Semi/Industrial nets, inshore, offshore, crustaceans/shrimp
WIOFish Fishery types: Semi-industrial, industrial
Countries reporting this harvesting: Kenya, Tanzania, Madagascar, Mozambique, South Africa
Average bycatch level score: 4.1
Average bycatch problem score: 4.1
<u>*Comments:*</u>
Large nets (otter trawls) with small meshes dragged along the sea bed over soft substrata targeting crustaceans such as shallow-water prawns (*Penaeus* spp), deep-water prawns (*Haliporoides triarthrus, Aristaemorpha foliacae*), langoustines (*Metanephrops* spp), crabs (*Chaceon* spp) and lobsters (*Palinurus delagoae*). Bycatch is diverse, greatly outnumbers the target catch, and is mostly killed by trawling; some bycatch species are retained, but most are discarded (reviewed in Fennessy *et al.* 2004). Notwithstanding legal requirements for the use of Bycatch Reduction Devices in most SWIOFP countries (mainly intended to reduce catches of turtles), high levels of bycatch still persist, and have led to the closure of the trawl fisheries in some SWIOFP countries (Fennessy *et al.* 2008). Banned in several SWIOFP countries (Seychelles, Comoros, Mauritius).

Discussion

Participants at the WIOFish workshops provided support for the perception that there is negligible bycatch in artisanal and subsistence fisheries (Figure 1). Although not explicitly stated, the rationale for the low scores is presumably that, owing to the impoverished nature of these fishers, all of the catch has value, notwithstanding the likelihood that some parts are more desirable than others. However, there are no published studies from the SWIO region which specifically demonstrate this. Internationally, there is a perception that artisanal and subsistence fisheries have traditionally received little attention from management authorities, hence bycatch cannot be quantified (e.g. Lewison *et al.* 2004b). In fact many SWIOFP countries have substantive monitoring programmes in place for these fisheries, but the data do not permit the identification of bycatch – probably because this catch category does not exist (other than for illegal species such as turtles or mammals), or because the target is not obvious. Thus, while sharks could be considered to be bycatch, the high value of their fins probably makes them a target; however, if only the fins are removed, and the carcass is discarded (as happens in some industrial fisheries), this would constitute true bycatch. The situation is further complicated by inconsistencies in the application of the definition of "artisanal" to certain fisheries, some of which are probably better classified as small-scale commercial or semi-industrial. Notably, recreational type fisheries (including "sport" and tournament" fisheries) also had no/low bycatch – presumably because of their tendency to target pelagic gamefish, and for undesirable catches to be returned alive to the water. As predicted, industrial fisheries (including "semi-industrial" and "foreign fleets") received higher bycatch scores, presumably as a function of both the targeting of specific species and the size/design of the fishing gear.

Catch from an industrial, shallow-water, prawn trawler, with high levels of bycatch, most of which will be discarded. (Photo: Sean Fennessy)

Regarding scores assigned to the various harvesting types, clearly those activities which consisted of hand selection of individual organisms were seen to present no (or very low) bycatch issues (Figure 2); broadly, as gear complexity increased, the scope for bycatch increased, with the various net types featuring prominently amongst the higher scores. Prawn trawling, having a clearly defined target and a large, diverse bycatch, scores highest, with pelagic longline and purse seine also scoring highly, as reported in Kelleher (2005), albeit that he refers to discard rates as opposed to bycatch. For some fisheries, the bycatch scores may appear lower than expected – but, as already discussed, this could be a consequence of a value judgement being applied to what constitutes bycatch, in the absence of a clear definition or better information on targeting or the absence thereof.

It is apparent that many of the fisheries described in the WIOFish database require monitoring, or improved monitoring – many of the fisheries reportedly had no data available (Annex 1), and even for those for which bycatch scores were provided, improved monitoring is required for some in order to be able to determine whether there are specific targets, and to be able to define them. This would allow improved understanding of what constitutes bycatch for these fisheries. Also important would be to improve available WIOFish information on the fate of the bycatch – is it discarded, used as bait, etc? If this can be established, it will improve future assessments of SWIO bycatch for better understanding of this complex issue, and ultimately facilitate better management.

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Annex:
List of zero-score aggregated harvesting types for which the listed countries provided a zero (hence unknown/no data) score for either bycatch level or bycatch problem).

Fishery type	*Fishery name*	*Aggregated harvesting type*	*Country*
Artisanal	Small nets, beach seine, fish	Beach seine	Madagascar
Subsistence	Small nets, beach seine, fish	Beach seine	Madagascar
Artisanal	Small nets, seine nets, crustacean	Beach seine	Kenya
Artisanal	Small nets, cast nets, fish & shrimps	Cast nets	Madagascar
Small-scale commercial	Small nets, cast nets, fish & shrimps	Cast nets	Madagascar
Subsistence	Small nets, cast nets, fish & shrimps	Cast nets	Madagascar
Artisanal	Small nets, cast net, fish & squid	Cast nets	Tanzania
Subsistence	Small nets, cast net, fish & squid	Cast nets	Tanzania
Artisanal	Diving, speargun & snorkel	Diving, Fish, spear	Tanzania
Subsistence	Diving, speargun & snorkel	Diving, Fish, spear	Tanzania
Recreational	Diving, speargun, recreational	Diving, Fish, spear	Mozambique
Other	Diving, hand/scoop net, ornamental fish	Diving, hand net	Tanzania
Subsistence	Diving, gathering, lobsters (sub)	Diving, lobster	South Africa
Recreational	Diving, gathering, ornamental shells	Diving, molluscs	South Africa
Artisanal	Diving, seagrass beds, sea cucumbers	Diving, sea cucumbers	Mozambique
Small-scale commercial	Small nets, mosquito nets, fish	Drag net	Madagascar
Artisanal	Small nets, mosquito nets, fish	Drag net	Madagascar
Subsistence	Other, dynamite, fish	Dynamite	Comoros
Artisanal	Small nets, gillnet, humphead parrot fish	Gillnet	Seychelles
Artisanal	Small nets, gillnets, sharks	Gillnet	Seychelles
Artisanal	Small nets, shark net, sharks/rays/fish	Gillnet	Mozambique
Artisanal	Small nets, gillnet, fish	Gillnet	Mauritius
Artisanal	Small nets, bottom gillnet, artisanal	Gillnet	Mozambique
Artisanal	Small nets, gillnets, crustaceans	Gillnet	Kenya
Subsistence	Small nets, gillnets, crustaceans	Gillnet	Kenya
Artisanal	Small nets, gillnets surface, fish	Gillnet, pelagic	Comoros
Small-scale commercial	Small nets, gillnets surface, fish	Gillnet, pelagic	Comoros
Subsistence	Small nets, gillnets surface, fish	Gillnet, pelagic	Comoros
Sport	Hook & Line, small boat and motor, sport	Hook + line	Mauritius
Artisanal	Hook & line, small boat/non motor, pirogue	Hook + line	Seychelles
Small-scale commercial	Mothership dories	Hook + line	Seychelles
Subsistence	Hook & line, shore, lobster (sub)	Hook + line, lobster	South Africa
Recreational	Hook & line, charter boat, gamefish	Hook + line, pelagic	Tanzania
Sport	Hook & line, charter boat, gamefish	Hook + line, pelagic	Tanzania
Tournament fishing	Hook & line, charter boat, gamefish	Hook + line, pelagic	Tanzania
Artisanal	Hook & line, longline, artisanal (demersal)	Longline, demersal	Madagascar
Foreign fleet	Hook & line, longline, tuna	Longline, pelagic	Mauritius
Industrial	Hook & line, longline, tuna	Longline, pelagic	Mauritius

Fishery type	*Fishery name*	*Aggregated harvesting type*	*Country*
Foreign fleet	Hook & line, longline surface, tuna	Longline, pelagic	Comoros
Foreign fleet	Hook & line, longline, tuna	Longline, pelagic	Mozambique
Other	Other, research, poisons	Poison	South Africa
Foreign fleet	Industrial nets, offshore, tuna	Purse-seine	Tanzania
Foreign fleet	Industrial nets, purse seine, tuna	Purse-seine	Comoros
Foreign fleet	Industrial nets, purse seine, tuna	Purse-seine	Kenya
Foreign fleet	Industrial nets, purse seine, tuna	Purse-seine	Mauritius
Foreign fleet	Industrial nets, purse seine, tuna	Purse-seine	Mozambique
Artisanal	Small nets, surrounding net (Zuwio)	Ring net	Tanzania
Subsistence	Small nets, surrounding net (Zuwio)	Ring net	Tanzania
Artisanal	Small nets, boat drag & seine (kavogo, kigumi)	Ring net	Tanzania
Subsistence	Small nets, boat drag & seine (kavogo, kigumi)	Ring net	Tanzania
Subsistence	Shore gathering, clams	Shore gathering	Mozambique
Artisanal	Shore gathering, general beach, ornamental shells	Shore gathering	Madagascar
Artisanal	Shore gathering, rocky shore, oysters	Shore gathering	Madagascar
Artisanal	shore gathering, intertidal, octopus	Shore gathering	Tanzania
Subsistence	shore gathering, intertidal, octopus	Shore gathering	Tanzania
Subsistence	Shore gathering, sandy beach, oyster	Shore gathering	Mozambique
Other	Shore gathering, sandy shores, turtles	Shore gathering	Tanzania
Recreational	Shore gathering, rocky shores, mussels (rec)	Shore gathering	South Africa
Artisanal	Traps, barrages, mangroves	Trap	Madagascar
Small-scale commercial	Traps, barrages, mangroves	Trap	Madagascar
Subsistence	Traps, barrages, mangroves	Trap	Madagascar
Artisanal	Traps, basket (gaiola)	Trap	Mozambique
Small-scale commercial	Traps, offshore, crabs	Trap, crustacean	Kenya
Artisanal	Traps, pots, lobsters	Trap, crustacean	Madagascar
Industrial	Industrial nets, inshore, crustaceans	Trawl	Tanzania
Semi-Industrial	Industrial nets, inshore, crustaceans	Trawl	Tanzania
Small-scale commercial	Industrial nets, inshore, crustaceans	Trawl	Tanzania

8.
MARINE MAMMALS

Table of contents

Previous page: Striped dolphin, rare in the SWIO. Photo by Peter van der Elst.

8. MARINE MAMMALS

A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean

Jeremy Kiszka[1]

Abstract

Information on diversity, spatial and temporal distribution, abundance, population structure of marine mammals in the Southwest Indian Ocean (SWIO) is relatively limited, despite evidence for exposure of these vulnerable species to a variety of threats. This chapter reviews existing information on the status and conservation issues of marine mammals in the SWIO, from 0 to 30°S, from eastern Africa to 60°E. Within the region, a total of 37 marine mammal species have been recorded (authenticated records, including sightings and/or strandings), including 32 cetaceans, 1 sirenian (the dugong *Dugong dugon*) and 4 pinnipeds (30% of global marine mammal biodiversity). Species diversity and distribution have been undertaken in many areas within the region. The existing literature does not provide sufficient information to identify cetacean hotpots in the SWIO, but it seems that oceanic islands and archipelagoes provide quality habitats for a diversity of toothed cetaceans. Among cetaceans, the humpback whale (*Megaptera novaeangliae*) is the most common and widely distributed large whale species during austral winter. The region constitutes a major breeding ground for this species in the southern hemisphere. The amount of knowledge on abundance and distribution of other large cetaceans is far more limited in the SWIO. The dugong is most likely the most endangered marine mammal species in the region. Dugongs have progressively declined in most countries of the region, and the only known viable population is located in the Bazaruto Archipelago, Mozambique. While bycatch is the most important threat to marine mammals, including the dugong, in the SWIO, other threats, including disturbance and noise pollution, have been identified. Overall, marine mammal knowledge has significantly increased over the last decade in the SWIO. However, many gaps remain on the location of hotspots of abundance and on the impact of major threats on their populations, especially through bycatch.

Introduction

Information on diversity, spatial and temporal distribution, abundance, and population structure of marine mammals in the southwest Indian Ocean (SWIO) is relatively limited. However, it has been highlighted that several marine mammal species were exposed to significant anthropogenic impacts, including disturbance, bycatch, and hunting.

This chapter reviews distribution, status, and population structure of marine mammals in this region. It also reviews interactions between these vulnerable species and fisheries, including bycatch, hunting as well as depredation. The geographical area considered in this synthesis includes the EEZ of eastern South Africa (Port Elizabeth as the westernmost limit), Mozambique, Tanzania, Kenya, the Seychelles, Madagascar, the Comoros, the French EEZ (Mayotte, Geyser and Zélée banks, Glorieuses, Juan de Nova, Europa, Bassas da India, Tromelin and La Réunion) and Mauritius. International waters of the region are also considered. The geographical range of the study area extends from 0 to 30°S, from eastern Africa to 60°E.

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Marine mammals in the SWIO: Country overview of status, distribution, abundance and population structure

Cetaceans fall into two principal orders, mysticetes (baleen whales) and odontocetes (toothed whales). Only one species of sirenian occurs in the SWIO, the dugong (*Dugong dugon*). Extra-limital records of pinnipeds have also been recorded on various tropical islands, such as Madagascar (Garrigue & Ross 1996) and the Comoros Archipelago (David *et al.* 1993), for example. However, pinnipeds are not regularly present in the region. The closest area where pinniped colonies are present are located along the south and southwest coasts of South Africa and involve the South African fur seal (*Arctocephalus pusillus*) (Best 2007).

Among baleen whales, there are still several taxonomic uncertainties regarding the status and identity of several species. Nevertheless, there are currently nine species known to occur in the SWIO region. Within the blue whale group, two subspecies co-occur: the Antarctic blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*). Concerning the toothed whales, some uncertainties exist regarding the range of several species, especially among beaked whales (Ziphiidae). For example, there are a number of unpublished records of sightings of anti-tropical species, such as True's beaked whale (*Mesoplodon mirus*) around Mayotte (eastern Comoros) (M. Vely, personal communication) and Shepherd's beaked whale (*Tasmacetus shepherdi*) off the Seychelles (G. Doremus, personal communication). Unconfirmed records of ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) also exist from Mayotte (Kiszka *et al.* 2007a) and eastern Madagascar (Ballance & Pitman 1998).

Within the SWIO area, a total of 37 marine mammal species has been recorded (authenticated records, including sightings and/or strandings), including 32 cetaceans, one sirenian (the dugong) and four pinnipeds (see Annex).

COUNTRY OVERVIEWS

South Africa (eastern region)

Extensive research has been undertaken on southern African marine mammals that commenced with the analysis of whaling data from Durban (Best 2007). A total of 41 species of cetaceans has been recorded in South Africa, 34 of these from the coast of the Indian Ocean. Along the east coast of South Africa, the most common species are the bottlenose dolphin (*Tursiops* spp.), Indian Ocean humpback dolphin (*Sousa plumbea*, Jefferson & Rosenbaum, 2014) and long-beaked common dolphin (*Delphinus capensis*). This latter species is seasonal in the region, being abundant during the winter sardine run, from June to August (between 15,000 and 30,000 individuals; Cockcroft *et al.* 1992). The inshore waters of KwaZulu-Natal also serve as a migration corridor for wintering humpback whales (*Megaptera novaeangliae*). Shore-based surveys of northward migrating humpback whales from Cape Vidal, northern KwaZulu-Natal between 1988 and 1999, suggested a population estimate of 1,700 individuals in 1990 (Findlay *et al.* 1994; Findlay & Best 1996). A further year of survey was conducted in 2002 and an increase of 9.9% per annum has been calculated for the period (Findlay & Best 2006). During the winter months, southern right whales (*Eubalaena australis*) congregate at certain sites to breed and calve, extending from the southwest coast of South Africa to Maputo. Southern right whales use sheltered bays and calm waters around small coastal islands during this season (Best 1990). The most significant wintering zone of this species is located between Port Elizabeth and Cape Town. Right whales arrive in the region's coastal waters in June and then depart by December. Calving peak occurs in August. From 1979 to 1998, the population calving on the south coast of South Africa increased at 7.1% a year. Another whale species that is frequently observed off the Indian Ocean coast of South Africa is the Bryde's whale (*Balaenoptera brydei*), particularly during austral winter, often associated with the migration of sardines (Best 2007).

Along the east coast of South Africa, most delphinid information collected relates to Indo-Pacific bottlenose (*Tursiops aduncus*) and Indian Ocean humpback dolphins

Humpback whale. (Photo: Jeremy Kiszka)

(hereafter humpback dolphins). Around 270 resident humpback dolphins occur in Algoa Bay. However, the total South African population is estimated at about 1,000 individuals (Karczmarski *et al.* 1999). Abundance estimates for *T. aduncus* have been documented for a section of the KwaZulu-Natal coast (Durban to 80km north) in 1984, 1985 and 1989, with 367, 433 and 520 dolphins (95% CI 156-970), respectively (Cockcroft *et al.* 1992). Another survey from the coast of Durban to 100km southwards produced uncorrected counts of 219-249 individuals in 1985 and 98-132 in 1990 (Cockcroft *et al.* 1992). A study of *T. aduncus* abundance in Algoa Bay suggested a population size of 28,482 individuals (95% CI= 16,220–40,744; CV= 0.220; estimate corrected for the proportion of distinctive individuals in the population; Reisinger & Karczmarski, 2010). This is the largest population estimate to date for this species along the South African coast, suggesting that Indo-Pacific bottlenose dolphins inhabiting the Algoa Bay region represent part of a substantially larger population that ranges along a considerable length of the South African coast (Reisinger & Karczmarski 2010).

Mozambique

Limited published information exists on the status and distribution of marine mammals in Mozambique. Mozambican waters are frequented by three species of large whales (humpback whale, minke whale *Balaenoptera acutorostrata* and sperm whale *Physeter macrocephalus*) and ten delphinid species (Rice & Saayman 1987; Findlay *et al.* 1994; Peddemors *et al.* 1997; Jefferson & Karczmarszki 2001). Humpback whales are the most common baleen whale species in Mozambique coastal waters, especially during austral winter. A survey in coastal waters between 14°26'S and 26°S, provided an abundance estimate of 5,811 humpback whales (Findlay *et al.* 1994).

Very little is known on the occurrence and distribution of other cetacean species. The rough-toothed dolphin (*Steno bredanensis*) has been reported from the Zambezi region (Best 1971). The most common cetaceans in Mozambique coastal waters are Indo-Pacific bottlenose dolphins and humpback dolphins, especially in Maputo Bay (105; 95% CI 31-152 humpback dolphins in Maputo; Guissamulo & Cockcroft 2004) and the Bazaruto Archipelago. Around Bazaruto, the abundance estimate of humpback dolphins is 165 (95% CI 118-277; Guissamulo & Cockcroft 2004). In general, individuals of bottlenose and humpback dolphins present an inverse seasonal trend; bottlenose dolphins are more abundant in winter while humpback dolphins are more common during summer.

The largest remaining dugong population in the SWIO region is believed to be in the Bazaruto Archipelago in Mozambique, where aerial surveys conducted between April 2006 and December 2007, estimated 247 animals (Cockcroft *et al.* 2008; Findlay *et al.* 2011). These authors suggest populations are declining and as the only viable population in the region are especially vulnerable. In other coastal areas of Mozambique, dugong appear relatively rare (WWF EAME 2004; Muir & Kiszka 2012).

Tanzania (including Zanzibar)

Eleven species of marine mammals have been recorded in Tanzania, including Zanzibar (Unguja Island). Dolphin species present include Indo-Pacific bottlenose dolphin, humpback dolphin, pantropical spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*), Risso's dolphin (*Grampus griseus*), rough-toothed dolphin and common bottlenose dolphin (*T. truncatus*) (Amir *et al.* 2002, 2005). Around Zanzibar, the most common species are Indo-Pacific bottlenose, humpback and spinner dolphins (Stensland *et al.* 1998; Amir *et al.* 2002, 2005). The most common large whale species is the humpback whale that migrates to shallow coastal waters every austral winter to breed and calve. Monitoring of Indo-Pacific bottlenose and humpback dolphins has been conducted off the south coast of Zanzibar since 1999. Population estimates range between 136 (124-172, 95% CI) and 179 (167-212, 95% CI) for Indo-Pacific bottlenose dolphin, and between 58 (56-79, 95% CI) and 65 (62-102) for humpback dolphins, in the approximately 26 km^2 study area (Stensland *et al.* 2006).

The dugong is very rare along the entire coast of Tanzania. However, the most important dugong habitats are associated with the Rufiji Delta east to Mafia Island and south to Kilwa, an area characterized by extensive shallow seagrass beds and sheltered bays and channels (Muir & Kiszka 2012). The exact size and range of the population in Tanzania is unknown, but anecdotal reports and infrequent captures indicate that numbers are very depleted (WWF EAME 2004).

Kenya

Very little is known on the diversity, distribution and occurrence of marine mammals off the coast of Kenya. Information is available from two main reports (Wamukoya *et al.* 1996; WWF EAME 2004). Aerial surveys were conducted in coastal waters of the entire seaboard in November 1994, using both aircraft and helicopters (254 hours of air time). No large whales were recorded, but five dolphin species were positively identified: common dolphin, Indian Ocean humpback dolphin, spinner dolphin, pantropical spotted dolphin and bottlenose dolphin (Wamukoya *et al.* 1996). The bottlenose dolphin species observed was *T. aduncus*, according to the technical supervisor of the survey (V.G. Cockcroft, personal communication). However, the identification of some species is somewhat uncertain. A further research programme has focussed on the residency and abundance of Indo-Pacific bottlenose dolphins in the Kisite-Mpunguti Marine Protected Area (largest MPA in Kenya), off the south coast of Kenya. A closed population model estimated a population size of 119 (95% CI 108-146) in 2006 and 122 (95% CI 110-143) in 2008. Movement patterns suggest this population is resident year-round (Perez *et al.* 2010).

In 2006 near-daily boat-based surveys, during four ten-week periods, of humpback dolphins took place in a 80 km^2 section of the Kisite Marine Park. Surveys involved 167 survey trips and used photographic identification as a mark–recapture technique. Estimated population size was 104 individuals (95% CI 67-160). Results suggest this to be an important humpback dolphin location and one that sustains dolphin-based tourism (Meyler *et al.* 2012).

Dugongs occurred in large numbers before the 1960s. A large aggregation of around 500 individuals had been seen in the south in 1967 (WWF EAME, 2004). This species declined drastically in the recent decades due to hunting and bycatch in gillnets. In 1994, the aerial survey conducted by Wamukoya *et al.* (1996) of the entire Kenyan coast recorded 10 dugong sightings, notably in the Tana delta area and in the Lamu Archipelago. Currently, dugong are only present in very small numbers, mostly confined to the Tana Delta area, the Lamu Archipelago and Kiunga (WWF EAME 2004; Muir & Kiszka 2012).

Union of the Comoros

A preliminary assessment of cetacean diversity was published in 2010 (Kiszka *et al.* 2010a). Twelve species of cetaceans have been recorded around the Comoros, including humpback whales that migrate to inshore waters for reproduction in winter. Around the Comoros, there is strong evidence that this species is common during austral winter, particularly from July to October (Ersts *et al.* 2011a). The high proportion of mother-calf pairs around the Comoros indicates this area constitutes an important nursing ground for this species (Kiszka *et al.* 2010a). The other most common species are spinner dolphin, pantropical spotted dolphin and melon-headed whale (*Peponocephala electra*). Other species have been observed, such as short-finned pilot whale (*Globicephala macrorhyncus*), Blainville's beaked whale (*Mesoplodon densirostris*) and Longman's beaked whale (*Indopacetus pacificus*) (Anderson *et al.* 2006; Kiszka *et al.* 2010a).

Dugongs still occur in the Comoros, especially in the Mohéli Marine Park, but in small numbers (WWF EAME 2004; Muir & Kiszka 2012). One species of pinniped, the subantarctic fur seal (*Arctocephalus tropicalis*), has been recorded (vagrant individual) on the island of Anjouan (David *et al.* 1993).

Mayotte (including Iris, Zélée and Geyser banks) and French dispersed islands

The diversity and distribution of marine mammals have been assessed around Mayotte (Kiszka *et al.* 2007a, 2007b, 2010b). The variety of available marine habitats around the island, in close proximity to one another, may well explain the high diversity of marine mammals in this area. Many genera of cetaceans are represented around Mayotte, especially delphinids (bulk of cetacean diversity), but also kogiids (dwarf sperm whale, *Kogia sima* and pygmy sperm whale, *K. breviceps*), physeterids (sperm whale), ziphiids (Blainville's beaked whale, Longman's beaked whale, Cuvier's beaked whale (*Ziphius cavirostris*), probably ginkgo-toothed beaked whale) and balaenopterids (humpback and blue whales and probably minke whale (Kiszka *et al.* 2007a; Kiszka 2010; Kiszka *et al.* 2010b). Humpback whales occur during austral winter for breeding. The high proportion of mother-calf pairs suggests that the surrounding waters of Mayotte constitute a nursing ground for this species in the region (Ersts *et al.* 2011a), like around the other Comorian islands (Kiszka *et al.* 2010a). The diversity of dolphins is particularly important around Mayotte, and several species are resident, especially Indo-Pacific bottlenose and humpback dolphins, spinner dolphins, pantropical spotted dolphins and the melon-headed whale.

Other oceanic species also occur, such as Risso's dolphin, short-finned pilot whale, Fraser's dolphin (*Lagenodelphis hosei*), false killer whale (*Pseudorca crassidens*), killer whale (*Orcinus orca*), pygmy killer whale (*Feresa attenuata*) and common bottlenose dolphin (Kiszka *et al.* 2010b). In addition, two other species have been recorded but are considered as very rare in the area: the rough-toothed dolphin and the striped dolphin (*Stenella coeruleoalba*) (Kiszka 2010). Dugong occur in small numbers in the lagoon although this species has declined since the early 80's due to hunting and as bycatch in several fisheries. Probably less than 10 individuals are present throughout the lagoon currently (Kiszka *et al.* 2007b; Pusineri *et al.* 2013).

Preliminary abundance estimates obtained from aerial surveys suggest a total number of 41 Indo-Pacific bottlenose dolphins (95% CI 30-67), 703 spinner dolphins (95% CI 643-1,046) and 375 pantropical spotted dolphins (95% CI 342-557) (Kiszka 2010). Using photo-identification data from 2004 to 2008, estimated annual abundances of bottlenose dolphins ranged from 47 ± 18 to 98 ± 50 individuals, suggesting low population size across its range around the island (estimated population home range is 978 km^2, Pusineri *et al.* 2014). Reef banks off north and north-eastern Mayotte (Iris, Zélée and Geyser banks) have been surveyed in 2002 and 2003, especially to evaluate the density and group composition of wintering humpback whales. The densities of humpback whales ranged from 0.027 to 0.618 whales/nm^2 across three reef banks. Females with calves were the most frequently encountered group type. Encounter rates ranged from 0.98 to 2.36 groups per hour of search effort. These results confirm that the eastern region of the Comoros may be an important area for humpback whales during the late austral winter months (Ersts *et al.* 2011a). Other cetacean species recorded in the shallow waters of these banks, including spinner, spotted dolphins and (only on Iris) Indo-Pacific bottlenose dolphins (Ersts *et al.* 2011a).

Aside from Mayotte, very little is known on the diversity and occurrence of marine mammals around the other French dispersed islands (*îles éparses*) in the Mozambique Channel (Europa, Bassas da India, Juan de Nova, Glorieuses and Tromelin). Dugong are absent around these isolated

False killer whales. (Photo: Jeremy Kiszka) islands. In 2009, a survey recorded 11 cetacean species in the surrounding waters of these islands (Doremus *et al.* 2009). The spinner dolphin appears the most common species in the inshore waters of Juan de Nova and Glorieuses islands. However, the common bottlenose dolphin was the most frequently encountered species in the offshore waters of Juan de Nova. Around Europa, two species of large whales were recorded: the fin whale (*Balaenoptera physalus*) and the sperm whale (Doremus *et al.* 2009). Strandings have also been reported from the French dispersed islands: a Risso's dolphin and a Cuvier's beaked whale on Juan de Nova, and a dwarf sperm whale on Grande Glorieuse (Doremus *et al.* 2009). The pygmy sperm whale has also been reported from Tromelin Island, off north-eastern Madagascar (Chantrapornsyl *et al.* 1991).

Madagascar

A review of marine mammal diversity indicates the presence of 27 species (Rosenbaum 2003). Some species (especially pinnipeds) are vagrants, such as the crabeater seal (*Lobodon carcinophagus*) and the subantarctic fur seal (*Arctocephalus tropicalis*) (Garrigue & Ross 1996; Rosenbaum, 2003). Baleen whales have been identified, including blue whale, fin whale, pygmy right whale (*Caparea marginata*) and southern right whale. However, the humpback whale appears to be the most abundant species (Rosenbaum 2003). Each year, during the austral winter, a large number of humpback whales aggregate on the known breeding grounds along the southeast coast, especially between Cap Sainte Marie south of Tolagnaro and Antongil Bay (Rosenbaum *et al.* 1997; Ersts & Rosenbaum 2003; Vahoavy 2003) and along the west coast (Cerchio *et al.* 2009; Benbow 2008). Other species recorded include four beaked whale species, pygmy and dwarf sperm whales and at least 10 delphinid species (Rosenbaum 2003).

Indo-Pacific bottlenose and humpback dolphins are the most common species of the 20 odontocetes present and are predominantly distributed along the west and north-east coasts (Cockcroft & Young, 1998; Rosenbaum, 2003; Razafindrakoto *et al.* 2004; Cerchio *et al.* 2009). Between 2004 and 2007, small vessel-based cetacean surveys were undertaken in the southwest region of Madagascar (covering approximately 60 km of coastline; Cerchio *et al.* 2009). Eight dolphin and two baleen whale species were recorded. The encounter rate of humpback whales is high during the breeding season, indicating that the region is an active breeding area (Cerchio *et al.* 2009). Since 2007, new small vessel-based surveys have been done in the northwest, especially in the Nosy Be region. Encounter rates and group size of coastal dolphins (particularly *T. aduncus* and *S. chinensis*) were significantly higher than in the south-western region. Initial interviews with local fishermen highlighted that dolphins were not hunted around Nosy Be, which may explain the higher occurrence of dolphins in the northwest (Cerchio *et al.* 2009).

The dugong is known to occur in Madagascar but its status remains unclear (WWF EAME 2004). However, in late 2009, during a dedicated aerial survey, seven dugong sightings were recorded in the northwest region (Ridoux *et al.* 2010; Muir & Kiszka 2012). The northwest coast of Madagascar is suspected to be an important area for dugong in the SWIO, but more quantitative surveys are needed to assess the distribution and abundance of this species.

Abundance estimates exist for two large whale species migrating off Madagascar: humpback whale and blue whale (presumably *B. m. brevicauda*) (Best *et al.* 2003). The population size of blue whales on the Madagascar Plateau was estimated between 424 (CV=0.42) and 472 (CV=0.48) (Best *et al.* 2003). An estimate of 2,532 (CV=0.27) humpback whales resulted from a yacht-based survey conducted in 1994 off southern Madagascar (Best *et al.* 1996). Johnston & Butterworth (2005) extrapolated this estimate up to 6,172 whales in 2003 using the preliminary increase rate based on the observations conducted from Cape Vidal, in South Africa. A mark-recapture model for Antongil Bay (NE coast) produced an estimate of 1,746 for the period 1996-1999. A subsequent abundance estimate of 8,325 (95% CI 2,323-14,328) humpback whales migrating in this bay was proposed for the periods between 2000 and 2006 (IWC, 2009).

Seychelles

The Seychelles Archipelago, including the Amirantes and Aldabra, was an important whaling ground for American whalers during the 19th Century (Wray & Martin, 1983). Leatherwood *et al.* (1984) reported the presence of sperm whales (including over the Seychelles Bank, east of Bird Island), spinner dolphins and bottlenose dolphins in Seychelles waters. Robineau (1991) recorded Bryde's whales offshore, west of the Seychelles, as well as blue and fin whales. Cetacean sightings and related environmental features were recorded during a NOAA survey (not targeting cetaceans) in 1995 covering a wide area of the western Indian Ocean, including oceanic waters of the Seychelles (Ballance & Pitman 1998). The most common species observed in this area were, in order of occurrence: sperm whales, spinner dolphins, striped dolphins, bottlenose dolphins and pilot whales (unspecified species, but likely short-finned pilot whale). Other species have been observed, including rough-toothed dolphins, dwarf sperm whales, pygmy sperm whales, melon-headed whales, pygmy killer whales and beaked whales (*Mesoplodon* spp). Longman's beaked whales have been recorded on several occasions in the Seychelles (Anderson *et al.* 2006). Off the atoll of Aldabra, opportunistic sightings have been collected for the period 1973-2007 by field workers. A total of 14 species of marine mammals was reported, including humpback whales (during austral winter), spinner dolphins, common bottlenose dolphins, short-finned pilot whales and the dugong. A total of 28 species has been recorded for the entire Seychelles' waters (Hermans & Pistorius 2008).

The dugong occurs in small numbers at Aldabra atoll (WWF EAME 2004). Subsequent changes in dugong numbers at Aldabra remains unknown (Hermans & Pistorius 2008). A recent study indicates that the most suitable dugong habitat is located in the central western area inside the atoll (Hamylton *et al.* 2012).

La Réunion

Ten species of cetaceans have been recorded around La Réunion (Dulau-Drouot *et al.* 2008). Dugong and pinnipeds are not present around the island. A few vagrant pinnipeds, such as the southern elephant seal (*Mirounga leonina*) and the subantarctic fur seal have been observed as strandings (V. Dulau-Drouot, personal communication). The most common species of cetaceans are the Indo-Pacific bottlenose dolphin, the spinner dolphin, the common bottlenose dolphin and the pantropical spotted dolphin (Dulau-Drouot *et al.* 2008). Indo-Pacific bottlenose dolphin show a high degree of site fidelity close to shores, especially on the west coast (Baie de Saint Paul, Saint Leu; Dulau-Drouot *et al.* 2008). Oceanic species are also observed occasionally, especially the melon-headed whale, the short-finned pilot whale and the Fraser's dolphin. Every austral winter, humpback whales aggregate to breed. During 2004-2010, surveys were conducted in the coastal waters of La Réunion, suggesting an increasing occurrence of humpback whales since 2007. In addition, between-year recaptures were reported for 2009-2010, with five individuals re-sighted on consecutive years (Dulau-Drouot *et al.* 2012). The southern right whale (three sightings) and the Bryde's whale (one stranding) have also been recorded around the island but they appear to be very rare (Kiszka *et al.* 2008a).

Mauritius

Early cetacean records mention the presence of the Blainville's beaked whale around Mauritius (Michel & Van Bree 1976). Corbett (1994) provided the most detailed study on the diversity and occurrence of cetaceans off the island. This report documents the presence of 13 cetacean species in the waters of Mauritius. The spinner dolphin (in inshore waters) and the sperm whale (offshore) were the most commonly encountered species. Other species that have been recorded include blue whales, humpback whales during austral winter and fin whales. Odontocete species include the pantropical spotted dolphin, Indo-Pacific bottlenose dolphin, common bottlenose dolphin, short-finned pilot whale, striped dolphin, Risso's dolphin, pygmy killer whale and melon-headed whale (Corbett 1994). Indo-Pacific bottlenose dolphins are also commonly encountered in coastal waters and occur in sympatry with spinner dolphins, particularly off the west coast such as in the Bay of Tamarin (Cadinouche *et al.* 2010). Population estimates of these two species have been produced using mark-recapture analyses. Abundance estimates of spinner and Indo-Pacific bottlenose dolphins are of 432 (95% CI 426-462) and 68 (95% CI 67-80) individuals, respectively (Cadinouche *et al.* 2010). These two species are targeted by an important dolphin watching tourism industry.

MIGRATORY ROUTES AND POPULATION STRUCTURE OF MARINE MAMMALS

Very little is known about the migration routes and population structure of marine mammals in the SWIO except for a limited number of species of large whales, particularly the humpback whale. Some studies have also been conducted on genetic population structure of the Indo-Pacific bottlenose dolphin (Natoli *et al.* 2008; Särnblad *et al.* 2011), Indian Ocean humpback dolphin (Mendez *et al.* 2011) and the spinner dolphin (Ceyrac 2011).

All balaenopterids (except the Bryde's whale) are known to undertake seasonal migrations between their breeding grounds during austral winter and their polar feeding grounds during summer. Humpback whales regularly congregate in nearshore waters and over banks, shoals and offshore reef systems during the breeding season (Dawbin 1966; Balcomb & Nichols 1982; Whitehead & Moore 1982). The IWC (International Whaling Commission) Scientific Committee recognizes seven breeding grounds and migratory corridors (termed as breeding stocks A to G) in the Southern Hemisphere (IWC 2007). In the SWIO, four sub-stocks are currently recognised based largely on distributional evidence and catch histories (Best *et al.* 1998): 1) an East African corridor which is parallel to the South African to Mozambican coasts (termed as C1 by the IWC), 2) Central Mozambique Current corridor to Comoros Archipelago (C2), 3) Madagascar Ridge corridor (C3; Figure 1) and the Mascarene Islands (C4). Analyses of mtDNA population structure and migration rates confirmed the high gene flow within the SWIO region, as well as with wintering grounds in the south-eastern Atlantic. A low gene flow has been found between the south-western and northern Indian Ocean wintering grounds (Rosenbaum *et al.* 2009). Photographic

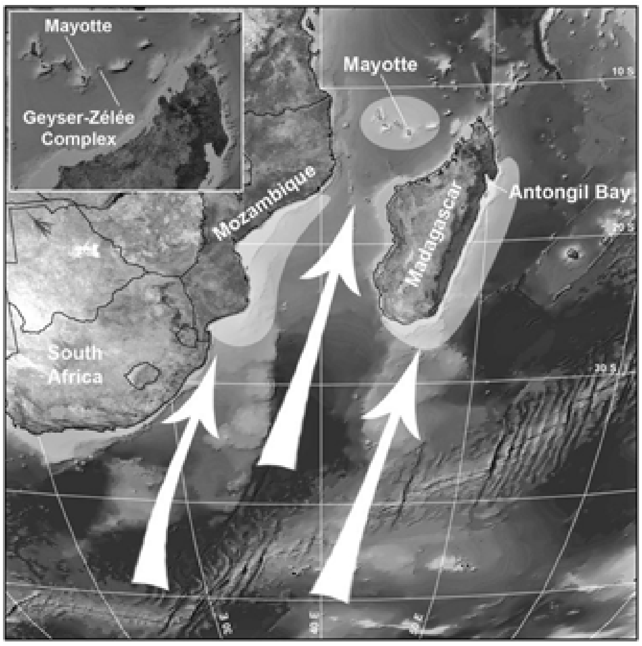

Figure 1: Relationship of sampling sites, migratory routes proposed by Best *et al*. (1998), and the general extent of the current management units recognized by the International Whaling Commission (from Ersts. 2011b).

and genetic evidences also confirmed regular movements of humpback whales within the SWIO region, especially between C2 (Mayotte, in the northern Mozambique Channel) and C3 (Antongil Bay, in north-eastern Madagascar; Ersts *et al.* 2011b). Refinement of humpback whale stock definitions has been a major objective of the IWC during the past decade, as early stock boundaries were shown to be poorly founded with respect to defining biological units.

In 2011 and 2012, 11 satellite transmitters were deployed on wintering humpback whales in the Comoros Archipelago (breeding stock C), including Mohéli and Mayotte (Fossette *et al.* 2014). Eight individuals were successfully tracked for 24.3 ± 12.4 days (range= 8-49 days) and travelled between 146 km and 5804 km in total. Whales either remained at their tagging site for several weeks (n= 3) or dispersed along the west coast (i.e. breeding sub-region C2, n= 4,) or east coast (i.e. breeding sub-region C3, n=1) of Madagascar. Two individuals travelled along relatively straight paths to distant, potential, foraging areas. One whale reached the French subantarctic islands while the other travelled to IWC foraging area III, one of the supposed Antarctic foraging areas for humpback whales of this breeding stock. This is the first time movements of humpback whales from this breeding stock have been described and their potential foraging areas in the Southern Ocean identified. Such dispersal pattern may have important implications for population estimates and for revising the definition of breeding regions established by the International Whaling Commission (Fossette *et al.* 2014).

In the Southern Hemisphere, a genetic (mtDNA) comparison of southern right whales from wintering grounds in Argentina, South Africa, Australia and New Zealand demonstrated differentiation between all wintering grounds (Patenaude *et al.* 2007). Whereas the most significant wintering ground for right whales is located off the south coast of South Africa in the SWIO, updated records provide indications of the existence of other migratory routes. Sightings of right whales were reported further north of the known distribution range; sightings were made off La Réunion, Mauritius and Madagascar. The north-eastern waters of Madagascar may have the northernmost sighting of this species in the western Indian Ocean (Rosenbaum *et al.* 2001). Right whale records in other areas of the SWIO may indicate the existence of former wintering grounds in the region, and that the increasing abundance of right whales may now allow rediscovering their past distribution and migration routes.

Two subspecies of blue whales are currently recognised in the Indian Ocean: the Antarctic blue whale (*B. m. intermedia*) and the pygmy blue whale (*B. m. brevicauda*). Antarctic blue whales are mainly found south of 60°S in summer. Their wintering grounds are not known, but whaling records suggest they may occur (at least young individuals) in the tropical area, such as south of the Mascarenes, off the southeast coast of South Africa or off southern Madagascar. Conversely, pygmy blue whales seem to occur further north in summer (~55°S), and move north to Madagascar and the Seychelles (Amirantes) in winter (Zemski & Sahzinov 1982; Best *et al.* 2003).

The migrations and movements of fin and sei whales are, like for blue whales, quite poorly known, primarily because their movements are oceanic (vs. coastal for humpbacks and rights). In summer, sei whales occur between the subtropical convergence and the Antarctic convergence (40-50°S). Fin whales are found further south during summer, essentially between 50 and 60°S. Both species migrate north to temperate and tropical waters. However, almost nothing is known on the location of their wintering grounds (Best 2007).

Investigation on small cetacean population structure has been undertaken for the three most coastal dolphin species in the SWIO: Indo-Pacific bottlenose dolphin, humpback dolphin and spinner dolphin. In South Africa, two coastal Indo-Pacific bottlenose dolphin populations have been identified along the coast of KwaZulu-Natal, one north and another south of Ifafa (Natoli *et al.* 2008). The low genetic diversity found in these two populations makes them particularly vulnerable to bycatch in the protective shark nets located along the KZN coast. The taxonomic status of *Tursiops* is under revision and genetic analyses have suggested that *T. aduncus* in the western Indian Ocean, (off South Africa and Zanzibar) and in the western Pacific Ocean (off China/Indonesia and Australia) should be classified as separate species (Natoli *et al.* 2008; Särnblad *et al.* 2011). Särnblad *et al.* (2011) suggested that the dolphins found off Zanzibar should be classified as *T. aduncus* alongside the South African animals. Analyses of genetic differentiation showed significant separation between the *T. aduncus* found off northern and southern Zanzibar despite the relatively short distance (approximately 80 km) between these areas (Särnblad *et al.* 2011).

Around Mayotte, the genetic population structure of *T. aduncus* has been assessed using mtDNA and 14 microsatellite markers (Kiszka *et al.* 2012). The analyses revealed no mitochondrial polymorphism and the presence of a single population. Photo-identification and stable isotope analyses (δ13C and δ15N) were also performed to reveal population substructure. Home range analysis revealed the presence of at least two communities of bottlenose dolphins around Mayotte: one occurring in the shallower waters inside the lagoon and a second in the vicinity of a deeper reef bank, situated further offshore in the northern part of the island. It has been suggested that intra-species niche partitioning may be a major driver of habitat segregation within this population (Kiszka *et al.* 2012).

An analysis of population structure and migration patterns of humpback dolphins using mitochondrial DNA data from 94 individuals from the coasts of South Africa, Mozambique, Tanzania and Oman, has been undertaken (Mendez *et al.* 2011). The genetic data were combined with 13 years of remote sensing oceanographic data of variables known to influence cetacean dispersal and population structure. This study showed strong and highly significant genetic distinction between all putative populations, except for those in South Africa and Mozambique (Mendez *et al.* 2011).

A quite similar pattern of fine-scale genetic population structure has also been found in the spinner dolphin in the SWIO, using samples from Zanzibar, Mayotte and La Réunion (Ceyrac 2011). MtDNA control region sequences and microsatellite markers (12 loci) were combined in this study. The main results highlighted a decreasing genetic diversity, from the continental coast of East Africa (Zanzibar) to the oceanic and remote island of La Réunion (Mascarenes).

Relationships with fisheries

Two types of interactions may occur between marine mammals and fisheries: biological interactions and operational interactions. Biological interaction includes trophic competition between these organisms and fisheries, where both marine mammals and fisheries exploit (at least partially) the same resources. Conversely, operational interactions include direct interaction between marine mammals and fisheries; including incidental catches in fishing gears and depredation (when marine mammals take advantage of fisheries by extracting caught fishes and baits). We only describe operational interactions between marine mammals and fisheries, especially bycatch and depredation. As some dedicated marine mammal hunting occurs in the Southwest Indian Ocean, a section is dedicated to describe the extent of this activity in the region, particularly along the west coast of Madagascar.

BYCATCH IN COASTAL FISHERIES

South Africa (KwaZulu-Natal region)

Fisheries in South Africa are highly diversified, including coastal artisanal to oceanic industrial fisheries. Along the east coast of southeast Africa, the major marine mammal bycatch problem has been reported in anti-shark nets in the KwaZulu-Natal region. The affected area stretches from Mzamba to Richards Bay (Cockcroft 1990). Today, nets cover 23 km of coastline out of a total of around 320km, and are managed by the KwaZulu-Natal Sharks Board (www.shark.co.za). Individual nets are 212m long and 6.1m deep, with a 25.5cm bar mesh and are anchored at each end. Main marine mammal bycatch comprises the Indo-Pacific bottlenose dolphin, humpback dolphin and common dolphin (Cockcroft 1990). On average, 76 (range 36-175) dolphins are taken as bycatch every year, of which 46% are common dolphins, 42% are bottlenose dolphins and 8% are humpback dolphins (Peddemors *et al.* 1998; Best 2007). Periodically whales become entangled in anti-shark nets, including minke, humpback and southern right whales (Cockcroft & Krohn 1994). On average 5.6 whales are trapped this way annually (Best *et al.* 2001). However, events of entanglements do not all result in whales' deaths as 75% are released alive from these nets. It should be noted that South Africa is replacing many of the shark nets with baited drumlines, which do not have a problem with marine mammal bycatch. Monitoring of southern right whale mortalities related to a diversity of anthropogenic factors was conducted between 1963 and 1988 off South Africa. Scarring from entanglement that appears as white lines was seen on the peduncle at the base of most of the photographed individuals' flukes (Best *et al.* 2001).

Mozambique

Entanglement in gillnets appears to be the main human-induced cause of dugong mortality along the entire coast and the level of this threat has augmented since the early 1990s as gillnet use has increased (WWF EAME 2004). Interview surveys with fishers have confirmed that humpback dolphins are also caught in the drift gillnet fishery (Guissamulo & Cockcroft 1997). However, the impact of gillnet entanglement on marine mammals is unknown in Mozambique.

Tanzania (including Zanzibar)

Cetaceans have been recorded as bycatch in gillnets at sites around Unguja Island, in the Zanzibar Channel and along the coast of northern Tanzania (Amir *et al.* 2002). The level of dolphin bycatch in the artisanal gillnet fishery has been investigated using a questionnaire-based survey with 101 gillnet vessel operators from 10 villages around Zanzibar (Amir *et al.* 2002). A total of 96 dolphins was reported to have been incidentally caught between 1995 and 1999: 43 Indo-Pacific bottlenose dolphins, 29 spinner dolphins, 5 Indian Ocean humpback dolphins and 19 unidentified dolphins. This study suggests that incidental capture of delphinids in the Zanzibar gillnet fishery may be high enough to negatively impact local populations (Amir *et al.* 2002). The high level of bycatch on the northern side of Zanzibar seems to be related to the high fishing effort in this zone. A study was also conducted to evaluate the magnitude of bycatch in the south-western coast of Zanzibar during 2003 and 2004 (Amir 2010). Data collected by on-board observers indicated high levels of capture compared to the small population size of the humpback and bottlenose dolphins. The annual bycatch rates represented mortality of 9.6% and 6.3% for Indo-Pacific bottlenose and humpback dolphin populations respectively. These rates indicated serious cause of concerns for the population of these two coastal species (Amir 2010).

During questionnaire surveys conducted in April 2007 and February 2008 in Mtwara, where 64 fishers were interviewed, 23% of the fishers had personally caught a dolphin (Indo-Pacific bottlenose, spinner, humpback and Risso's dolphins) in gillnets. However, even respondents who had not personally caught a dolphin still cited gillnets as a major threat. Indo-Pacific bottlenose dolphins were most frequently identified as the species caught, although spinner dolphins were also cited as being caught, particularly in offshore gillnets (Institute of Marine Science, unpublished data). Dolphins have also been recorded as bycatch in Pangani, Temeke, Rufiji and Kilwa (SeaSense, unpublished data).

Dugong bycatch is still frequent in Tanzania; 26 individuals (adults, juveniles and cow-calf pairs) were reported as bycatch from 2000 to 2004 (Muir & Kiszka 2012). These incidental captures mostly occurred in the Rufiji Delta and off Kilwa (WWF EAME 2004). Fishers also report incidental capture of humpback whales in gillnets every year, although these are generally cut free. Dead humpback whales have been found stranded on beaches, still entangled in gillnets (Kiszka *et al.* 2008a).

Kenya

Little is known about any marine mammal bycatch along the coast of Kenya. Incidental catches of dugongs in gillnets and trawls were reported during interview surveys conducted in 14 villages in 2003 (WWF EAME 2004). Cetacean bycatch is currently undocumented, but is expected to occur in areas where gillnets are used (e.g. Bofa, Tenewi Ziwayuu and

Manda regions; Kenya Marine & Fisheries Research Institute, unpublished data). Occasional reports document dolphin bycatch off Kenya, involving Indian Ocean humpback and Indo-Pacific bottlenose dolphins (Kenya Marine & Fisheries Research Institute, personal communication). Although the extent of marine mammal bycatch in Kenya is unknown, it could potentially be considerable due to the extensive use of gillnets (Kiszka *et al.* 2008a).

Union of the Comoros

Cetacean bycatch is considered to be very low around the Comoros. From recent interview surveys, spinner dolphin seems to be the most frequent bycatch species. Bycatch species may also include bottlenose dolphin, humpback dolphin (this species has still not yet been formally recorded around the Comoros; Kiszka *et al.* 2010a) and Risso's dolphin (Poonian *et al.* 2008). Artisanal longline is the primary gear responsible for cetacean bycatch although the extent of cetacean bycatch seems very low, and available information is only based on interview surveys. In addition, these data seem to be biased by species misidentification, as some species that were identified as bycatch that have never been recorded around the Comoros (Poonian *et al.* 2008). In contrast, dugong bycatch has been reported in the Comoros, especially in the marine park of Mohéli, where the species is mainly to be found. The fishing method involved in these catches is gillnetting. No quantitative information exists on the scale of dugong bycatch in the country, even though dugong bycatch occurs regularly (Kiszka *et al.* 2008a).

Mayotte, French dispersed islands

Dugong bycatch and deliberate hunting has been recorded around Mayotte, but has declined in recent decades due to the reduction in numbers of this species (Kiszka *et al.* 2007b; Pusineri *et al.* 2013). Incidental catches in seine nets are likely very rare. During an interview survey in 2007 (n=406), only ten fishers declared that they had caught a cetacean (all were dolphins) and eight of the animals were released alive. Of these ten dolphins, four were caught by net, three by hand line and three by longline (Pusineri & Quillard 2008) and species involved were thought to be Indo-Pacific bottlenose, spinner and spotted dolphin. There is evidence for interactions between Indo-Pacific bottlenose dolphins and the hand line fishery, as well as between short-finned pilot whales (and possibly melon-headed whales) and the pelagic longline fishery. Injuries on the dorsal fin region have been documented in these species, and would likely be due to interactions with these fisheries (Kiszka *et al.* 2008b). Remains of gillnets have also been observed on humpback whales migrating to Mayotte on several occasions although no mortalities have been observed to date (Kiszka *et al.* 2008a). Overall, based on the small numbers reported it is considered that the current bycatch of cetaceans in Mayotte is likely to have a negligible impact on these species. No information on bycatch is available around the French dispersed islands, especially as fishing is restricted to pelagic fisheries, in which marine mammal bycatch appears anecdotal.

Madagascar

Marine mammal bycatch has been reported to occur in commercial, artisanal and traditional fisheries (*Direction des Pêches et des Ressources Halieutiques*, unpublished data), although accurate quantitative data are lacking. Gillnets were reported to incidentally capture dolphins, whales and dugongs off many villages in the north-eastern, south-western, western and north-western coastal zones (Andrianarivelo 2001; Kiszka *et al.* 2008a; Razafindrakoto *et al.* 2004). A project was initiated in 2005 to evaluate the extent of bycatch in artisanal fisheries in the south-western region of Madagascar. A total of 111 interviews was analysed which indicated 56 bycatch events in these villages between 2000 and 2005. Indian Ocean humpback, Indo-Pacific bottlenose, spinner, Fraser's dolphins and humpback whales have been reported as bycatch in gillnets (Andrianarivelo 2001; Razafindrakoto *et al.* 2004). Bottlenose and spinner dolphins represented 48% and 32%, respectively, of the total cetacean bycatch between 2000 and 2005 (Razafindrakoto *et al.* 2008).

Seychelles

No marine mammal catch has been formally recorded as bycatch in coastal fisheries of the Seychelles (Kiszka *et al.* 2008a), although incidental captures may occur in the semi-industrial pelagic longline fishery, where large delphinids (primarily *G. macrorhynchus* and *P. crassidens*) regularly depredate lines (Rabearisoa *et al.* 2010).

La Réunion

There is a minimal incidence of cetacean bycatch reported around La Réunion. Bycatch has been mainly recorded in the gamefish sport-fishery that uses troll-line (Kiszka *et al.* 2008a). Predation in the longline fishery is known to occur with Risso's dolphins (on bait), false killer whales (on catches) and short-finned pilot whales (on both baits and catches), but very few cases of bycatch of this species were reported (J. Bourjea, personal communication). Capture of Indo-Pacific bottlenose dolphin in beach-seine nets is also reported, although this appears to be a rare event. Hook injuries and dorsal fin disfigurements due to fishing lines have been recorded in spinner, Indo-Pacific bottlenose and common bottlenose dolphins; however, no mortalities have been documented to date (Dulau *et al.* 2007).

Mauritius

No cetacean bycatch information has been published for Mauritius (Kiszka *et al.* 2008a).

BYCATCH IN OCEANIC FISHERIES (LONGLINE, PURSE-SEINE)

Two of the major fisheries that occur in the SWIO are purse-seining and longlining. Information on marine mammal bycatch in these oceanic fisheries is very scarce and is mostly anecdotal (IOTC, 2007). Nevertheless, indications are that marine mammal bycatch in this fisheries sector is very low. Since 2007, there has been a reduction in the tuna fleet, for economic and piracy reasons, suggesting a probable further decline in cetacean fisheries interactions. In contrast, the eastern tropical Pacific (ETP), purse-seining caused the decline of several dolphin species, especially spinner dolphin and pantropical spotted dolphin, which still have not recovered (Gerrodette & Forcada 2005). Bycatch in the ETP is due to dolphin-tuna (yellowfin *Thunnus albacares*) associations, whereas these interactions appear rare in the SWIO. However, large whales (*Balaenoptera* spp) do associate with tunas in the western Indian Ocean. A single purse-seine bycatch of a sei whale has been reported by Romanov (2001). According to IOTC (Indian Ocean Tuna Commission), the extent of marine mammal bycatch is insignificant in the oceanic purse seine fisheries (IOTC 2007); although this statement should be confirmed with on-board fisheries observer data before it is fully accepted.

Bycatch records of marine mammals in the pelagic longline fishery have been anecdotally reported. Around the island of Mayotte (NE Mozambique Channel), there is evidence of interaction between oceanic delphinids and the longline fishery, especially short-finned pilot whales, as non-lethal injuries on the dorsal fin have been observed on several individuals (Kiszka *et al.* 2008b). Between 2009 and 2010, an observer programme in the longline fishery around Mayotte recorded only one marine mammal (false killer whale) bycatch in the pelagic longline fishery. The animal was released alive (Kiszka *et al.* 2010c). Another bycatch has been mentioned from the longline fishery off La Réunion, involving a Risso's dolphin (Poisson *et al.* 2001).

Spinner dolphins. (Photo: Jeremy Kiszka)

TARGETED CAPTURE OF MARINE MAMMALS

Regional overview

Direct exploitation of marine mammals occurred in the past (generally prior to the 1990s) in the coastal zones of several countries of the SWIO. Marine mammals were targeted for bait and for direct consumption. The most commonly hunted species was probably the dugong, especially along the east coast of Africa, including Madagascar, Comoros and Mayotte (see for review WWF EAME 2004; Muir & Kiszka 2012). Deliberate hunting of dugong has declined in recent decades due to the reduction in numbers of this species (Kiszka *et al.* 2007b). Now, this species is very rare throughout the region, probably due to the combined effect of direct hunting and bycatch in gillnets (WWF EAME 2004; Muir & Kiszka 2012). Actually, dugong hunting is presently very rare in the region, although two individual dugongs were hunted off the west coast of Madagascar in 2008 (Y. Razafindrakoto, personal communication). When taken as bycatch, animals are indeed consumed as dugong meat is still very appreciated by fishermen, especially in Madagascar. Similarly, dugong are a desired source of meat in parts of Mozambique where targeting around Inhaca Island has been reported (WWF EAME 2004).

Several species of small delphinids were targeted until the mid-1990s off the south coast of Zanzibar, including bottlenose, humpback and spinner dolphins, both for bait (longline) and human consumption. This activity likely reduced the local dolphin populations. However, the hunt was gradually replaced by dolphin-oriented tourism beginning in 1992 (Amir 2010). In the Seychelles, although the national legislation prohibits the capture of cetaceans, it has been estimated that hundreds of dolphin were annually caught by local schooners at the edge of the Seychelles plateau (de Lestang 1993). Several local scientists reported the elusive behaviour of dolphins around the northern islands of the Seychelles, which could be a result of harassment of dolphins by fishers (M. Vely & D. Rowat, personal communication).

Madagascar

Dolphins are opportunistically hunted by fishermen in the coastal waters of Madagascar for local consumption and sale of meat, especially in the south-western region, around Anakao (Andrianarivelo, 2001; Razafindrakoto *et al.* 2004; Cerchio *et al.* 2009). Interviews of fishermen from the village of Anakao suggest that over 6,000 individuals were killed between 1985 and 2000, with 57% of takes occurring after 1995 (Cerchio *et al.* 2009). Species most impacted were spinner, Indo-Pacific bottlenose and humpback dolphins, all having a strong coastal distribution and thus vulnerable to hunting (Andrianarivelo 2001). In 2005, a drive hunt of 100-200 spinner dolphins was reported, supporting the figures reported in the interviews. Interview surveys indicated that while there was some bycatch in coastal fisheries, it was likely much less damaging than the directed hunts reported (Cerchio *et al.* 2009).

DEPREDATION

Depredation is defined as the removal of fish from fishing gear by sharks, cetaceans and other marine predators (e.g. pinnipeds); as opposed to predation, which is the capture of free ranging fish (Gilman *et al.* 2006). The extent of depredation on longline catches throughout the Indo-Pacific has been summarized by Nishida & Shiba (2005) and Nishida (2007). Depredation by predators on pelagic and bottom longlining is a global issue that can have negative impacts both for the species and the fishing industry (Rosa & Secchi 2007). False killer and short-finned pilot whales are the known cetacean species involved in depredation in the tropical waters of the SWIO, while the killer whale is involved in depredation events off South Africa (Petersen & Williams 2007). In addition, Risso's dolphin and common bottlenose dolphins have been identified as responsible for bait depredation (P. Bach, personal communication). Previous observations on depredation related this phenomenon with the specific features of bottom topography such as seamounts, shoals and semi-closed sea areas. Although cetacean depredation is sporadic, its impact can be significant to the landings of the fishing industry. While the magnitude of the depredation remains poorly understood, including any impact on the mammal itself, we summarized the known depredation status in the waters of the SWIO.

South Africa

The main fishing areas targeting swordfish and tuna include the South African EEZ, the southern Atlantic and Indian Oceans. Monitoring of depredation was conducted between 2002 and 2007 for the longline fishing industry; these surveys indicated that killer whales are the principal predator interacting with longline fisheries in this region (Petersen & Williams 2007). These killer whale interactions predominantly occurs on the Agulhas Bank and along the continental shelf toward Port Elizabeth. The study evaluated the loss of 561 fish from 116 longline sets in which killer whales were interacting, 83% of these were swordfish, and 10-20% depredation occurred in the sets deployed (Petersen & Williams 2007). There is also evidence of depredation on the catches made by small-scale commercial line fishers. Garratt (1980) reported localised but intense depredation by bottlenose dolphins on linefish catches in southern KZN, suggesting that local *Tursiops* schools had learned this behaviour and become habituated so as to impact substantially on the livelihood of the fishers at certain sites.

Seychelles

The semi-industrial longline fisheries grew rapidly between the period of 1995 and 2001. However, since 2001, these fisheries have declined as fishermen encountered economic losses due to depredation and, more recently, piracy. Depredation rates of up to 25% were reported annually for yellowfin tuna within Seychelles waters. The main target of this semi-industrial fishing industry is swordfish even though tuna are also exploited in these small commercial fisheries. Cetaceans involved in the depredation are mainly short-finned pilot whales and false killer whales (Romanov *et al.* 2010). The highest depredation rate occurred in areas of the highest swordfish CPUE, suggesting that cetaceans congregate in areas of high swordfish abundance. The proportion of sets with cetacean depredation was about 16% which represented an average 60% of the fish caught. Economic loss was estimated at 340€/1,000 hooks which equates to about 1,000,000€ over the 1995-2006 period (Rabearisoa *et al.* 2007). Recent fishing operations around Mahé plateau show a higher depredation level attributable to cetaceans (20%) and to sharks (51%). GLM analysis demonstrated that deeper set longlines reduce the risk of depredation by sharks, while longer soaking period increases risk of depredation overall (Romanov *et al.* 2010).

La Réunion and Mayotte (France)

Pelagic longlining was first developed after the introduction of this type of fishery in 1990s off Réunion Island (France). The main fishing area includes the south-western and western equatorial waters of the Indian Ocean. The evaluation of depredation was conducted for small-scale commercial fisheries between 1997 and 2000. False killer and short-finned pilot whales were the main identified depredators interacting with longline fisheries during the surveys. An average of 4.3% (80t) of the annual swordfish catch was damaged by cetaceans, representing a rate of catch loss between 3.7% and 5.5% (Poisson *et al.* 2007). Furthermore, the interaction also occasionally damages the fishing gear. Three juveniles of dolphins (species unknown) were incidentally captured and released alive during the surveys conducted between 1997 and 2000. A scientific survey in the framework of *IOSSS-Espadon* was conducted in July 2010 off La Réunion to assess the stock of swordfish. However, depredation by pilot whales was not observed during this survey (Le Couls *et al.* 2010).

Around Mayotte, depredation impact on catches in the local small-scale longline fishery seems only marginally important (3.7% of whole fish production). It involves false killer and short-finned pilot whales, but also common bottlenose and spinner dolphins depredating on baits (Kiszka *et al.* 2010c).

Mitigation measures

BYCATCH

Several mitigation measures have been investigated and some implemented to reduce marine mammal bycatch in the SWIO, especially in South Africa and more recently off the south coast of Zanzibar. Off the coast of KwaZulu-Natal, considerable experimentation has taken place since the 1980s with low cost devices to reduce the cetacean catch in shark nets (Peddemors & Cocroft 1994; Cliff & Dudley 2011). These included acoustic deterrents (pingers) and air filled floats. Results suggested that these devices do attract the dolphins' attention but do not necessarily alert the dolphin to danger or prevent entanglement. Live dolphins that are caught in anti-shark nets are routinely released. During the sardine run, in winter, the nets are lifted to avoid marine mammal mortality as sardine shoals attract a huge number of top predators, including dolphins and large whales (Best 2007). In a further attempt to reduce bycatch, the authorities have introduced drumline fishing systems instead of nets.

In the early 2000s, a survey using independent observers was conducted off the south coast of Zanzibar (Menai Bay) to estimate coastal dolphin bycatch (essentially *T. aduncus* and *S. plumbea*) in drift- and bottom set gillnets (Amir 2010). The project covered 24% of the fishing effort and the estimated total bycatch represented 9.6% and 6.3%, respectively of the estimated Indo-Pacific bottlenose and humpback dolphins resident in the area (Amir 2010). Consequently, these bycatch levels were not considered sustainable. In 2007 and 2008, another project aimed to assess the efficiency of acoustic alarms (Fumunda FMDP-2000 pingers) in reducing dolphin bycatch. Pingers reduced the bycatch of dolphins in both drift- and bottom set gillnets, however the reduction was only significant in the drift gillnets (Amir 2010). New initiatives are currently underway to extend the use of pingers to reduce dolphin bycatch off Zanzibar (P. Berggren, personal communication).

DEPREDATION

A project has been developed to minimise depredation by marine mammals in the pelagic longline fishery (Rabearisoa *et al.* 2009). The goal of this project was to mitigate and reduce depredation caused by cetaceans (mainly false killer and short-finned pilot whales) on longline-caught swordfish and tunas in the SWIO region. The project aims to test the deployment of physical protection of pelagic longline-caught fish using a device called a *spider.* (Rabearisoa *et al.* 2009). It was concluded that the logistical aspects of deploying this device well exceeded the requirement to deploy large numbers of hooks at an industry standard approaching one hook every six seconds. The spider outperformed, logistically and as a depredation mitigation device, the earlier sock-type of physical protection that fully enclosed the hooked fish. However, the spider device did not function well with large fish. Rabearisoa *et al.* (2010) have experimentally extended this work, including the use of visually reflective devices. However, to date this experimental work has only been tested with coastal Indo-Pacific bottlenose dolphins at Saint-Paul Bay, La Réunion, and not yet with species involved in depredation of longline caught fish.

INDIRECT EXPLOITATION: A WAY TO MITIGATE BYCATCH

The global trend for whale watching and dolphin tourism provides compelling incentives to protect marine mammals. In several locations this aspect of ecotourism generates substantial economic benefits. Examples exist from KwaZulu-Natal, southern Mozambique, Mauritius and elsewhere. Concepts of ecotourism and whale watching were specifically developed with the stakeholders of four villages in the Anakao region of south-western Madagascar, as an alternative to hunting and as a viable source of economic support. Fishermen from these villages officially created an association to protect whales and dolphins through the promotion of ecotourism (Y. Razafindrakoto, personal communication).

Summary, gaps, and recommendations

GAPS AND RECOMMENDATIONS

The SWIO supports a high marine mammal diversity relative to the worldwide scale (30% of known marine mammal species). However, very little is known about the actual distribution and abundance of species, except in some coastal locations: KwaZulu-Natal, Maputo Bay, Bazaruto Archipelago, south coast of Zanzibar, Mayotte, La Réunion, for example. Even less information exists on abundance and distribution of cetaceans in oceanic waters in the SWIO. However, extensive aerial surveys conducted by the University of La Rochelle (UMS Pelagis, France) from December 2009 to April 2010 produced 1,274 effort-related sighting records (with at least 18 marine mammal species recorded; Ridoux *et al.* 2010; Mannocci *et al.* 2014). These surveys provided new information on habitat preferences and spatial variations of the abundance of cetaceans in the region, particularly around the Mascarene Islands, Madagascar, the Seychelles and the Comoros (Mannocci *et al.* 2014). Very limited information on the distribution, abundance and critical habitat of some endangered marine mammal species exists in the region, particularly for *T. aduncus*, *S. plumbea* and *D. dugong.* Therefore, based on this retrospective analysis, further aerial surveys should be implemented, especially along the coast of Kenya (northern area), Tanzania (Rufiji Delta, for example) and the north-west coast of Madagascar, where these regionally endangered species potentially occur and are known to be impacted by fisheries activities. This work could provide critical information to define hotspots of abundance and habitat of these vulnerable species, and focus attention to mitigate threats such as bycatch (through MPA implementation, for example).

As bycatch is probably the most significant threat to marine mammals (especially coastal species), it is urgent to better assess the extent (geographical and numerical) of bycatch in the region, especially in artisanal fisheries. However, a project has been initiated to evaluate the extent of bycatch in multiple gears used in coastal artisanal fisheries (J. Kiszka, unpublished data) and results will be available in due course.

Where the extent of bycatch and marine mammal population boundaries and abundance are well known (Zanzibar, for example), experimental work on mitigation measures should be strongly encouraged (such as acoustic alarm testing).

Except for the recovering humpback whale, almost no information exists on the stock structure of large cetaceans. For several dolphin species (the most coastal and impacted by fisheries), information is now partially available on population structure and boundaries. Available information suggests that coastal cetaceans are best managed at the local scale. However, these population boundaries should be better defined and a regional project on coastal marine mammal population structure and boundaries should be further encouraged, especially using various approaches such as genetic and chemical tracer (stable isotopes, pollutants) analyses.

As depredation is a major issue in the SWIO region, further work to better assess habitat and population characteristics of some deep-water dolphins is critically needed, particularly for *Globicephala macrorhynchus*, *Pseudorca crassidens* and *Grampus griseus*. Future projects should attempt to define hotspots of habitat and abundance of these species in the SWIO, and develop mitigation measures.

VULNERABLE SPECIES AND HOTSPOT DEFINITION

This Retrospective Analysis concludes that marine mammal mortality through fisheries interactions in the SWIO, while not exhaustively studied, is generally low and certainly lower than many other regions of the world. While this is primarily true for offshore regions, there is greater concern for coastal species and fisheries. Through this Retrospective Analysis, it is suggested that three coastal marine mammal species are particularly affected by human activities, including fisheries, and are consequently highly vulnerable:

- *Dugong dugon* (classified as Vulnerable by IUCN, Annex).
- *Sousa plumbea* (still officially classified as Near Threatened under *Sousa chinensis*, but unofficially classified as Vulnerable by IUCN, Annex).
- *Tursiops aduncus* (classified as Data Deficient by IUCN, Annex).

The dugong is probably the most endangered and threatened marine mammal in the SWIO, despite available knowledge on this species, most is empirical and anecdotal (WWF EAME 2004; Muir & Kiszka 2012). Dugongs have progressively declined in most SWIO countries, and the only known viable population is located in the Bazaruto Archipelago, Mozambique (Cockroft *et al.* 2008; Findlay *et al.* 2011). Along the northwest coast of Madagascar, aerial surveys highlighted the existence of a potentially important aggregation of dugong (Ridoux *et al.* 2010), while populations in Mayotte are of uncertain viability (Kiszka *et al.* 2007b; Pusineri *et al.* 2013).

In Zanzibar, Madagascar and South Africa, coastal dolphin bycatch and direct hunting is threatening several species (including those previously cited), and potentially others such as the spinner dolphin. This Retrospective Analysis underlines the fact that these three vulnerable species are patchily distributed in the SWIO region, and that critical attention should be given to the following areas:

- Bazaruto Archipelago (critical area for dugongs in the SWIO, *T. aduncus* and *S. plumbea*).
- Northwest coast of Madagascar (important area for *T. aduncus*, *S. plumbea* and potentially a critical habitat for *D. dugon*, as underlined by a preliminary survey in 2010; Ridoux *et al.* 2010).
- South coast of Zanzibar (critical habitat for both *T. aduncus* and *S. plumbea*, with high bycatch level).

These areas may be considered as hotspots, as they are critical habitat for at least two of the three most vulnerable marine mammal species in the SWIO. It is clear that other areas are also potentially important for these species (for example off Kenya), but need to be further identified in the future, through regional collaboration and the implementation of a regional research project on the status and distribution of the most endangered marine mammals in the SWIO. In the future, a clear priority should be given to the study and management of these three species. For management purposes, stock boundaries should be further investigated (in the frame of this new potential initiative), as management of marine mammal populations is clearly a transboundary issue. Of significance for SWIOFP is the recognition that fisheries development in these sensitive areas needs to be carefully monitored and controlled, and in many cases restricted.

Dugong – probably the most endangered and threatened marine mammal in the SWIO. (Photo: Nils Bertrand)

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Annex:
Marine mammals recorded (authentic) in the Southwest Indian Ocean (multiple sources), their IUCN population trends and status.

	STATUS					POPULATION TREND	IUCN STATUS
	Common	*Rare*	*Vagrant*	*Resident*	*Migrant*		
CETACEA							
MYSTICETI							
Balaenidae							
Eubalaena australis	x				x	Increasing	Least concern
Neobalaenidae							
Caperea marginata		x			x	Unknown	Data deficient
Balaenopteridae							
Balaenoptera musculus		x			x	Increasing	Endangered
Balaenoptera physalus					x	Unknown	Endangered
Balaenoptera borealis					x	Stable	Least concern
Balaenoptera acutorostrata	x				x	Unknown	Endangered
Balaenoptera bonaerensis					x	Unknown	Data deficient
Balaenoptera brydei				x		Unknown	Data deficient
Megaptera novaeangliae	x				x	Increasing	Least concern
ODONTOCETI							
Physeteridae							
Physeter macrocephalus	x			x		Unknown	Vulnerable
Kogidae							
Kogia breviceps		x		x		Unknown	Data deficient
Kogia sima	x			x		Unknown	Data deficient
Ziphiidae							
Ziphius cavirostris	x			x		Unknown	Least concern
Berardius arnouxii		x		x		Unknown	Data deficient
Indopacetus pacificus		x		x		Unknown	Data deficient
Mesoplodon mirus		x		x		Unknown	Data deficient
Mesoplodon densirostris	x			x		Unknown	Data deficient
Delphinidae							
Steno bredanensis		x		x		Unknown	Least concern
Sousa plumbea	x			x		Assumed to be declining	Vulnerable
Tursiops aduncus	x			x		Unknown	Data deficient
Tursiops truncatus	x			x		Unknown	Least concern
Stenella longirostris	x			x		Unknown	Data deficient
Stenella attenuata	x			x		Unknown	Data deficient
Stenella coeruleoalba		x		x		Unknown	Least concern
Delphinus delphis	x			x		Unknown	Least concern
Lagenodelphis hosei		x		x		Unknown	Least concern
Grampus griseus	x			x		Unknown	Least concern
Globicephala macrorhynchus	x			x		Unknown	Data deficient
Feresa attenuata		x		x		Unknown	Data deficient
Peponocephala electra	x			x		Unknown	Least concern
Pseudorca crassidens	x			x		Unknown	Data deficient
Orcinus orca	x			x		Unknown	Data deficient

PINNIPEDIA (CARNIVORA)							
Otaridae							
Arctocephalus pusillus	x		x			Increasing	Least concern
Arctocephalus tropicalis		x	x			Increasing	Least concern
Phocidae							
Mirounga leonina		x	x			Unknown	Least concern
Lobodon carcinophagus		x	x			Unknown	Least concern
SIRENIA							
Dugongidae							
Dugong dugon	x			x		Declining	Vulnerable

9.
SEA TURTLES

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Previous page: Young green turtles, tagged and photo-identified, before release on Juan de Nova. Photo by Jérôme Bourjea.

9. SEA TURTLES

A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean[1]

Jérôme Bourjea[2]

Abstract

The bycatch of sea turtles is of growing concern for the management of many fisheries, from large scale pelagic fisheries to small scale artisanal and coastal fisheries. The Southwest Indian Ocean (SWIO) hosts important nesting and feeding grounds for sea turtles but evidence points to populations facing significant human threats, especially from fisheries. We review the global status of each of the five known sea turtle species in the western Indian Ocean: *Chelonia mydas, Eretmochelys imbricata, Lepidochelys olivacea, Caretta caretta* and *Dermochelys coriacea*. Information on their diversity, status and human-related threats in each of the nine SWIO countries is presented and analysed: South Africa, Mozambique Tanzania (including Zanzibar), Kenya, Madagascar, Comoros, Seychelles, Mauritius and La Réunion/Mayotte/Eparses (France). Despite long-term monitoring programmes within this region (>30 years), data availability in the SWIO remains inadequate for thorough population assessment, partly attributable to the complex life history of these species. This chapter highlights as significant the impacts of three major fisheries in the SWIO: gillnetting, prawn/shrimp trawling and longlining. However, it is important to view the impacts of fisheries in the light of land-based and other coastal threats. It is clear that, despite strong legislation prohibiting the direct take of turtles throughout the entire SWIO, fisheries are still regarded as the most important threat in this region. Several recommendations and research priorities are proposed in this chapter.

Introduction and objectives

Sea turtles are highly vulnerable reptiles that have been subjected to direct exploitation for centuries, resulting in severely depleted populations in many cases. As the awareness of their plight and threatened status grew, so too has the advent of their protection in many regions, including the Southwest Indian Ocean (SWIO). Whilst this protection has been successful in many cases, the threat to sea turtles remains high because of inadequate compliance with regulations and especially mortality posed by fisheries. The region has over the past few decades seen a huge increase in fisheries diversification and effort, often resulting in higher turtle mortalities as a bycatch.

The SWIOFP programme has as an overriding objective the development of fisheries in the region, especially offshore and industrial fisheries. Concurrently, such development is to take place in a sustainable manner in full recognition of an ecosystem approach (EAF). This places a burden on future fisheries development with respect to mortalities induced on harmless and vulnerable animals such as sea turtles. In a comprehensive Gap Analysis for SWIOFP (van der Elst *et al.* 2010), it was concluded that all available information about sea turtles in the WIO should be collated and interpreted in a Retrospective Analysis. This would then serve as a baseline document to inform future fisheries development strategies in the WIO region in the light of an EAF approach. In particular it would contribute to management at a regional level. In view of the above, this chapter has been compiled to serve that purpose and provide a status of knowledge on sea turtles in the WIO, especially in the light of fisheries interactions. Moreover, this analysis highlights specific gaps and challenges.

1. Part of this report reflects (a) an updated analysis of the FAO workshop held in Zanzibar in 2006 to assess the relative importance of sea turtle mortality due to fisheries, (b) its subsequent publication in the 2008 *WIO Journal of Marine Science (7 (2))* and (c) IOSEA MoU National Reports and database facilities.

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Even if locally sea turtle behaviour, feeding and reproduction are well understood, the lack of a global vision and understanding of their movement between the successive habitats and their interaction with regional fisheries does not lead to appropriated measures for conservation at the regional level. In support of this, SWIOFP developed, under its biodiversity component, an activity related to the study of the open sea movement of sea turtles in the WIO using a modelling approach based on telemetry and tagging. The final objective thus being to assess interaction between sea turtles and open sea fisheries within an ecosystem approach. A synopsis of most of the information on sea turtle threats can be accessed via the individual countries' national reports' online facility maintained by the IOSEA MoU (www.iosea-turtles.org). This Retrospective Analysis provides the most up to date assessment of sea turtle status at a regional level in the WIO, with a special focus on fisheries interactions.

Regional sea turtle biodiversity overview

SPECIES DISTRIBUTION, STATUS AND HOTSPOTS IN THE SWIO

The Southwest Indian Ocean is known to host five species of sea turtle (Marquez 1990; Ratsimbazafy 2003; Seminoff 2004). Of these, the green turtle (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) are the most widely distributed and abundant in this region, with the green turtle being by far the most numerous. These two species have also been the most severely impacted by directed exploitation (Hughes, 1974a, b; Frazier, 1980, 1982). Loggerheads (*Caretta caretta*) and leatherbacks (*Dermochelys coriacea*) are most common in South African waters, but less common in the rest of the region, and have little importance in relation to commercial and directed exploitation (Hughes, 1974 a, b, Hughes 2010). Relatively little has been documented on the olive ridley (*Lepidochelys olivacea*) and this species is not considered to be much more that a vagrant to the region. Details per country and species are provided in Table 1.

Table 1: Nesting and sightings recorded per country (H>1,000 individuals per annum; M =100-1,000 ipa and L<100 ipa; R = rare; ? = No information available). All reports are available on the website *http://iosea-reporting.org/test/reporting/NewQuerySites.asp* accessed July 2012).

Species distribution, status in the SWIO						
	Green	***Loggerhead***	***Leatherback***	***Hawksbill***	***Olive ridley***	Legislation
Kenya	Nesting-(M)	Nesting-(R)	Nesting-(0)	Nesting (M)	Nesting (L)	Protected
	In-water sightings (H)	In-water sightings (?)	In-water sightings (?)	In-water sightings (L)	In-water sightings (R)	
Madagascar	Nesting (M)	Nesting (L)	Nesting (R)	Nesting (M)	Nesting (?)	Protected
	In-water sightings (H)	In-water sightings (L)	In-water sightings (R)	In-water sightings (L)	In-water sightings (R)	
Mauritius: Main island	Nesting (R)	Nesting (?)	Nesting (0)	Nesting	Nesting (?)	Protected
	In-water sightings (H)	In-water sightings (H)	In-water sightings (R)	In-water sightings (M)	In-water sightings (R)	
Mauritius: Outer islands	Nesting (H)	Nesting (0)	Nesting (0)	Nesting (L)	Nesting (?)	Protected
	In-water sightings (H)	In-water sightings (R)	In-water sightings (R)	In-water sightings (M)	In-water sightings (?)	
Mozambique	Nesting (M)	Nesting (M)	Nesting (L)	Nesting (L)	Nesting (L/?)	Protected
	In-water sightings (H)	In-water sightings (?)	In-water sightings (?)	In-water sightings (?)	In-water sightings (?)	
Réunion	Nesting (L)	Nesting (0)	Nesting (0)	Nesting (0)	Nesting (0)	Protected
	In-water sightings (M)	In-water sightings (R)	In-water sightings (R)	In-water sightings (L)	In-water sightings (R)	
Eparses islands	Nesting (H)	Nesting (R)	Nesting (0)	Nesting (L)	Nesting (0)	Protected
	in-water sightings (H)	in-water sightings (R)	in-water sightings (R)	in-water sightings (L)	in-water sightings (R)	
Mayotte	Nesting (H)	Nesting (0)	Nesting (0)	Nesting (L)	Nesting (?)	Protected
	in-water sightings (H)	in-water sightings (R)	in-water sightings (R)	in-water sightings (M)	in-water sightings (R)	
South Africa	Nesting (0)	Nesting (H)	Nesting (M)	Nesting (0)	Nesting (R)	Protected
	In-water sightings (M)	In-water sightings (H)	In-water sightings (R)	In-water sightings (L)	In-water sightings (R)	
Tanzania	Nesting (M)	Nesting (M)	Nesting (0)	Nesting (M)	Nesting (R)	Protected
	In-water sightings (H)	in-water sightings (L)	in-water sightings (R)	in-water sightings (L)	in-water sightings (R)	

SPECIES OVERVIEWS

A summary profile of each species, including its main nesting sites, migration patterns and feeding grounds is presented, together with its IUCN Red List status (The IUCN Red List of Threatened Species. Version 2014.2. <www.iucnredlist.org>. Downloaded on 26 October 2014.). Also included is its CITES status which for each of the species is allocated to Appendix I: international trade and transport prohibited.

Loggerhead *(Caretta caretta)*

IUCN: Endangered; CITES: Appendix I

Loggerheads are known to nest mainly along the beaches of southern Mozambique and in the Maputaland section of the iSimangaliso Wetland Park, KwaZulu-Natal (South Africa) where populations have been protected and well monitored since 1963 (Hughes 1971, 1974, 1993, 1996; Videira *et al.* 2008; Videira *et al.* 2010). This species is also known to nest in the south of Madagascar but few data are available. The Maputaland nesting population has been monitored since 1966 and it appears to have an important increasing trend in the number of loggerhead nests since then (Fig. 2a, Hughes 2010, Nel *et al.* 2013a. Feeding grounds were identified through mark recapture with recoveries from KwaZulu-Natal beaches reported from Mozambique and Tanzania and Zanzibar, indicative of a northward migration (Hughes 1989). Satellite tracking data are in agreement with such a finding and confirm that most of the feeding grounds are along the coast of Mozambique (4 sat-tags in 1996, (Papi *et al.* 1997), numerous sat-tags deployed subsequently (Ronel Nel: *pers.comm*).

Olive ridley *(Lepidochelys olivacea)*

IUCN: Vulnerable; CITES: Appendix I

Although this species is widely distributed in the region, it is relatively rare and little is known about its behaviour and life history in the SWIO. It is not known to nest regularly in the region, with only a few records of nesting having occurred on the East African coast: South Africa and Madagascar (Frazier 1975). The main known nesting sites in the Indian Ocean are in India (Shaker *et al.* 2003). This species is almost neritic, travelling or resting in surface waters and migrating along the continental shelves between nesting sites and feeding grounds (Marquez 1990). Due to the low occurrence of nesting and in-water sighting, nothing is known on the migration behaviour of this species in the SWIO, or indeed whether specific feeding grounds exist in the region.

Green turtle *(Chelonia mydas)*

IUCN: Endangered; CITES: Appendix I

The green turtle is the most abundant sea turtle species in this region and is known to nest on beaches of most countries of the SWIO. Nesting sites are primarily found on isolated islands but nesting also occurs along much of the Madagascar and East African coasts as far south as 25°S. Main nesting hotspots are presented in Figure. 1 and seen to include the Eparses Islands (*i.e.* Europa, Glorieuses and Tromelin), Mayotte, Mohéli and the outer Seychelles islands (*i.e.* Aldabra group).

Long-term monitoring of these nesting sites has allowed estimating trends in abundance as indicated:

- Europa – monitored since 1986: 7,000-10,000 nesters/year; annual growth rate: +2% (Le Gall 1988; Lauret-Stepler *et al.* 2007; Bourjea *et al.* 2011. ; Fig. 2b).
- Glorieuses – monitored since 1987: 1,500-2,500 nesters/year; annual growth rate: +3.5% (Lauret-Stepler *et al.* 2007; Bourjea *et al.* 2011.; Fig. 2b).
- Tromelin – monitored since 1987: 1,000-2,000 nesters/year; annual growth rate: -1.7% (Le Gall 1988; Lauret-Stepler *et al.* 2007; Bourjea *et al.* 2011.; Fig. 2c).
- Mayotte – monitored since 1998: 3,000 -5,000 nesters/year; annual growth rate: +0.9% Bourjea *et al.* 2007; Fig. 2c).
- Mohéli (Comoros) – monitored since 2000: 4,000 -6,000 nesters/year; annual growth rate: 17.7% (Bourjea *et al.* 2015(a) Fig. 2d).
- Aldabra – monitored since 1981: 6,000 nesters/year; annual growth rate: x 7 in 40 years (Mortimer *et al.* 2011a).

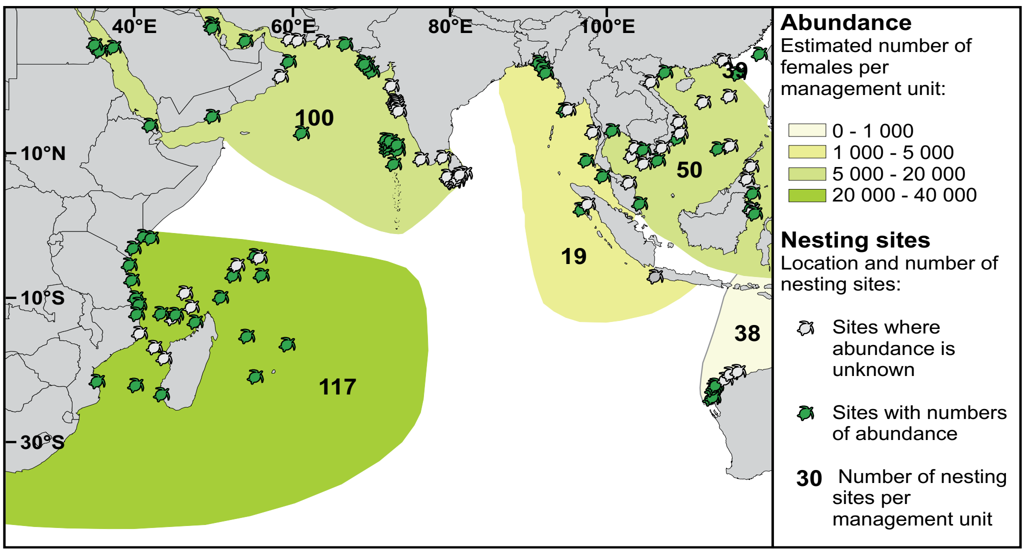


Figure 1: Current state of knowledge of main green turtle nesting sites with estimates of abundance in the Indian Ocean. (Source: SWOT/OBIS-SEAMAP, Kelonia, Ifremer)

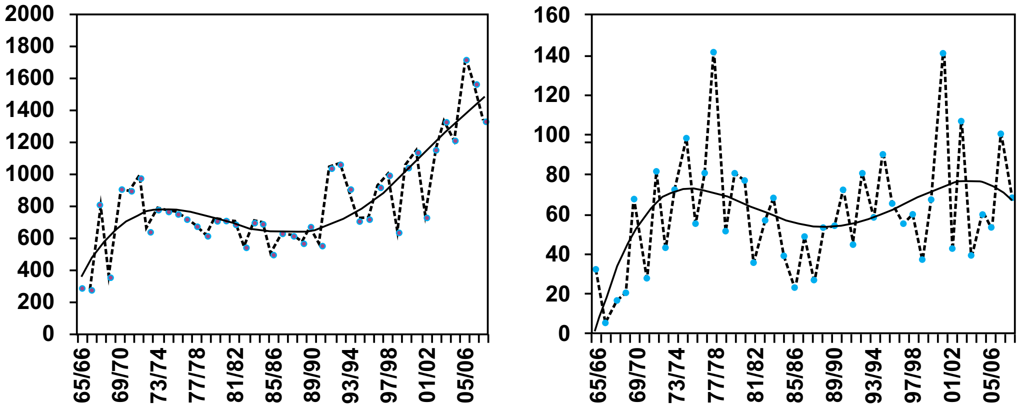


Figure 2a: Long term trends in nesting activity, expressed as nest counts, of turtles in the Maputaland index survey area 1965-2008: loggerheads left, leatherbacks right (based on Nel *et al*. 2013a).

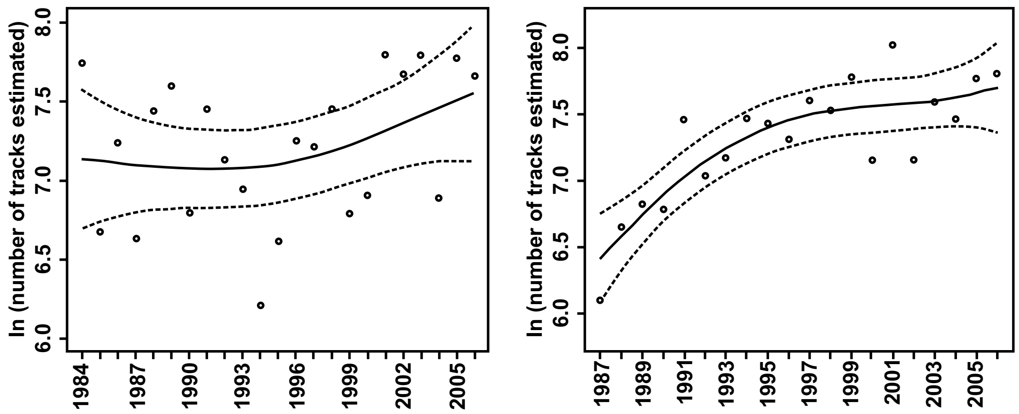


Figure 2b: Time series plots and smoothing spline regression of the annual green turtles track abundance for Europa Island 1986-2008 (left) and Glorieuses Island 1987-2008 (right) (Bourjea *et al*. 2011; Jean 2011).

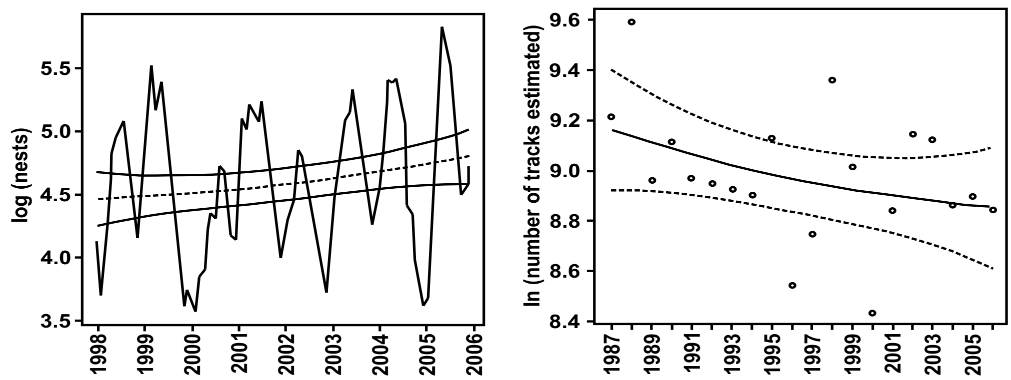


Figure 2c: Time series plots and smoothing spline regression of the annual green turtle track abundance for Mayotte (left) and Tromelin Island 1986-2008 (data source: Bourjea *et al*. 2007; 2011).

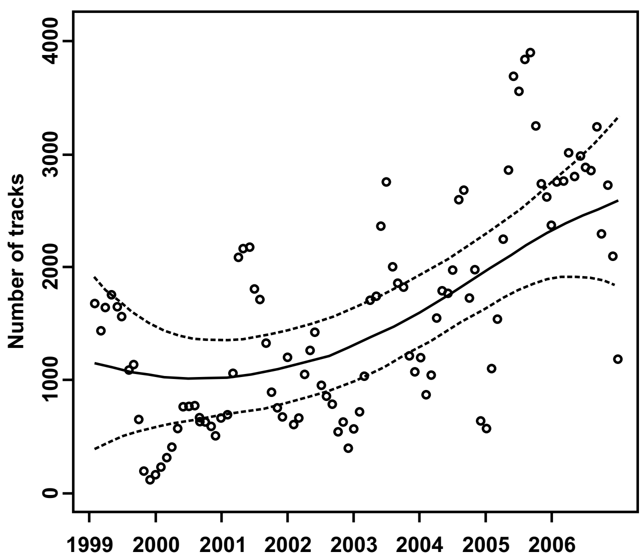


Figure 2d: Fitted trend to monthly track counts on Itsamia beaches, Mohéli, Comoros Archipelago: 1999-2007. Solid line is the fitted smooth (cubic smoothing spline) of the predicted number of tracks per month from the Gam trend component; dashed lines are 95% confidence intervals; grey open circles are observed track counts; dotted line is the linear regression slope calculated on Gam fitted values (R^2=0.88, df = 94, slope coefficient =17.7 SE 0.7). From Bourjea *et al*. 2015(a).

The green turtle is known to migrate between nesting sites and foraging grounds. On reaching adulthood, reproductive females typically make long distance migrations between feeding sites composed of sea grass beds, and their natal breeding beaches (Limpus *et al.* 1992). They show great fidelity to both nesting (Meylan 1982) and feeding grounds (Limpus *et al.* 1992), even though these may be separated by thousands of kilometres (Mortimer & Carr 1987). Attempts have been made to identify foraging areas using flipper tagging (Le Gall and Hughes 1987, Mortimer, 2001; J.A. Mortimer and SIF unpublished data; Kelonia/IFREMER unpublished data) as well as via satellite telemetry (Pelletier *et al.* 2003; Girard *et al.*2006, Garnier *et al.* 2012). Moreover, a large green turtle satellite tagging project concluded in 2014 in the SWIO is likely to assist in investigating this issue[3] (Fig 3a).

Results of these studies to date indicate that green turtles nesting along the East African coast confine their migration to along the coast. This is in contrast to those nesting on islands (*e.g.* Comoros, Eparses and Mayotte) which reach the East African or Malagasy coast via "migration corridors" (Fig. 3b). This behaviour is believed to be mainly attributable to the fact those areas are characterized by a network of large sea grass beds (Dalleau 2012, Bourjea *et al.* 2013). Key results also indicate that 35% of the tracked nesting green turtles forage in marine protected areas (MPAs) and that Northern Mozambique Channel and west Madagascar are the main foraging grounds (Fig. 3c).

Hawksbill *(Eretmochelys imbricata)*

IUCN: Endangered; CITES: Appendix I

This is the most equatorial of the sea turtle species and nests mainly in the Seychelles Archipelago. Hawksbill are distributed throughout the Seychelles, with the main concentrations on the granitic islands and the sandy cay islands (Mortimer 1984, Mortimer et Donnelly 2008, Allen *et al.* 2010, Mortimer *et al.* 2011b). Over previous decades, this region represents one of just five nations in the world with more than 1,000 females nesting annually (Meylan & Donnelly, 1999). Nesting hotspots monitored and respective trends for this species in the region are:

- Cousin and Cousine islands (Seychelles: granitic group): 200-250 increasing (Allen *et al.* 2010)
- D'arros (Amirante group): 60-75 nesters/year, increasing (Mortimer *et al.* 2011b)
- Silhouette (granitic island): up to 140 tracks per years, no trend (McCann 2010)
- Juan de Nova (Eparses islands): 10-30 nesters/years, increasing (Lauret-Stepler *et al.* 2010). Note that this is the southern known nesting site for this species in the SWIO.

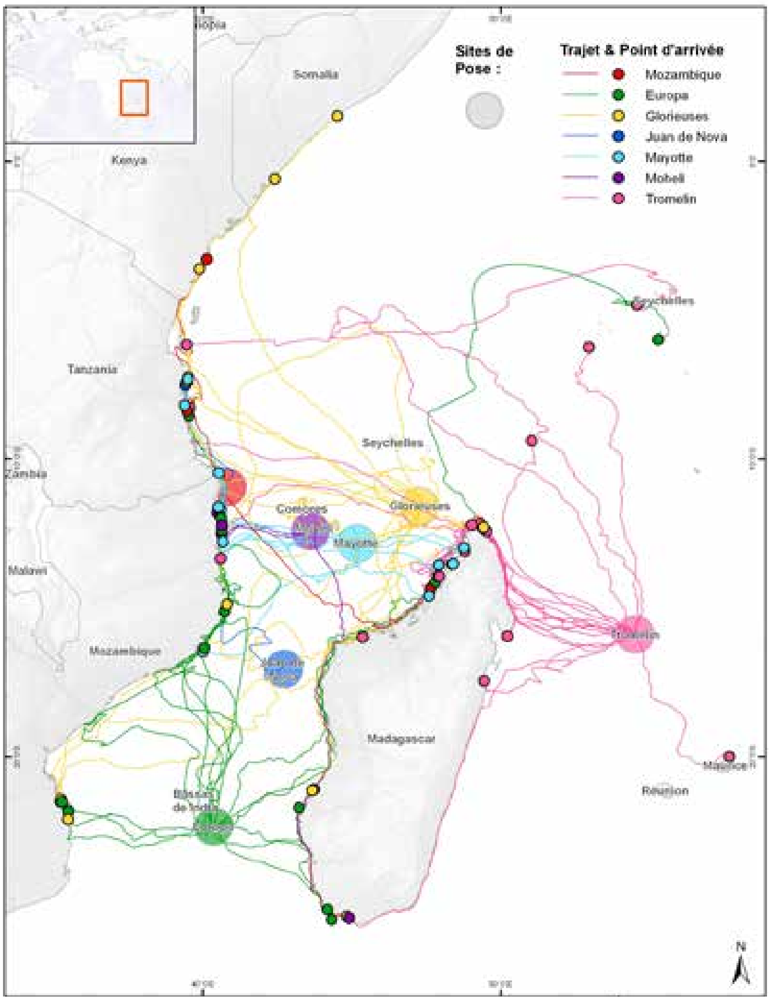
Hawksbill turtles may be found feeding on invertebrates and sponges on most of outer coral reef slopes in the SWIO. They migrate between nesting sites and feeding grounds but the number of recaptures from tagging studies (Mortimer 2,000) and the low number of satellite trackings in the SWIO has thus far failed to reveal their precise migration routes and the location of the adult feeding habitat in the SWIO.

Leatherback *(Dermochelys coriacea)*

IUCN: Vulnerable; CITES: Appendix I

Leatherbacks are the most pelagic and widely distributed sea turtle species in the SWIO but nowhere common. This species is known to nest mainly along southern Mozambique and Maputaland beaches of KwaZulu-Natal (Hughes 1971, 1974, 1993, 1996; Videira *et al.* 2008; Nel *et al.* 2013a). This species is also known to nest in the south of Madagascar but few data are available. The main hotspot for nesting leather-

Figure 3a: Post nesting trajectories of female green turtles tracked from nesting sites in the SWIO (Europa, Juan de Nova, Glorieuses, Mayotte, Tromelin). Bullets indicate final foraging ground; colour indicates if the female was nesting. (See Dalleau 2013; Bourjea *et al.* 2013.)



3. Satellite tracking can be seen at the following link: http://wwz.ifremer.fr/laRéunion_eng/Live-Sea-Turtles

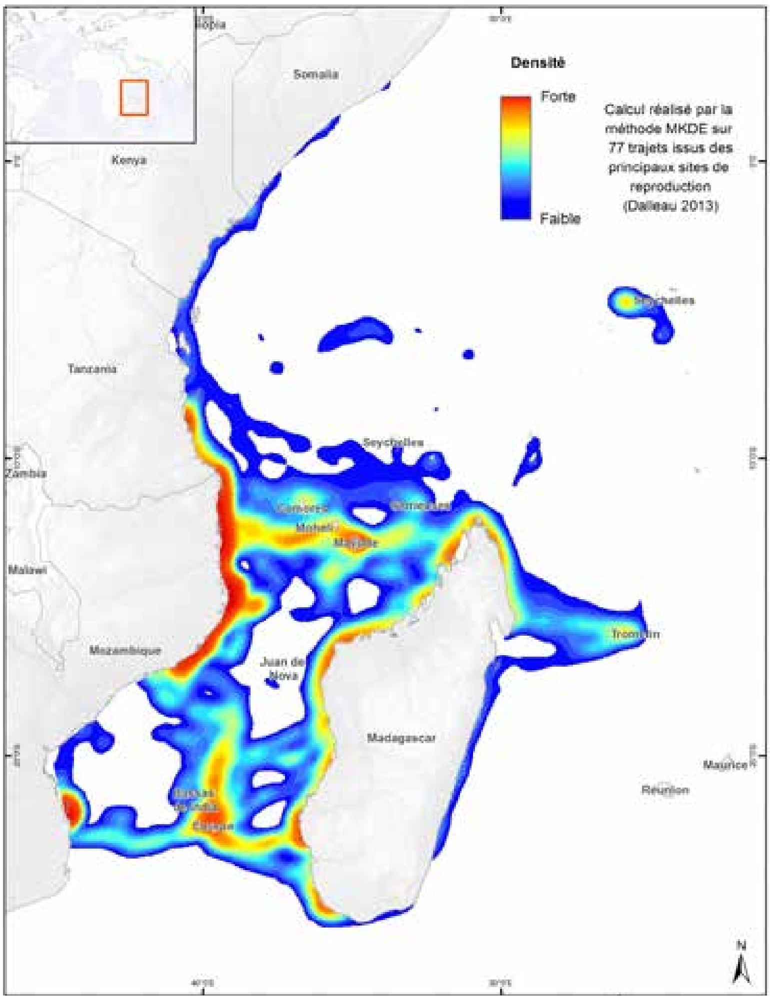


Figure 3b: Density-utilisation modelling of migrating female green turtle nesting in the SWIO. (See Bourjea *et al* 2013; Dalleau 2013 for details).

back is Maputaland where populations of nesting females have been monitored since 1966. Despite this species' populations being depressed, the monitoring results do not indicate growth although the number of nests appears to be stable. Leatherbacks make the most extensive migrations among turtles, wandering over large oceanic areas with fairly complex routes (Luschi *et al.* 2003). They do not really migrate between nesting and feeding grounds, rather their post nesting routes are described as prolonged sojourns in extended feeding areas in the SWIO (Luschi *et al.* 2006). This species feeds over an extended large pelagic area in the south of the Africa continent (from Mozambique to Namibia; Luschi *et al.* 2006), targeting macro-plankton.

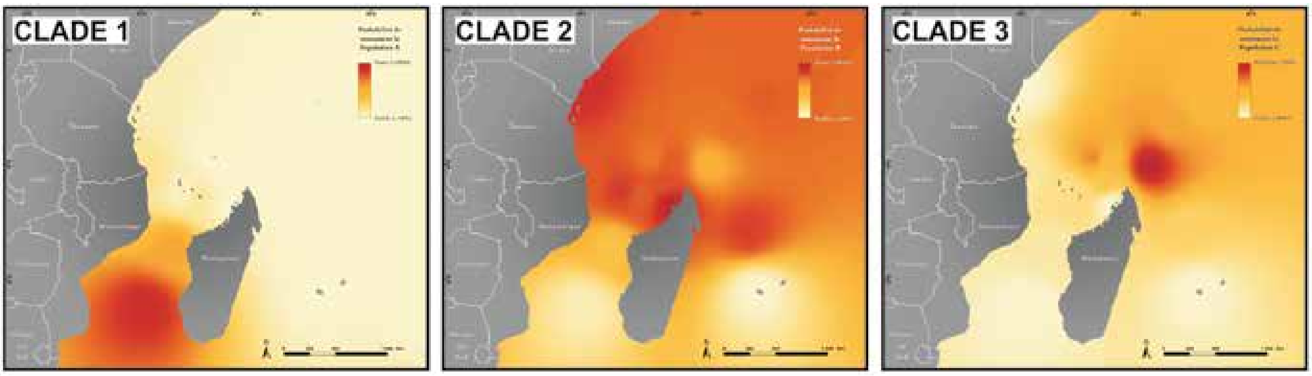


Figure 4: South West Indian Ocean iso-frequency map constructed by inverse distance weighted interpolation method (Watson and Philips, 1985) and using haplogroup frequencies of nesting green turtles (i.e. Clade 1= sub-stocks a1 + a2; Clade 2= sub-stock b2; Clade 3= sub-stock b1). From Bourjea *et al*. 2015(b).

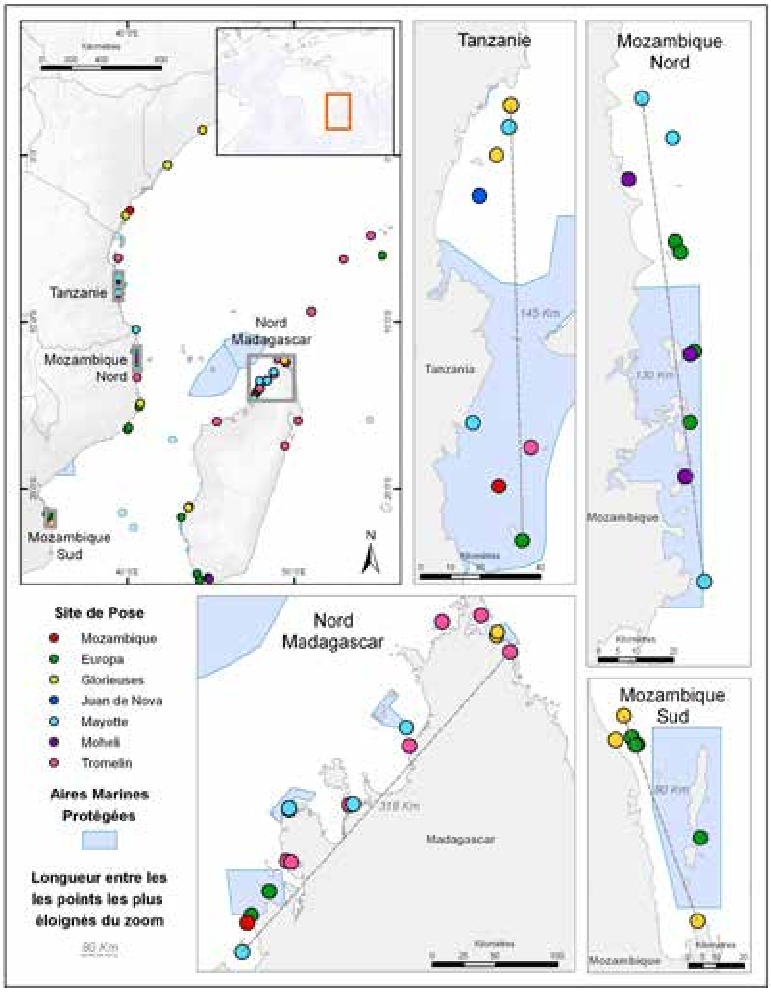


Figure 3c: Main green turtle foraging areas, identified by tracking from their nesting sites in the SWIO (See Bourjea *et al.* 2013; Dalleau 2013).

REGIONAL GENETIC STRUCTURE

Robust data with which to assess population structure of sea turtles in the SWIO are only available for the green turtle. Among 14 of their nesting sites in the SWIO, pairwise comparisons of haplotype frequencies showed significant genetic differentiation among rookeries suggesting that the SWIO hosts two main genetic stocks of nesting green turtles that could themselves be divided into two sub-stocks: A: the southern Mozambique Channel (SMC), that could be composed of two sub-stocks (a1) Europa and (a2) Juan de Nova, and B: the northern SWIO (N-SWIO) comprising two sub-stocks (b1) the Seychelles Archipelago stock – SEY; and (b2) the remaining northern SWIO rookeries (Fig. 4; Bourjea *et al.* 2007, Bourjea *et al.* 2015(b)). The newly revealed differentiation of the Seychelles population is supported by restricted migrations of females tracked from the Amirantes group suggesting relatively limited links with other regional stocks (Bourjea *et al.* 2015(b)). However, the main gap at this stage, is the lack of information on the genetic composition of green turtle aggregations that inhabit the extensive foraging grounds found along the East African coast, Malagasy coasts, the Seychelles, Amirantes Banks and other shallow zones within the region. As mentioned before, satellite tracking studies and flipper tag returns (Mortimer, 2001; Bourjea *et al.* 2013) clearly demonstrate that these habitats are shared by different breeding populations within the SWIO region and therefore by those of different genetic stock. As most of the green turtle bycatch occurs on the foraging grounds, it is considered that unravelling the level of stock mixing on feeding sites is a high priority and subsequently to protect turtles from fisheries' impact in their critical foraging grounds.

In the case of loggerhead, leatherback, olive ridley and hawksbill only the latter has been studied to some extent, highlighting that Seychelles and Chagos hawksbill nesting females are part of the same population although they are clearly different from the Australian hawksbill stock (Mortimer and Broderick 1999).

Available information by country

In order to assess the relative importance of sea turtle mortality attributable to fisheries in the SWIO; a summary is presented of sea turtle diversity, status and threats for each of the nine SWIOFP countries of the SWIO: South Africa, Mozambique, United Republic of Tanzania, Kenya, Madagascar, Comoros, Seychelles, Mauritius and France /Réunion/Eparses/ Mayotte (see Table 1 for a summary).

SOUTH AFRICA

Sea turtle diversity and status

All five sea turtle species can be found here but only two nest regularly, namely loggerheads and leatherbacks (Hughes, 1974a, b; 1993; 1996a, b). Nesting is confined to a 200 km stretch of north-eastern coast of South Africa where assessment of nestings indicates a small leatherback population (175 – 352 nests/ year; Fig. 2a) but a large population of loggerheads of up to 3,000 nests annually; Fig. 2a; Nel, 2010; Nel *et al.* 2013a). The eastern seaboard of South Africa serves as a feeding and developmental area for hawksbill and green turtles and the occasional olive ridley.

Threats

Threats in South Africa are relatively well managed with a virtual absence of direct take, mainly because the nesting zone forms part of the iSimangaliso Wetland Park. Besides natural predation of eggs and hatchlings by honey badgers, water mongoose, monitor lizards, ghost crabs and fish and bird predators, there are few other land-based sources of mortality. However, interactions with a number of fisheries do exist in the South African EEZ, notably with longlining operations, small prawn trawl fishery (10% of trawls; Fennessy, 2004.) and coastal gillnets.

Turtle bycatch in the South African pelagic longline fishery operating in the South African EEZ was assessed by Petersen *et al.* (2009) and identified as a key threat to turtle populations (Petersen *et al.* 2009; Nel 2010). A total of 181 turtles was caught on 2,256 observed sets between 1998 and 2005, at a rate of 0.04/1,000 hooks. By species this was 0.02/1,000 hooks for loggerhead (60.0% of the total turtles captured), 0.01/1,000 hooks for leatherback (33.8%) and 0.001/1,000 hooks for hawksbill and green turtle (respectively five and three individuals). These fisheries operated in both Atlantic and Indian Oceans, with most of the turtles caught on the Walvis Ridge and on the shelf edge north of the Orange River (25-31 °S and 0-15 °E). Nevertheless, the impact on SWIO turtle populations will be unquestionable considering the high incidence of loggerheads which nest on the KwaZulu-Natal coast. Based on extrapolation of these data a range of 190-560 turtles are caught annually in the South African longline fishery. Significantly, the catch rates of sea turtles in the swordfish and tuna fisheries differ greatly, with swordfish directed operations taking a much larger catch (89.5%) of the sea turtles (Petersen *et al.* 2009).

Turtles are also taken incidentally in the Thukela inshore shrimp trawl fisheries off KwaZulu-Natal and around 10% of drags may capture a turtle as bycatch, amounting to an estimated 20-50 mortalities per year, primarily loggerheads and green turtles (Fennessy, 2004.)

Along the KwaZulu-Natal coast there are gillnet installations to protect bathers from shark attack. These nets are serviced regularly, but nevertheless do capture turtles: about 62/ year average for 2006-2010, with approximately half released alive (Young, 2001; www.shark.co.za). Results for the period 1981-2008 indicate that loggerheads were caught most frequently at 40.9 (SE ± 2.18) turtles/yr (Brazier *et al.*, (2012) – see Table 2 for details).

MOZAMBIQUE

Sea turtle diversity and status

All five species are known to nest along the coast of Mozambique. (Gove and Magane, 1996; Louro *et al.* 2006; Costa *et al.* 2007; Videira *et al.* 2008). According to Hughes (1971), the green turtle is most widespread but nests predominantly north of the Tropic of Capricorn, from Quewene Peninsula to the Quirimbas Archipelago with the main concentrations of nesting in the Primeiras and Segundas Islands and Quirimbas Archipelago (ex. Vamizi and Rongui Islands ; Costa *et al.* 2007; Videira *et al.* 2008; Videira *et al.* 2011 ; Garnier *et al.* 2012). Small and immature animals are also concentrated around Bazaruto and Inhassoro and some may be found in Maputo Bay. Loggerhead and leatherback turtles are more common in the south and nesting beaches are found along

Table 2. Catch statistics for loggerheads, leatherbacks, green turtles, hawksbill and olive ridleys taken in the shark nets off the KZN coast, 1981-2008 (after Brazier *et al.* (2012)).

Catch statistics: 1981–2008				
Species	***Total catch per species (percent of overall catch)***	***Mean annual catch (number)***	***Total % mortality***	***Mean annual mortality (mean ± SE)***
Loggerhead	1146 (67.4%)	40.9 ± 2.18	53.2%	21.8 ± 1.58
Leatherback	150 (8.8%)	5.36 ± 0.60	62.7%	3.4 ± 0.47
Green	334 (19.6%)	11.9 ± 1.13	67.6%	8.0 ± 0.86
Hawksbill	54 (3.1%)	1.93 ± 0.35	70.4%	1.4 ± 0.22
Olive ridley	17 (1.0%)	0.61 ± 0.16	70.6%	0.4 ± 0.12

the entire coast from Ponta d'Ouro to the Bazaruto Archipelago (Hughes, 1971; Costa *et al.* 2007). The most important nesting areas for these species are the Matutuine coast (from Ponta d'Ouro to Santa Maria) (Videira *et al.* 2008; Videira *et al.* 2011).

Threats

While coastal development presents threats to sea turtles and their habitats, the main threats to the nesting species in this country are related to direct exploitation for eggs, meat and shell (Costa *et al*. 2007, Videira *et al*. 2008). This includes artisanal fishery-related threats, such as beach seine captures and entanglement in gillnets, which seem to be a dominant threat all over the coast (Kiszka, 2012). An estimated 240-420 are caught by this sector annually, more than ¾ being green turtles (Louro *et al.* 2006). In terms of semi-industrial and industrial fisheries, the shrimp trawlers are a significant source of mortality on the Sofala Bank, one of the main shallow water shrimp fishing grounds of Mozambique. Gove *et al*. (2001) tentatively estimated that an annual range of 1,932 -5,436 turtles may be killed in these fisheries, about 1/3 attributable to semi-industrial and 2/3 to industrial fisheries. There has also been a previous spate of illegal longlining that was believed to be responsible for scores of decapitated turtles washing up on Mozambique shores (Louro *et al.* 2006).

TANZANIA – INCLUDING ZANZIBAR

Sea turtle diversity and status

All five SWIO species of sea turtles occur off the 900 km long coast of Tanzania and in Zanzibar waters. Of these, only the green and hawksbill are known to nest (Aitchison, 1993; Howell and Mbindo, 1996; Khatib *et al*. 1996). Although exact nesting population abundance is unknown, important nesting sites for green turtles in Zanzibar are Misali (west), Vumawimbi and Kiuyu in Pemba, and Matemwe and Mnemba Islands in Unguja. Key turtle nesting sites of relative importance are Mafia (high), Temeke (medium), Mtwara (low) and Pangani (medium). An average of 450 green turtle nests have been recorded and 5–10 hawksbill nest per year (Muir, 2005; Sea Sense, unpublished data). However, these figures only represent data for part of the Tanzania's mainland coastline. Foraging and population trends are unknown.

Threats

The main threats to sea turtles in the coastal zone include collection of eggs, slaughter for meat and habitat disturbance. Zanzibar used to be one of the world's major clearing houses for tortoise shell but populations are believed now to be a small fraction of what they once were due to various human impact- although no past data are available. Tourism development resulting in destruction of nesting beaches, as well as the direct take for meat, medicine and curios, are major concerns for sea turtle conservation in Zanzibar.

With regard to coastal fisheries, information gathered from questionnaire interviews and catch monitoring indicates that bottom set 'Jarife' (6-inch mesh) and 'sinia' (12-inch mesh) gill nets pose a major threat to sea turtles. These mortalities are both incidental and targeted and while numbers vary, surveys suggest that at popular fishing sites such as Songo Songo, Mtwara, Kilwa and Mafia on Zanzibar, the mortalities are very high. Monitoring at some sites suggests that 45-60% of gill net fishing trips catch turtles, accounting for several thousand turtles annually. Gillnets were introduced in Zanzibar in the late 1960s (Tarbit, 1984) and their use has increased so that 5,329 gill nets were in use in Zanzibar and Pemba in 2008 (Sobo *et al.* 2008). The drift nets usually target large pelagic fish such as kingfish, sailfish and tuna, and can have a length of 500-900 m with variable mesh size of 7-20cm (Amir *et al*. 2002).

The level of mortality from inshore commercial prawn trawlers, pelagic longline and purse seine nets in the Tanzania EEZ is unknown. The commercial prawn trawl fishery involves 14 to 22 vessels and is known to capture turtles as a bycatch. This fishery has been periodically closed due to reduced prawn stocks, high level of bycatch and commercial non-viability of the fishery.

KENYA

Sea turtle diversity and status

The sea habitats of the Kenyan coast, which include coral reefs, sea grass meadows and sandy beaches, provide diverse habitats for sea turtles, so that Kenya's waters host all five of the SWIO species of sea turtle. Of these, the green, hawksbill and olive ridley turtles nest in Kenya (Frazier, 1975; Okemwa *et al*. 2004) while according to Frazier (1975), leatherbacks and loggerheads use Kenya's waters as foraging grounds as well as migratory routes. An aerial survey in 1994 indicated that sea turtles are widely distributed along the coastline within the 20m isobath mainly associated with sea grass beds and coral reefs (Wamukoya *et al*. 1996). Based on a study from 1997 to 2000, 684 nests were recorded over the four years, of which green turtles made up 94% of the nesting activity, with the remainder of the nests comprising hawksbill and olive ridley nests (Okemwa, 2003).

Sub-adult loggerhead turtle with satellite tracking tag mounted on her carapace. (Photo: Jérôme Bourjea)

Threats
There are sources of mortality related to all life stages of sea turtles in Kenya. Egg predation and nest inundation, together with egg poaching are a threat on most nesting beaches. However, information seems to indicate that the relative mortality due to fisheries either as targeted or incidental is approximately 95% of all documented turtle mortalities in Kenya (Wamukoya *et al.* 1997), with approximately 58% of sea turtles killed as a result of entrapment in fishing nets (Okemwa *et al.* 2004). Estimated incidental catch rates of turtles in shrimp trawls seems to be as high as 2-3 turtles/ day during the shrimp season (Mueni and Mwangi, 2001; Mwatha, 2003), equating to about 100-500 turtles/ year when Turtle Excluder Devices (TED) were not in use (Wamukoya *et al.* 1997). Other documented sources of mortality include entanglement and pollution but are relatively low, with the main constraint being the lack of data on foraging and developmental habitats of the turtles in Kenya and on turtles migrating out of Kenyan waters.

MADAGASCAR

Sea turtle diversity and status
All five SWIO species of sea turtle have been reported to occur in the coastal waters of Madagascar. (Marquez, 1990; Ratsimbazafy, 2003; Seminoff, 2004; Humber & Hykle, 2011). With exception of the leatherback, all four other species are known to nest along the coast of Madagascar although the distribution of the nesting sites differs according to each species (Ratsimbazafy, 2003). While green turtles nest on beaches of the north, south and west Malagasy coast, the loggerhead is known to nest mainly in the southeast (Rakotonirina & Cooke 1994). Hawksbill have been seen nesting in the northwest (Sondrona 2001), on the Barrens islands (Rakotonirina 2008) and frequently in Nosy Iranja (Bourjea *et al.* 2006). Few nesting records are known from the east side of Madagascar.

Madagascar is also known to be an important feeding area for sea turtles. Fig. 5 shows the main foraging areas in Madagascar per species, deduced from tagging recaptures, indicating that most loggerhead originate from South Africa (Hughes 1981) and greens from several French islands of the South West Indian Ocean (Le Gall & Hughes, 1987).

Figure 5: Main foraging areas of marine turtles in Madagascar (from Rakotonirina B., adapted from Rakotonirina & Cooke 1994); Cm: green turtle, Ei: hawksbill turtle Cc: loggerhead, Lo: olive ridley, Dc: leatherback.

Threats
Sea turtles are under considerable threat from a variety of human activities including poaching, fishing and habitat disturbance (Rakotonirina & Cook, 1994, Ciccione *et al.* 2002). Land-based collection of eggs is common although precise numbers are not known (Lilette, 2007). Similarly, the scale of habitat destruction at nesting beaches is not documented. Fisheries do take turtles, both as a target and as a bycatch. There is a long history of fishers taking sea turtles for meat (Rakotonirina & Cook, 1994) and, despite increased regulations and awareness, this continues today. Direct capture of juvenile and adult turtles of all five species takes place using a variety of gear types, both in the traditional (artisanal) and in the industrial fisheries, with the former being the most important (Lilette, 2007). Various surveys provided an estimation of the levels of catches by artisanal fisheries: 13,000 (Hughes, 1981), 12,000 (Rakotonirina, 1987) and 11,000 to 15,000 (Rakotonirina & Cooke 1994). A more recent study showed that the annual turtle catch in the south-western province of Tulear alone is between 10,000 and 16,000, 93% of which were green turtles (Humber *et al.* 2011).

Considering industrial bycatch, trawlers are historically an important source of turtle mortality in Madagascar (Randriamiarana *et al.* 1998). However, since the voluntary and compulsory introduction of Turtle Excluding Devices (TED) in 2003 and 2005 respectively, virtually all mortality from this source has ceased (Rakotonirina *et al.* 2006).

A workshop for "*The adoption of a management and conservation plan for sea turtles in Madagascar*" was held in Madagascar in 2011 designed to strengthen sea turtle research and conservation in Madagascar (Humber & Hykle 2011). The creation of a suite of marine protected areas to protect turtle habitats is an on-going activity. In addition, several eco-tourism ventures have been established focusing primarily on sea turtles, in areas where nesting occurs, such as in Nosy Iranja Kely, in the north-west of Madagascar that has stable nesting sites for green and hawksbill sea turtles (Bourjea *et al.* 2006).

A complete set of information on marine turtle and human related interactions in Madagascar is available (Rakotonirina 2012)

COMOROS

Sea turtle diversity and status
Two species of sea turtles are commonly found in the waters of Comoros: the hawksbill and green turtle, but no information appears to be available regarding other sea turtle species in this country. Both species are known to nest in Comoros, with greens being dominant. Because of habitat degradation, the low number of suitable nesting beaches and a high level of poaching in Anjouan and Grande Comoros, Mohéli is by far the most important site in the Comoros Archipelago for green turtles (Frazier 1985). Enhanced by its protected MPA status, Mohéli's beaches at Itsamia are amongst the most significant nesting sites for this species in the SWIO. More than 5,000 nesting females were estimated in 2005 on the five beaches monitored daily by a local community based

assocation jointly with the Marine Park of Mohéli ADSEI[4]/ MMP field guards (ADSEI, *unpublished data*) as part of a monitoring programme that has been running since 1998 (Bourjea *et al.* 2015). There was marked growth in nesting activity over the last decade, with an increase of 226% (ranging from 143%-391% with 95% confidence intervals) from 1999 to 2006 Bourjea *et al.* 2015). Hence, the Itsamia beaches have one of the largest nesting populations, with a higher rate of increase than any other site in the SWIO. Long-term protection of the beaches and offshore waters by the Itsamia community, despite several years of intense exploitation by people from other islands, is reasoned to be the primary explanation for these remarkable numbers.

Threats

Habitat degradation and poaching are clearly the main threats for green and hawksbill turtles in the Comoros Archipelago. Very few data on interactions with fisheries are available for Comoros. Domestic fisheries in this country are mainly composed of artisanal small mesh nets, essentially unregulated (ADSEI, *unpublished data*) and thought to be important sources of mortality of green turtles. Besides foreign tuna fisheries (purse seine and longline) that operate in the EEZ of Comoros, there have been substantial shark fishing rights allocated to foreign countries (Kamardine Bonaile, *pers. com*). These are certain to induce turtle mortality although no data are available.

The consumption of turtle meat is generally common on Grande Comore and Anjouan, but the habit varies between different villages on Mayotte and Mohéli. Although nearly all inhabitants of Comoros are Muslim, the consumption habits depend on religious beliefs, demography and ethnic origin of the village (Lilette 2007). For example, at Itsamia, on the south east of Mohéli, the community is Islam shafeite, with a belief system that forbids the consumption of animals that live in two different worlds. Hence, marine turtles that live in the water and nest on land are "haram" (i.e. "forbidden" and /or "sacred") and turtle meat is not consumed, and reportedly never was. However, the introduction of motorised boats to the Comoros in the early 1980s allowed the beaches of Itsamia to be easily reached by people from Anjouan and Grande Comore, which resulted in the active exploitation and trade of turtles and their meat, especially reproductive females butchered on the beaches of Itsamia (Lilette 2007).

SEYCHELLES

Sea turtle diversity and status

Green turtles, hawksbills, loggerheads, and leatherbacks have long been known to occur in Seychelles (Frazier 1984), but comparatively recently has the occurrence of olive ridleys been documented (Remie & Mortimer 2007). Nevertheless, only green turtles and hawksbills nest in Seychelles (Frazier 1984; Mortimer 1984). At sites where nesting turtles have enjoyed long-term protection their numbers have increased or remained stable. This is so for hawksbills at nature reserves and protected inner islands (Mortimer and Bresson 1994, Hitchins 2004, Mortimer 2004, Allen *et al.* 2010), at some sites in the Amirantes (Mortimer *et al.* 2011) and for green turtles at atoll of Aldabra (Mortimer 1985, 1988; Mortimer *et al.* 11a). However, numbers have declined where there has been heavy poaching, as on the developed islands of Mahé, Praslin and La Digue. Seychelles hosts the largest population of nesting hawksbills in the western Indian Ocean with 1,000 -2,000 nesting females annually (Mortimer 1984; Mortimer & Donnelly 2008).

Threats

Poaching of nesting females, loss of habitat through coastal developments and disturbance of feeding grounds through reclamation, port activities, dredging and related activities are important threats for hawksbill turtles in the inner islands – especially Mahé, Praslin and La Digue. Green turtles in particular are still being poached, especially in the inner islands where nesting populations are on the verge of local extinction (Mortimer 2004, 2006).

Turtles are protected in Seychelles, while the use of trawling, driftnets and shark gillnets are also prohibited in Seychelles' waters. Fishery-related mortality of sea turtles is thus most likely associated with longlining and purse seining: Seychelles host an important European purse seine fleet that targets tuna. Sea turtle bycatch in this fishery was estimated based on data collected through French and Spanish observer programmes representing a total of 1,958 observed fishing sets (Amande *et al.* 2008). Turtles were only infrequently recorded and almost exclusively recorded from FAD and log-associated tuna shoal sets (95%). Over the whole period of observations a total of 74 individuals was caught. These observations were mainly reported during the second part of the year when the fishery is more actively fishing around FADs. The species composition of these bycatches was dominated by the olive ridley, the green and hawksbill turtles. According to these observations, olive ridley seems the most impacted by the fishery in the north–west Indian Ocean area (up to the equator). Greens and hawksbill had the lowest bycatch rates here but were predominantly caught in the north of the Mozambique Channel. Near 90 % of the turtles caught were released alive (Amande *et al.* 2008).

There are sizeable artisanal line and trap fisheries in Seychelles and hawksbill turtles do at times get hooked in artisanal hook and line fisheries in shallow waters (Mortimer 1998). However, this is not considered a major source of mortality.

MAURITIUS

Sea turtle diversity and status

Only two species of sea turtles are commonly found in the waters of Mauritius: the hawksbill and green turtle, although others such as the leatherback may also occur at times. Nesting of sea turtles is common on all the outer islands of St. Brandon, Agalega, and Chagos (Mangar & Chapman 1996). However, few nests of these two species are found on main islands of Mauritius and Rodrigues, presumably depleted

4. *Association pour le Developpement Socio Economique d'Itsamia*: the main local association that is spearheading conservation of sea turtles in the South East of Mohéli.

after years of development and disturbance (Thompson 1981).

Threats

Natural disturbances such as those due to storms, cyclones and erosion are believed to represent one of the major threats. Illegal egg collection also seems to be an important source of mortality but no data are available. Although foreign, open sea fisheries (longline and purse seine) operate in Mauritian waters and land their catch here, surprisingly few data are available regarding interaction with sea turtles.

LA RÉUNION/MAYOTTE/EPARSES (FRANCE)

Sea turtle diversity and status

All five SWIO species of sea turtles are found in the French waters of the SW Indian Ocean, but only two species (green and hawksbill) are known to nest on the French islands of Mayotte, La Réunion and the Eparses Islands of Europa, Juan de Nova, Glorieuses and Tromelin. The green turtle is the dominant species and assessments show overall large, stable or increasing nesting populations in the Eparses islands (Lauret-Stepler *et al*. 2007, Bourjea *et al.* 2013) and Mayotte (Bourjea *et al*. 2007). In La Réunion Island, nesting started again in 2005 after a 25 years absence and more than 11 green turtle nests have been recorded in a three year period (Ciccione and Bourjea, 2006). Since then, green turtle nesting activity remained stable, with 0 to 3 nesting individuals per year. These French islands are also increasingly recognized as important development zones for green and hawksbill turtles where they find suitable seagrass and algal habitats (Jean *et al.* 2009; Ballorain 2010; Bourjea *et al.* 2011).

Threats

Although very few data are available for fisheries activities in the outer Eparses islands, the offshore longline fishery, comprising 39 offshore longliners in 2006, seem to have had a very small impact on sea turtles with very low incidental capture and mortality rates. In 1999, a three-year study showed that less than 0.004 turtles per 1,000 hooks were caught by this fishery, with the main impacted species being the loggerhead turtle (Poisson and Taquet 2001; Miossec and Bourjea 2003;). A more recent study investigated the origin of loggerhead turtles accidentally caught by the French semi industrial longline fishery using satellite telemetry. The study revealed that this turtle bycatch probably originated from both Omane's rookeries and from South African nesting sites (Dalleau *et al.* 2013).

Since 2009, an observer programme led by Terres Australes et Antartiques Françaises (TAAF) has been underway on purse seiners active in the Eparses islands' EEZ, further confirming a very low sea turtle by-catch rate. In Mayotte, only one study has been conducted which indicated higher bycatch rates: in 29 longline sets of 500 hooks, four loggerhead turtles were caught alive (0.28 turtles per 1,000 hooks). All were released alive (Kiszka *et al.* 2010).The use of trawling and gillnets is banned in La Réunion. Rare cases of artisanal handline bycatch have been recorded over the last 6 years (Ciccione, pers. comm.).

SOMALIA

Although Somalia is not a formal member of the SWIOFP programme, it has had observer status. Moreover, it has a long coastline with significant biodiversity issues of relevance to the WIO, including sea turtles. In a biodiversity survey and fisheries assessment programme conducted in March 1998 under the auspices of IUCN, extensive turtle foraging regions were identified. A two day low level aerial survey recorded in excess of 3,000 green turtles foraging in shallow coastal waters along a 760 km stretch of the Puntland Red Sea coast - up to the Horn. A maximum number of 1,600 turtles were counted in a 96 km section of coast. Turtle tracks were also recorded but only amounted to 11 over an 800 km section of coast around the Horn. During the survey extensive shark gill netting was recorded with a high (but unquantified) bycatch of green turtles (van der Elst and Salm 1998).

Mark-recapture programme on juvenile green turtle in the Eparses Islands; here in the mangrove of Europa Island. (Photo: Jérôme Bourjea)

Sea turtle status in the SWIO and the relative importance of fishery related mortality

Although not enough has been done in the Southwest Indian Ocean to identify and quantify the relative importance of various human pressures on turtles, some useful documents do exist. For example: National Reports to the IOSEA MoU and FAO project GCP/ INT/919/JPN "*Interactions between Sea Turtles and Fisheries within an Ecosystem Approach to Fisheries Management*", a regional workshop organised by the Directorate of Fisheries of Zanzibar and FAO to assess the relative importance of fishery-related sea turtle mortality in the SWIO region (FAO, 2006), provide the best overview of fisheries impacts in this region. Moreover, in 2010, the MTSG[5] spatially integrated information for each species such as nesting sites population abundance and trends, genetic and telemetry from fine- to coarse- spatial scales in order to define Regional Management Units (RMUs) for sea turtles globally[6] (Wallace *et al*. 2010). This approach concluded that for each of the five species, all of the SWIO is considered to be a single RMU or part of a larger one (Wallace *et al*. 2011). Based on this work, the MTSG elaborated conservation priority portfolio categories for each of the global RMUs. This portfolio was developed based on a combination of scores from risk and threats matrices for all RMUs, including threats like direct utilisation of sea turtles and eggs, coastal development, pollution, climate change impacts and fisheries bycatch. These risk and threat matrices allow for the identification of categories: 1) High Risk-High Threats; 2) High Risk-Low Threats; 3) Low Risk-Low Threats; 4) Low Risk-High Threats. It was concluded that the state of turtles in the SWIO RMUs by species is as follows (Wallace *et al*. 2011):

Species	***Risk***	***Threat***
Loggerhead	High	Low
Green	Low	High
Hawksbill	Low	Low
Olive ridley	High	High
Leatherback	High	Low

In relation to fisheries, these available reports and papers have highlighted the fact that fisheries interactions with sea turtles constitute a major threat in the SWIO. Furthermore, given the trans-boundary nature of sea turtle populations, a regional approach is essential and overdue.

The Zanzibar workshop (FAO 2006) was designed to assess the relative importance of fishery related sea turtle mortality in the SWIO. In order to understand and interpret any impact, population modelling needs to be undertaken. However, this requires information on the relative magnitude of natality, mortality, emigration and immigration (or dispersal), and the underlying processes should be understood. Life cycles of sea turtles are particularly complex, given their longevity, delayed maturity, wide geographic distribution, and the use of different habitats, ranging from terrestrial to pelagic, for varying amounts of time throughout their lives. Despite long-term monitoring programmes, such as for green and hawksbill turtles in Seychelles, green turtles from the French Iles Eparses, and loggerhead and leatherback turtles in South Africa, the overall conclusion was that data availability in the WIO was insufficient for thorough population modelling. It was evident that many of the region's countries did not have reliable nesting data and none had comprehensive in-water abundance estimates (Table 1). Furthermore, the data presented showed inconsistencies and lack of standardization in collection protocols. The second outcome of the workshop analysis was the recognition of the need to standardize data collecting initiatives so that they take place regularly, with set monitoring protocols based on consistent effort and data standards. It was noted that often data are collected without a clear understanding of their usefulness in relation to data analysis, and often lacking a sound statistical basis. For example, many tagging and nest protection programmes are not recording nesting success per sampling effort, which makes the data inadequate for statistical analysis. However, all data and information available on sea turtles, both qualitative and quantitative, were integrated in the analysis if they were collected by species, location, and main sources of mortality.

Within this approach, fisheries were considered a major source of threat for sea turtles in the SWIO-RMU. Mortality due to incidental capture in pelagic fisheries (i.e. longline, driftnet and purse seine) and coastal fisheries (i.e. longline, driftnet, gillnet, trawl and traps) were scored per species for each life history phase (with the lower the score the more important the threat), using numbers killed per fishery (or relative index such as CPUE) provided by each country. Table 3 shows the threats attributable to fisheries for each of the five turtle species. In the SWIO, coastal fisheries and gillnets, seem to have the highest impact on sea turtles, with a particular relevance to green turtles. Trawlers appear to mainly threaten turtles that have a more coastal behaviour (namely green and hawksbill) whereas turtle species which display more pelagic behaviour during their life stages seem to be more impacted by longlines (namely leatherback and loggerhead).

A recent study assessing the interaction between purse seiner and marine turtle in the Atlantic and Indian oceans explored the relative level of threat of this fishing activity (Bourjea *et al.* 2014). Based on a substantial observed dataset on almost 16,000 fishing sets and 14,124 specific observations on Drifting Fish Aggregation Devices (DFAD), it was possible to evaluate any turtle entanglement in the pieces of net normally suspended below the DFAD. It was found that the purse-seine fishery has a very low impact on marine turtles, with an estimated annual number of individuals incidentally captured of 218 (SD = 150) and 250 (SD = 157) in the Atlantic and Indian Ocean, respectively, with more than 75% being released alive. The study also investigated the impact of DFADs and found it not to be a main source of capture of turtles, but did consider the use of DFADs to be a key conservation issue for the purse seine fishery as drifting objects may attract juveniles of marine turtles, implying

5. The IUCN Marine Turtle Specialist Group.
6. Full details can be found in Wallace *et al*. 2010.

Table 3: Incidental take in fisheries in the SWIO for five species of sea turtle. Each species was scored per life history phase, and the lower the score the more important the threat. Data collection is detailed in FAO, 2006 and were updated with recent results. (threats ranked: 1-4 with 1 = high threat level; high importance to take action; 2 = Medium threat level; 3 = Low threat level; low importance to take action; 4 = No threat level; N/A = Not applicable.

Incidental take in fisheries in the SWIO											
	Leatherback			***Hawksbill***		***Green***		***Loggerhead***		***Olive ridley***	
Incidental take in fisheries	*Adult*	*Juvenile*	*Hatchl.*	*Adult*	*Juvenile*	*Adult*	*Juvenile*	*Adult*	*Juvenile*	*Adult*	*Juvenile*
Longline (shallow and deep set)	2	2	4	4[c]	2?[c]	4	2?	1.5[j]	1.5[j]		
Demersal longline	2	2		2.5?	2.5?			4[i]	4[i]		
Purse seine	4	4	4	4	3.5	3.5	3.5	4	3.5	3.5	3.5
Trawl	3.5	3.5	4	3.54	3.54	2.5[f]	2.5[f]	2.5	2.5	2	2
Coastal gillnets	2.5[a]	2.5[a]	4	2	2	1	1	2	2	2	2
Nets/traps/Pots	4	4		3.5	3.5	3	3	4	4	3	3
FADs	4	4		4	3.5?	4	3,5[g]	4	3.5?	3	3
Hook and line	3.5	3.5		3.5	3.5	3.5	3.5	3	3		
Dynamite fishing	4	4	4	4[d]	4[d]	4[h]	4[e]	4[l]	4[l]	3	3
Spearing	4	4		4[e]	4[e]	4	4	4	4		
Drift-netting	4	4		4	4	?	?	4	4		
Poison	4	4		4	4	3	3	3[e]	3[e]		
Beach seine netting	4	4		4	4	4[i]	4[i]	3[e]	3[e]		

[a] Specific to Tanzania, and the special case of bather-protection nets in South Africa.
[b] Specific to Seychelles.
[c] South Africa & Réunion (4)
[d] Tanzania (2)
[e] Kenya (3) & Zanzibar (2)
[f] Trawling more important in Kenya, Yemen and Tanzania.
[g] Region has a large purse seine FAD driven fishery (Emerging issue)
[h] Rating of 2 for Tanzania/Zanzibar
[i] Rating of 3 for Mozambique
[j] South Africa good data between 2000-2004; a 43% bycatch on Cc; no other member state had data.
[k] South Africa not considered a problem; other member states no data.
[l] Zanzibar (2) & Yemen (3)

the need for improving their construction to avoid entanglement (e.g. avoiding nets in the design of FAD structures).

A recent semi-quantitative Ecological Risk Assessment requested by the Indian Ocean Tuna Commission (IOTC) to investigate interaction with Indian Ocean fisheries lead to the same global conclusion as above but concluded that data paucity is a great concern so there is low confidence in this result (Nel *et al.* 2013b). One of the main remaining gaps concerns the impact of coastal activities such as artisanal fisheries, which are known, for example, to kill between 11,000 and 15,000 per year at a single location on the West Coast of Madagascar (Humber *et al.* 2011). In order to investigate such interactions with artisanal fisheries, it is proposed that the survey method such as Rapid Bycatch Assessment is undertaken (Moore *et al.* 2010). This method was piloted in the SWIO with promising initial results (Kiska, 2012).

Balancing threats, mitigation measures and their application to sea turtles

There are currently 115 known sites of importance identified across the nine nations (South Africa, Mozambique, United Republic of Tanzania, Kenya, Madagascar, Comoros, Seychelles, Mauritius and France /Réunion/Eparses/Mayotte) in the SWIO that provide nesting, developmental and feeding habitats to sea turtles (Annex; IOSEA DataBase). The conservation efforts that are taking place across these countries are summarised in ten categories ranging from monitoring programmes, to building restrictions and fishing gear modifications (Fig. 6). The most commonly employed conservation measures are *in situ* monitoring (54%) accompanied by Marine Protected Areas (51%). Hatcheries and egg relocation is reported for 23% of the sites. This is in agreement with the fact that direct take (nesting turtle poaching, egg harvesting), is currently known to be the largest threat to sea turtles across the region. Fishing gear modifications are reported to be used in only 10% of the cases, which is disconcertingly one of the lowest of all mitigation measures (Fig. 6).

It is important to view the impacts of fisheries in the light of other land-based or coastal threats. It is clear that, despite strong legislation prohibiting the direct take of turtles throughout the entire SWIO, it is still regarded as the most important threat. An evaluation of the level of take and impact thereof was provided in Table 3. Appropriate conservation policies to address fisheries' threat to turtles in the SWIO should be backed up by legislation but can only be implemented if they are adequately designed and developed with all stakeholders (namely fishermen, scientists and managers) in order to gain consensus. The capacity to implement such measures must exist locally as well as regionally and follow-up over the short-term and long-term is paramount to achieving success. Without such an approach, these policies are unlikely to have any effects on turtle populations. This should be of major concern, especially in countries where priorities are not biodiversity conservation but more socio-economic development.

Regional conventions and commissions

It has long been recognised that sea turtles are under pressure from a number of natural and anthropogenic factors, both in the terrestrial phase of their life cycle as well as in the aquatic marine environment. Conservation efforts can only succeed if the major threats can be managed and especially at a transboundary level. In response, several regional instruments and structures attend to sea turtle issues.

All nine SWIOFP countries have now signed the Convention on Migratory Species' *Memorandum of Understanding for the Conservation and Management of Sea Turtles and their Habitats of the Indian Ocean and South East Asia* (IOSEA) (www.ioseaturtles.org). This MoU aims to develop and assist countries of the region in the implementation of the regional strategy for management and conservation of sea turtles and their habitats. Accordingly, IOSEA has been successfully co-ordinating and closely monitoring region-wide conservation efforts in the Indian Ocean for years. This has included the development of a state-of the-art online reporting facility, satellite tracking, genetic regional database and a global bibliographic resource.

Similarly, at the scale of the Indian Ocean, the Western Indian Ocean -Marine Turtle Task Force (WIO-MTTF) is a technical, non-political, working group comprised of specialists from eleven countries: Comoros, France (La Réunion), Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa, Tanzania and the United Kingdom, as well as representatives from intergovernmental organizations, academic, and non-governmental organisations within the region. The Task Force falls under the aegis of the Nairobi Regional Seas and the IOSEA Conventions.

The IUCN Marine Turtle Specialist Group (MTSG), one of the IUCN/Species Survival Commission's specialist groups, is responsible for conducting regular *Red List* assessments of each sea turtle species on a global scale. However, because sea turtle population traits — as well as environmental conditions — vary geographically, the global extinction risk assessment framework represented by the *Red List* does not adequately

Figure 6: Frequency of mitigation measures used to reduce impacts on sea turtles and their habitats at 150 selected sites in nine countries of the South West Indian Ocean: South Africa, Mozambique, Tanzania, Kenya, Madagascar, Comoros, Seychelles, Mauritius and France /Réunion/Eparses/Mayotte. Full details are available at http://iosea-reporting.org. Compilation from 2012 reports.

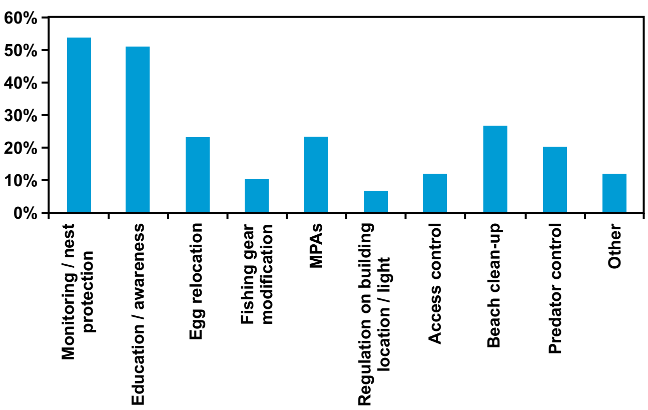
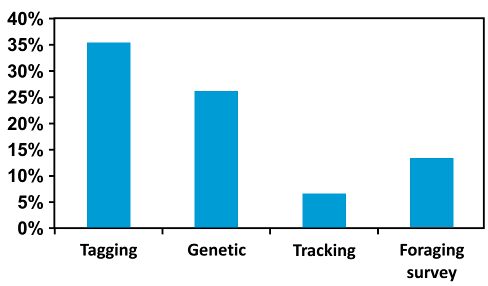


Figure 7. Frequency of the main research activities conducted or on-going on sea turtles and their habitats at 150 selected sites in nine countries of the South West Indian Ocean: (South Africa, Mozambique, Tanzania, Kenya, Madagascar, Comoros, Seychelles, Mauritius and France/Réunion/Eparses/Mayotte. Full details are available at http://iosea-reporting.org. Compilation from 2012 reports.



assess conservation status of spatially and biologically distinct sea turtle populations. The MTSG has debated the utility and validity of this global classification system for decades, and has advocated for regional assessments using criteria that are more appropriate for assessing extinction risk of sea turtle populations. In fact, recent MTSG species assessments have attempted to address this problem of setting global conservation priorities by evaluating species' status in each ocean basin based on data compiled at the sub-ocean basin level. Thus, the MTSG has promoted the defining of smaller population units for assessments and developing a system for assessing the conservation status of such population units (Wallace *et al*. 2010, 2011).

The Indian Ocean Tuna Commission is playing an increasingly constructive role in turtle conservation. In 2005, the IOTC adopted Resolution 05/08, superseded by Resolution 09/06 on Sea Turtles which sets out reporting requirements on interactions with sea turtles and accordingly provides an executive summary per species for adoption at the Working Party on Ecosystem and By-catch and then subsequently at the Scientific Committee. In 2011, IOTC developed a "Sea Turtle Identification Card" to be distributed in all longliners operating in the Indian Ocean (www.iotc.com).

Green turtle returning to sea after laying eggs on Mohéli Island. (Photo: Jérôme Bourjea)

Recommendations and identification of research priorities

Based on FAO (2006), IOSEA country annual reports and available recent literatures, there are four current focus areas suggested for future research and management.

Firstly, regarding fishery-related threats, the impacts of three major fisheries were identified as significant in the SWIO: gillnetting, prawn/shrimp trawling and longlining, as well as artisanal fisheries, leading to a number of recommendations/priorities. These are:

- the lack of quantitative data is the greatest weakness and therefore should be addressed at all levels, incorporating artisanal and industrial fisheries, and should involve local communities, fisheries administrations, and regional fisheries management organizations (RFMO).The regional Rapid Bycatch Assessment (RBA) approach promoted by SWIOFP (Kiska 2012) is clearly a valuable approach, especially regarding the assessment of the poorly known impact of small-scale fisheries in the countries of the SWIO. Such datasets, added to the current knowledge on bycatch is the first step to propose and adopt appropriate local and regional mitigation measures.
- research that will highlight turtle-fisheries interactions that could potentially lead to the reduction in bycatch, such as time-area closures, should be promoted.
- turtle monitoring and a comprehensive regional observer training programmes have already been provided by SWIOFP and should urgently be implemented to collect data on both local and foreign fishing fleets.
- experimentation with mitigation measures, including TEDs and circle hooks should be encouraged.

The second focus area relates specifically to illegal, unreported and unregulated fisheries (IUU). While all RFMOs recognize the problem of IUU fisheries and the data deficiency associated with them, it is important to explicitly emphasize that resolving this complex issue is intimately related to mitigating problems of sea turtle bycatch. Based on that, the national administrations are encouraged to review, improve, harmonize and enforce legislation on turtles whereas RFMOs and national administrations are encouraged to recognize the potentially significant impacts of IUU fishing on sea turtle populations in the region, especially for areas like Somalia where there is a lack of monitoring and control of fishing and fisheries in the EEZ.

The third focus area relates to the biology and ecology of sea turtles. Countries of the SWIO are encouraged to provide information on long-term abundance and nesting trends, but these should be conducted in a structured, scientifically robust manner. Training programmes and capacity building will be the basis of this focus as indeed has already been initiated under IOSEA MoU, MTTF or NGOs such as WWF and specific projects (*e.g.* SWIOFP). More complex questions, such as genetic stock structures and population dynamics of sea turtle stocks in the region (including hatching success, sex ratios, and natural mortality), should be addressed. In fact, even if tagging research activities are well covered in the SWIO with more than 35% of the sites doing classic tagging, only 6.7% of the sites have a satellite tracking project (Fig. 7). Such a low percentage accentuates the poor state of knowledge of sea turtle spatial dynamic in the SWIO, an important issue in terms of regional management. In contrast, with 26% of the sites covered, the regional genetic structure is currently well known for the green turtle (Bourjea *et al*. 2007, 2015(b)) but still poorly known for all other species. Undertaking such more complex research questions, however, requires collaborative research, as suggested by FAO (2006). For example, the project on detecting migration routes of sea turtles in the SWIOFP region using spatial telemetry represents a fundamental approach to identify hotspot of abundance and accordingly map risk estimates of interaction fisheries in the open ocean and coastal areas (Bourjea *et al*. 2013) and should be extended at a large scale to other species.

The fourth and last focus area relates to the socio-economic complexities of the region. Within the situation of the SWIO, it is generally agreed that turtle catches, direct or as bycatch, are intimately linked to social, economic, and political dynamics. It was thus recognised that sustainable fisheries and an ecosystem approach to fisheries management is to be promoted if socio-economic, cultural and resource-use studies are included in future research plans. Without resolving root cause issues of livelihood, resource access and governance, even the best attempts at technological advances, such as gear modifications, will have limited success (FAO, 2006).

In conclusion and from a regional perspective it is strongly recommended that the SWIO Fisheries Commission, IOTC and the IOSEA strengthen their collaboration and coordination on all issues related to Sea Turtle Management and especially by adopting the IOSEA-MoU to serve as baseline policy.

Green turtle returning to sea in Glorieuses. (Photo: Jérôme Bourjea)

Known sea turtle databases

There are a considerable number of databases that provide insight into the status of sea turtles. Most can be accessed via the internet.

- IOSEA– Régional Database
  www.ioseaturtles.org
- TORSOOI/IFREMER/KELONIA– France, La Réunion, île Eparses Comoros, Nosy Iranja sites
  www.torsooi.com
- Conseil Général de Mayotte, Base de Données Tortue Marine
  Contact Mireille Quillard *mireille.quillard@wanadoo.fr*
- Ezemvelo KZN Wildlife, South Africa
  Contact Ronel Nel *Ronel.Nel@nmmu.ac.za*
- Natal Sharks board, South Africa
  www.shark.co.za
- Nature Seychelles
  www.natureseychelles.org
- Seychelles Island Foundation
  www.sif.sc
- Marine Conservation Society, Seychelles
  Contact David Rowat *david@mcss.sc*
- Jeanne Mortimer personal Seychelles database
  Contact *mortimer@ufl.edu*
- Blue Ventures, Madagascar
  Contact *frances@blueventures.org*
- IHSM / Berthin Racotonirina, Madagascar
  Contact *fanozaty@yahoo.fr*
- Associaçao para investigaçao costeira e marinha, Mozambique
  www.aicm.org.mz
- SeaSens Tanzania database
  www.seasense.org
- KESKOM, Kenya
  Contact *kescoms@yahoo.com*
- IOTC
  www.iotc.org

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Annex:
115 sites of importance identified across the nine nations (South Africa, Mozambique, United Republic of Tanzania, Kenya, Madagascar, Comoros, Seychelles, Mauritius and France/Réunion/Eparses/Mayotte) in the SWIO that provide nesting, developmental and feeding habitats for sea turtles. All reports are accessible at http://iosea-reporting.org.

Country	*Site/area*	*Prov./State*	*Coordinates*
COMOROS			
Comoros	Ile aux tortues		
Comoros	Beaches north of Mohéli	Mohéli Island	
Comoros	Itsamia	Mohéli Island	12° 22' 0" S; 43° 52' 0" E
Comoros	Itsamia 1	Mohéli Island	
Comoros	Itsamia 2	Mohéli Island	
Comoros	Itsamia 3	Mohéli Island	
Comoros	Itsamia 4	Mohéli Island	
Comoros	Itsamia5	Mohéli Island	
Comoros	Mohéli Marine Park	Mohéli Island	
Comoros	Nioumachoua Islands	Mohéli Island	12° 24' 0" S; 43° 42' 0" E
Comoros	Bimbini	Ndzouani Island	
Comoros	Beaches of Grande Comores and Anjouan	Ngazidja Island	
Comoros	MalE Beach	Ngazidja Island	
FRANCE			
France	La Réunion		20° 55' 0" S; 55° 31' 0" E
France	Mayotte		12° 47' 0" S; 45° 12' 0" E
France	Europa	French Iles Eparses, TAAF	22° 21' 0" S; 40° 21' 0" E
France	Glorieuses	French Iles Eparses, TAAF	11° 33' 0" S; 47° 17' 0" E
France	Juan De Nova	French Iles Eparses, TAAF	17° 03' 0" S; 42° 45' 0" E
France	Tromelin	French Iles Eparses, TAAF	15° 33' 0" S; 54° 31' 0" E
KENYA			
Kenya	Bodo		4° 36' 25" S; 39° 23' 52" E
Kenya	Chandani Beach		1° 59' 22" S; 41° 17' 39" E
Kenya	Chole		1° 53' 20" S; 41° 22' 35" E
Kenya	Funzi		4° 35' 58" S; 39° 25' 52" E
Kenya	Msambweni		4° 27' 11" S; 39° 29' 51" E
Kenya	Ashuwei Beach	Ashuwei, Coast	1° 56' 47" S; 41° 19' 36" E
Kenya	Bofa	Kilifi, Coast	3° 35' 59" S; 39° 53' 39" E
Kenya	Ishakani Beach	Lamu, Coast	1° 42' 9" S; 41° 31' 28" E
Kenya	Kiunga	Lamu, Coast	1° 44' 49" S; 41° 29' 23" E
Kenya	Kiunga Mwini Camp	Lamu, Coast	1° 45' 16" S; 41° 30' 36" E
Kenya	Kiunga Village	Lamu, Coast	1° 45' 10" S; 41° 30' 22" E
Kenya	Kiwaiyu Village	Lamu, Coast	2° 1' 14" S; 41° 15' 42" E
Kenya	Kongowale Beach (Northern End)	Lamu, Coast	1° 57' 5" S; 41° 19' 22" E
Kenya	Kongowale beach (Southern End)	Lamu, Coast	1° 57' 37" S; 41° 18' 57" E
Kenya	KSV	Lamu, Coast	1° 57' 28" S; 41° 18' 38" E
Kenya	Kui	Lamu, Coast	1° 50' 2" S; 41° 26' 21" E
Kenya	Kui Fisher Camp	Lamu, Coast	1° 49' 29" S; 41° 26' 21" E
Kenya	Magogo 1	Lamu, Coast	1° 52' 2" S; 41° 24' 37" E
Kenya	Mdoa 1	Lamu, Coast	1° 45' 58" S; 41° 30' 31" E
Kenya	Mkokoni Camp	Lamu, Coast	1° 57' 25" S; 41° 18' 1" E
Kenya	Mkokoni Village	Lamu, Coast	1° 57' 41" S; 41° 18' 2" E
Kenya	Mkokoni Water Front	Lamu, Coast	1° 58' 20" S; 1° 17' 46" E
Kenya	Mwongo (Mongo) Shariff North	Lamu, Coast	1° 51' 7" S; 41° 25' 31" E
Kenya	Shella	Lamu, Coast	2° 17' 49" S; 40° 54' 22" E
Kenya	Watamu	Malindi, Kilifi	3° 23' 0" S; 39° 59' 1" E
Kenya	Jumba Ruins	Mombasa, Coast	3° 56' 55" S; 9° 48' 48" E
Kenya	Tiwi	South Coast	4° 15' 13" S; 39° 36' 2" E
Kenya	Kipini	Tana Delta, Coast	2° 32' 31" S; 40° 27' 28" E
Kenya	Takaungu	Vipingo, Mombasa	3° 41' 5" S; 39° 52' 7" E
MADAGASCAR			
Madagascar	Nosy Hara (Parc National)	North (Diana)	12° 14' 35" S; 9° 00' 44" E
Madagascar	Baie de Antongil et 3 Parcelles Marines du P.N. Masoala	Northeast (Analanjirofo)	15° 44' 37" S; 49° 50' 01" E
Madagascar	Ile Sainte Marie	Northeast (Analanjirofo)	16° 59' 14" S; 9° 54' 07" E
Madagascar	Manambato	Northeast (Analanjirofo)	16° 32' 22" S; 49° 50' 27" E
Madagascar	Archipel [Barralums]	Northeast (Sava)	12° 47' 42" S; 49° 49' 44" E
Madagascar	Nosy Iranja	Northwest (Diana)	13° 35' 30" S; 47° 48' 49" E
Madagascar	Nosy Sakatia	Northwest (Diana)	13° 17' 40" S; 48° 10' 07" E

Madagascar	Ambinanikely Beach / Tolagnaro	Southeast (Anosy)	25° 02' 07" S; 46° 58' 44" E
Madagascar	Ankaramanihy	Southeast (Anosy)	24° 25' 45" S; 47° 18' 18" E
Madagascar	Evatraha	Southeast (Anosy)	24° 58' 38" S; 47° 05' 34" E
Madagascar	Itapera - Tolagnaro	Southeast (Anosy)	24° 51' 37" S; 47° 07' 33" E
Madagascar	Lokaro - Tolagnaro	Southeast (Anosy)	24° 56' 28" S; 47° 06' 33" E
Madagascar	Sainte Luce	Southeast (Anosy)	24° 46' 11" S; 47° 11' 54" E
Madagascar	Tolagnaro	Southeast (Anosy)	25° 02' 07" S; 46° 58' 44" E
Madagascar	Ambohibola	Southwest (Atsimo-Andrefana)	25° 04' 30" S; 44° 06' 48" E
Madagascar	Anakao	Southwest (Atsimo-Andrefana)	23° 39' 59" S; 43° 38' 22" E
Madagascar	Andavadoaka	Southwest (Atsimo-Andrefana)	22° 04' 30" S; 43° 14' 33" E
Madagascar	Fiharenamasay (Tsifota / Manombo-Sud)	Southwest (Atsimo-Andrefana)	22° 58' 45" S; 43° 28' 04" E
Madagascar	Ifaty	Southwest (Atsimo-Andrefana)	23° 08' 44" S; 3° 36' 41" E
Madagascar	Lamboara	Southwest (Atsimo-Andrefana)	22° 10' 40" S; 43° 14' 53" E
Madagascar	Morombe	Southwest (Atsimo-Andrefana)	21° 44' 56" S; 3° 21' 47" E
Madagascar	Nosy Andriamitaroke	Southwest (Atsimo-Andrefana)	21° 44' 56" S; 43° 21' 47" E
Madagascar	Nosy Ve	Southwest (Atsimo-Andrefana)	23° 38' 56" S; 43° 36' 13" E
Madagascar	Nosy Ve - Androka	Southwest (Atsimo-Andrefana)	25° 29' 00" S; 44° 59' 00" E
Madagascar	Salary Nord	Southwest (Atsimo-Andrefana)	22° 34' 46" S; 43° 17' 15" E
Madagascar	Toliara	Southwest (Atsimo-Andrefana)	23° 19' 59" S; 43° 37' 50" E
Madagascar	Iles Barren	West (Melaky)	18° 29' 33" S; 43° 48' 11" E
Madagascar	Belo-sur-Mer	West (Menabe)	20° 44' 36" S; 44° 00' 30" E
MAURITIUS			
Maurice	Agalega		
Maurice	Gris Gris		
Maurice	St. Brandon		
MOZAMBIQUE			
Mozambique	Quirimbas Archipelago,the Primeiras and Segundas Islands	Cabo Delgado Province	
Mozambique	Maputo Special Reserve, Inhaca Island	Maputo Province	
SEYCHELLES			
Seychelles	Aldabra Atoll	Aldabra Group	09° 24' 03" S; 6° 20' 27" E
Seychelles	Cosmoledo, Astove, Assomption	Aldabra Group	09° 45' 53" S; 47° 04' 50" E
Seychelles	African Banks, Desnoeufs, Desroches, Marie-Louis	Amirantes Group	05° 24' 55" S; 53° 15' 12" E
Seychelles	Alphonse / Bijoutier / St. Francois	Amirantes Group	07° 03' 15" S; 52° 44' 49" E
Seychelles	D`Arros island / St. Joseph Atoll	Amirantes Group	05° 25' 39" S; 53° 18' 57" E
Seychelles	Farquhar Atoll and Providence islands	Farquhar Group	09° 49' 53" S; 51° 02' 35" E
Seychelles	Main Islands: Mahé, Praslin, La Digue	Inner Islands	04° 29' 34" S; 55° 39' 43" E
Seychelles	Marine National Parks: Curieuse MP, Ste. Anne MP, Silhouette MP	Inner Islands	04° 25' 33" S; 55° 32' 41" E
Seychelles	Private islands managed as de facto nature reserves: Anonyme, ...	Inner Islands	04° 30' 01" S; 55° 41' 22" E
Seychelles	Strict Nature Reserves: Aride Island and Cousin Island	Inner islands	04° 16' 36" S; 55° 35' 32" E
Seychelles	Platte island; Coetivy island	Platte & Coetivy	06° 30' 18" S; 55° 38' 21" E
Seychelles	Offshore banks and shoals away from land: Seychelles Bank, etc.	Seychelles territorial waters	04° 29' 60" S; 54° 23' 03" E
SOUTH AFRICA			
South Africa	iSimangaliso National Park	KwaZulu-Natal	27° 0' 45" S; 32° 51' 59" E
TANZANIA			
Tanzania	Juani Island	Mafia Archipelago	8° 0' 0" S; 39° 46' 60" E
Tanzania	Kungwi Island	Mafia Archipelago	8° 0' 0" S; 39° 46' 60" E
Tanzania	Mafia Island	Mafia Archipelago	7° 51' 43" S; 39° 45' 18" E
Tanzania	Shungi Mbili Island	Mafia Archipelago	8° 0' 0" S; 39° 45' 33" E
Tanzania	Madete	Mainland - Bagamoyo District	6° 24' 23" S; 39° 34' 30" E
Tanzania	Mainland Coast	Mainland - Kilwa District	8° 54' 33" S; 39° 32' 14" E
Tanzania	Maziwe Island	Mainland - Maziwe	5° 29' 60" S; 39° 3' 60" E
Tanzania	Mainland Coast + Mapanya Island	Mainland - Mkuranga District	
Tanzania	Mainland Coast	Mainland - Mtwara District	10° 15' 14" S; 40° 10' 53" E
Tanzania	Mainland Coast + Simaya Island	Mainland - Rufiji District	
Tanzania	Mainland Coast	Mainland - Temeke	6° 48' 54" S; 39° 18' 0" E
Tanzania	Amani Gomvu	Mainland - Temeke District	6° 56' 29" S; 39° 30' 21" E
Tanzania	Buyuni	Mainland - Temeke District	7° 7' 20" S; 39° 32' 37" E
Tanzania	Kimbiji	Mainland - Temeke District	6° 57' 48" S; 39° 31' 4" E
Tanzania	Yale Yale Puna	Mainland - Temeke District	7° 4' 26" S; 39° 32' 28" E
Tanzania	Songo Songo Archipelago	Songo Songo Archipelago	8° 31' 20" S; 39° 30' 7" E
Tanzania	Matemwe Island	Zanzibar + associated islands	5° 52' 3" S; 39° 21' 14" E
Tanzania	Misali Island	Zanzibar + associated islands	5° 14' 21" S; 39° 36' 15" E
Tanzania	Mnemba Island	Zanzibar + associated islands	5° 49' 13" S; 39° 23' 1" E
Tanzania	Pemba Island	Zanzibar + associated islands	5° 4' 47" S; 39° 45' 28" E
Tanzania	Zanzibar (Unguja) Island	Zanzibar + associated islands	6° 5' 49" S; 39° 21' 35" E

10.
SEABIRDS

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Previous page: Common Noddies, Comoros. Photo by Ross Wanless.

10. SEABIRDS

A review of status, distribution and interaction with fisheries in the Soutwest Indian Ocean

Ross M. Wanless[1]

Abstract

The SWIO region has globally significant seabird assemblages, including 11 seabird families, around ⅓ of the world's species, and at least nine endemic taxa. A high proportion of the endemic taxa are of conservation concern, with invasive species on islands and fisheries impacts contributing most to their poor conservation status. Biogeographically, the region's seabirds can best be divided into two main assemblages: the procellariiform-dominated southern waters, and the tuna-associated seabirds of tropical waters. By virtue of their extent and numbers of islands for seabirds to breed, the French territories and Seychelles have the highest seabird diversity, with South Africa's assemblage being both significant in numbers and diversity, and in terms of uniqueness for the SWIO region. Fisheries in the region can have very significant, negative impacts on seabirds, through direct mortality and through reducing food availability (direct competition with seabirds or through removing commensal species with which seabirds associate). Direct mortality can be overcome without major impacts on fishing activities in trawl and longline operations. However the scale and nature of impacts from gillnet fishing in the region remains unknown, and could be significant in areas where high gillnet fishing effort overlaps with the foraging ranges of diving seabirds such as shearwaters and cormorants. Over-exploitation of tuna stocks is expected to have significant impacts on tropical seabirds, and should be investigated. Coordinated monitoring of seabird colonies, if the results are made public, can become a very cost-effective means to track changes in the marine environment. Although identifying marine hotspots for seabirds is relatively new and requires significant new and ongoing research effort, BirdLife International's marine IBA programme offers a rigorous approach that could help fisheries and conservation managers to incorporate seabird considerations in management and spatial planning.

Seabird biodiversity in SWIO

Seabirds are defined as species that derive their sustenance primarily from the sea and which spend the bulk of their time (when not on land at breeding sites) at sea. This definition excludes shorebirds (waders, herons and egrets, ibises, etc.), which derive varying amounts of energy from marine sources but which are essentially terrestrial/freshwater/estuarine. Eleven seabird families occur within the geographical scope of the Soutwest Indian Ocean as breeding species. They are typically referred to as penguins (Spheniscidae), albatrosses (Diomedeidae), petrels and allies (Procellariidae), storm-petrels (Hydrobatidae), diving-petrels (Pelecanoididae), tropicbirds (Phaethonidae), gannets and boobies (Sulidae), cormorants (Phalacrocoracidae), frigatebirds (Fregatidae), skuas (Stercorariidae), gulls and terns (Laridae).

Taxonomic revisions make definitive statements about seabird diversity an invidious exercise. Globally there are ~350 species belonging to the 11 families (plus the alcids which are exclusively northern hemisphere seabirds) that occur in the SWIO region. Around a third of those (i.e. >100 species) either breed on islands in, or are at least occasional visitors to, the SWIO. To place this statistic in some perspective, this is similar to the diversity of seabird species in New Zealand's territorial waters. Most of the seabirds found in the SWIO region fall broadly into three categories: (a) Indo-Pacific or pan-tropical, (b) highly migratory Procellariiformes from high southern latitudes, and (c) predominantly Atlantic species with distributions that are relatively marginal to the SWIO. Consequently, levels of endemism are relatively low compared with other regions. There are, however, at least nine extant, breeding endemics (Table 1) of which five are listed

1. BirdLife South Africa & Percy FitzPatrick Institute, University of Cape Town. Email: rosswanless@gmail.com

as globally threatened, including two critically endangered species (BirdLife International 2008). Half of these are from sub-Antarctic islands, two from La Réunion Island and two from the Arabian seas. The procellariiforms dominate the SWIO endemic seabirds, represented by two albatrosses (Amsterdam *Diomedia amsterdamensis* and Indian Yellow-nosed *Thalassarche carteri*), three petrels (Jouanin's *Bulweria fallax*, Reunion *Pseudobulweria aterrima*, and Barau's *Pterodroma baraui*), the Persian Shearwater *Puffinus persicus* and Salvin's Prion *Pachyptilia salvini*.

Some popular literature considers the St Paul Island-endemic MacGillivray's Prion *Pachyptila macgillivrayi* a valid species (e.g. Onley and Scofield 2007). This awaits genetic analyses or a formal, modern taxonomic treatment. Other dubious taxa include the Round Island Petrel (Mauritius), which is now known to be an extraordinarily rare four-species hybrid complex of *Pterodroma* petrels (Brown *et al.* 2011). The Imperial/King/Blue-eyed Cormorant/Shag *Phalacrocorax atriceps* complex is frequently split into several species, some of which may result in valid, island-endemic taxa in the sub-Antarctic islands of the SWIO. Finally, from the taxonomic disarray that is the cryptic, super-species complex, formerly lumped into Audubon's Shearwater *Puffinus lherminieri*, arises the very doubtful Mascarene Shearwater *Puffinus atrodosalis* (sometimes considered to be part of the Tropical Shearwater *P. bailloni* group (e.g. Onley and Scofield 2007)) and even more doubtful Mohéli/Comoro Shearwater *Puffinus [persicus?] temptator*. More believable but still requiring adequate taxonomic treatment is the Arabian/Persian Shearwater *Puffinus persicus*. See Onley and Scofield (2007) for speculative details on this complex issue.

In addition to some endemic and very range-restricted species, the SWIO region is host to globally important numbers of more widespread seabird species. The Seychelles and French islands together hold significant proportions of tropical seabird populations, some of which have huge numbers of breeding species. The region has 25% of the world's Sooty Terns *Sterna fuscata*, with prodigious colonies at Juan de Nova (French- Mozambique Channel = 2 million pairs), Cosmoledo Atoll (Seychelles = 1.8 million), Bird Island (Seychelles = 1 million) and Europa Island (French- Mozambique Channel = 1 million) (Le Corre and Jaquemet 2005, BirdLife South Africa unpubl data). Aride Island, Seychelles, has >10% of the world's Tropical Shearwaters and Lesser Noddies *Anous tenuirostris*, and Seychelles holds roughly 15% of the global population of the latter (Fishpool and Evans 2001; BirdLife International 2012). Aldabra Atoll has the world's second-largest frigatebird colony, estimated to be 10,000 pairs in 2000, and is the only oceanic breeding site for the Caspian Tern *Sterna caspia* (Fishpool and Evans 2001). For two of the southern African endemic seabirds, the Nelson Mandela Bay area (where the city of Port Elizabeth is located, southeastern South Africa) has always been important for seabirds.

Seabirds and trawler, South Africa. (Photo: Ross Wanless)

Table 1. Endemic seabirds of the SWIO region and their IUCN-listed conservation status. CR = Critically endangered; EN = Endangered; VU = Vulnerable; NT= Near threatened; LC= Least concern; ? indicates no threat assessment due to taxonomic uncertainty.

Species	*IUCN Status*	*Breeding islands*
Amsterdam Albatross *Diomedea amsterdamensis*	CR	Amsterdam
Indian Yellow-nosed Albatross *Thalassarche carter*	EN	Amsterdam, St Paul, Prince Edward Crozet and Kerguelen archipelagos
Barau's Petrel *Pterodroma baraui*	EN	La Réunion
Jouanin's Petrel *Bulweria fallax*	NT	Socotra Archipelago and islands off Oman
Reunion/Mascarene Petrel *Pseudobulweria aterrima*	CR	La Réunion
Salvin's Prion *Pachyptilia salvini*	LC	Prince Edward, Marion, and Crozet Archipelago
Persian Shearwater *Puffinus [bailloni] persicus*	?	Islands off Arabian peninsula
Socotra Cormorant *Phalacrocorax nigrogularis*	VU	Islands in Persian Gulf and Arabian Sea
Kerguelen Tern *Sterna virgata*	NT	Prince Edward, Marion, Crozet and Kerguelen archipelagos

Subsequent to the implosion of African Penguin (*Spheniscus demersus*) numbers at Atlantic colonies, the SWIO island of St Croix now hosts the largest colony (>8000 pairs in 2011) and ~50% of the global population (>11,000 pairs in 2011 out of an estimated ~23,000 pairs globally) breeds in the Bay (Crawford *et al.* 2011). Similarly, the near-total collapse of Namibia's Cape Gannet *Morus capensis* colonies has resulted in Bird Island, next to St Croix Island, now hosting 65% of the global population (~90,000 out of ~120,000 pairs in 2005/06) (Crawford *et al.* 2007).

For species breeding in the subAntarctic, the SWIO holds significant numbers of several Procellariforms: Wandering Albatross (*D. exulans* – 74% global breeding pairs), Sooty Albatross (*Phoebetria fusca* – 39% global breeding pairs), Light-mantled Albatross (*P. palpebrata* – 32% global breeding pairs), Grey-Headed Albatross (*T. chrysotoma* – 20% global breeding pairs) and Southern and Northern Giant-Petrels (*Macronectes giganteus* and *M. halli* – 30% and 26% global breeding pairs, respectively) (ACAP 2010).

Distribution and migration patterns, including important bird areas

There is great variation, mixing and overlap of habitat types and seabird community composition in the SWIO. Nevertheless, broadly speaking one may identify three biogeographic zones with characteristic species assemblages. These are (a) tropical waters (north of ~25°S), (b) the temperate and sub-Antarctic, Procellariiform-dominated waters (south of ~25°S), and (c) the neritic waters of South Africa.

BirdLife International has embarked on a programme to identify marine Important Bird and Biodiversity Areas (IBAs) globally (Howgate and Lascelles 2007), including a strong focus on the SWIO (Derand *et al.* 2009; Kappes *et al.* 2010). At the time of writing no marine IBAs had been formally designated in the SWIO, but reference is made to areas that have been identified as being important to seabirds; it is likely that marine IBAs will coincide with many of the sites described below, and the term IBA is used accordingly.

Tropical waters

These waters are dominated numerically by the tropicbirds (two species), boobies (three species), frigatebirds (two species) and terns (>10 species), with *Puffinus* shearwaters also common, but less abundant and usually less visible than the other groups. None has substantial ranges during breeding. However, because there is not the marked seasonality in the tropics as there is further to the south, there tends to be less rigid periodicity to the breeding cycles, with some species' breeding cycles being less than 12 months. Indeed, it is not unusual to find seabirds present at breeding colonies year-round (Le Corre 2001). The main breeding grounds are the islands off Arabia and the Socotra Archipelago, Seychelles, the Mascarenes and the Mozambique Channel.

Migration patterns are not well understood for most tropical seabird species. With few exceptions, tropical seabirds associate very strongly with tuna, and feed in association with them (Le Corre 2001). As a consequence, their post-breeding dispersal is likely to be linked to broad-scale oceanic features (such as productive upwelling or mixing areas) to which forage fish, and consequently tunas, are attracted. Recent work using tracking technologies to identify foraging ranges of seabirds in La Réunion, Seychelles and other Southern Hemisphere tropical sites has identified five large-scale IBAs in the SWIO (Le Corre *et al.* in press). A sixth important site is located in the central Indian Ocean. The SWIO sites include (i) the Seychelles basin (east of the granitic Seychelles), (ii) the pelagic waters encompassing the Aldabra Group northwards and west of the Seychelles Basin, (iii) from La Réunion southwards, (iv) the area south of Madagascar and (v) the southern third of the Mozambique Channel and southwards to ~30°S. The principal species for which these areas are important are Wedge-tailed Shearwater (i), Greater Frigatebird (ii,v), Red-tailed Tropicbird *Phaethon rubricauda* (v) and Barau's Petrel (iii-v).

Temperate and sub-Antarctic waters

These pelagic waters, sub-Antarctic and cool-temperate islands and the highly productive South African continental shelf waters, are dominated by the procellariiform seabirds (albatrosses, petrels and allies, storm-petrels and diving-petrels) and a cameo role from the Southern Skua *Catharacta antarctica*. In addition, several species of near-shore-foraging larids and cormorants breed here, with only one breeding species (Antarctic Tern *Sterna vittata*) migrating northwards during the austral winter.

The procellariiform seabirds are amongst the most mobile birds on earth, and are capable of traveling prodigious distances, even when foraging to provision chicks (Weimerskirch *et al.* 1997; Croxall and Gales 1998; Baker *et al.* 2007; Rolland *et al.* 2009). Individuals of many species circumnavigate the globe repeatedly when not breeding, or as immatures (BirdLife International 2004). Consequently, efforts to identify 'hotspots', or marine IBAs, are complex and the results often encompass vast expanses of ocean (e.g. Delord and Weimerskirch 2009; 2011).

Many species which breed in the sub-Antarctic SWIO, as well as other Procellariiformes from colonies in both the Atlantic and Pacific oceans, migrate to the South African continental shelf and surrounding waters (BirdLife International 2011). In the austral summer, the numbers of Southern Ocean Procellariiformes in the area drop as adult birds leave to breed. They are replaced by migratory species from the northern hemisphere, including several Procellariiformes and larids (unpubl. data).

Neritic South African waters

The highly productive shelf waters, particularly the Benguela system south and west of South Africa (and north into Angola) have given rise to a suite of endemic seabirds, including Africa's only penguin, the African Penguin, the Cape Gannet, four cormorant species, a gull (Hartlaub's Gull *Larus hartlaubi*) and a tern (Damara Tern *Sterna baleanarum*) (Crawford *et al.* 2006). All disperse after breeding to some extent, and with minor exceptions, all remain in coastal waters. This zone is important for several non-endemic coastal species, primarily the Kelp Gull *Larus dominicanus* and several tern species, that also breed at coastal locations. Finally, a suite of northern hemisphere larids migrate to these waters in the austral summer.

Marine IBAs are likely to be focused on the breeding colonies, which in this part of the Indian Ocean include only St Croix and Bird islands near Port Elizabeth.

Features of seabirds in each of the SWIOFP countries

Of the eight SWIOFP countries, three hold exceptional diversity of breeding species. These are the French islands, Seychelles and South Africa. Between them they have all the major breeding sites in the SWIO, and all the endemic species of the SWIO aside from the two species from the islands of the far northwestern Indian Ocean. Nevertheless, all eight countries have terrestrial IBAs of global importance for seabirds, hosting >1% of the global population of at least one species, or congregations of >20 000 individuals (Fishpool and Evans 2001).

As tracking technology continues to miniaturise, and thereby bringing the technology within reach of researchers interested in smaller, tropical seabirds, we may well discover more pelagic sites that are globally significant. Climate change, and with it the profound, but as yet unpredictable consequences for the marine environment, may also add or subtract breeding and visiting species from the SWIOFP countries' national lists. Case in point is the distribution of the Flesh-footed Shearwater *Puffinus carneipes*, which migrates westward into the SWIO waters from the eastern Indian Ocean.

Field guides to the birds of the region from the 1990s reported this species as incidental from places like Mauritius or Comoros (see Sinclair and Langrand 1998; Onley and Scofield 2007). More recently sightings from both these locations (pers. obs.; V. Head pers. comm.), suggest a possible increased presence in the region. Also, the traditionally sedentary and highly natal philopatric Cape and Australasian *M. serrator* gannets have colonised St Paul Island relatively recently (Lequette *et al.* 1995). Similar changes in abundance or presence can be expected to continue as fishing and climate change continue to shape the distribution of marine biodiversity.

Common Noddy and Sooty Terns, Comoros. (Photo: Ross Wanless)

Comoros

Breeding seabirds in this archipelago are characterised by low numbers and low diversity, mostly common, pantropical species and confined (with two exceptions) to a single offshore stack close to the eastern extreme of Mohéli Island (pers. obs.). Small numbers of White-tailed Tropicbirds *Phaethon lepturus* and the Tropical/Persian/Comoro Shearwaters breed in forested uplands on Mohéli, the latter in sufficient numbers for the site to be declared an IBA by BirdLife International (Fishpool and Evans 2001, K. Green pers. comm.). All seabirds in the region associate strongly with feeding tunas (pers. obs.)

French islands

The French territories in the SWIO stretch from Mayotte in the north to the Kerguelen Archipelago in the deep south Indian Ocean, and include La Réunion, Mayotte, the Isles Esparses (Islands of Bassas da India, Europa, Glorieuses, Juan de Nova, Tromelin), Amsterdam Island, St Paul, and the Crozet and Kerguelen archipelagos. With such a vast biogeographic range, it is small wonder that the French territories encompass six of the SWIO-endemic species listed in Table 1. The territorial waters include virtually all the seabird species typically found south of the equator, with the exception of the coastal species in South African waters. The cool-temperate and sub-Antarctic islands have highly speciose breeding assemblages relative to anywhere else in the region. Although strict quantification has not been attempted, because of this vast biogeographic spread, the French territorial waters collectively are the most biodiverse in the SWIO for breeding seabirds.

Kenya and Tanzania (including Zanzibar)

Local oligotrophic coastal waters are notably depauperate in seabirds and only the small island of Latham, south of Dar es Salaam, has colonies of regional significance with large populations of Masked Boobies, Swift & Sooty terns and Brown Noddies (Crawford *et al.* 2006). Other breeding assemblages include the globally important Roseate Tern *Sterna dougali* (Fishpool & Evans 2001). Offshore, migratory movements of wide-ranging, tropical species add diversity, but small numbers of birds to the countries' seabird communities.

Madagascar

The few intact breeding colonies on offshore islands, in estuaries and remote beaches around Madagascar's coast, host reasonable numbers (globally unremarkable) of relatively common, widespread species – mostly near-shore-foraging terns (Fishpool and Evans 2001). However, the region's offshore islands have not been extensively surveyed (M. Le Corre pers. comm.) and may yet reveal some surprises.

Madagascar's EEZ is important for all the species breeding in, and migrating to, the Mozambique Channel (notably frigatebirds, tropicbirds and terns), and the southernmost waters are part of the IBA identified by Le Corre *et al.* (in press) for Barau's Petrel.

Mauritius

With the exception of the 'Round Island Petrel' hybrid complex, described above, Mauritius has low numbers of common, pantropical seabird species breeding. Southern Ocean Procellariiformes occasionally venture into Mauritian waters, and they are at some risk from tuna longline fishing effort. However, by virtue of its extensive EEZ, Mauritius' waters are assumed to be important for a wide diversity of tropical seabirds, including the endemics petrels of La Réunion.

Mozambique

Here, as in Kenya and Tanzania, there are few major seabird breeding colonies. This is probably due to the lack of suitably remote or inaccessible islands. However, as for Madagascar, the territorial waters of Mozambique are important for all the species breeding in and migrating to the Mozambique Channel (notably frigatebirds, tropicbirds and terns), and the southernmost waters are part of the IBA identified by Le Corre *et al.* (in press) for Barau's Petrel.

Seychelles

The Seychelles is arguably the most important country in the SWIO region for seabirds. Its ~155 far-flung islands combine to create an area of territorial waters that is staggeringly vast: ~1.4 million km². Although it hosts no endemic seabirds, it has the greatest diversity of breeding species in the tropical waters (18 species), and has globally important colonies of several species, with millions of seabirds in total. Several islands or island-groups are of exceptional importance. The assemblages and number of individuals at Cousin and Aride islands in the granitics, the astonishing numbers of Sooty Terns at Bird Island and Cosmoledo Atoll, and the Aldabra Group with both the diversity and numbers of seabirds (especially of large-bodied species such as boobies and frigatebirds) are all recognized internationally as sites of exceptional biodiversity and conservation value.

South Africa

By virtue of the extension into the SWIO, the ranges of all the endemic seabirds of the Benguela Ecosystem, essentially an Atlantic Ocean phenomenon, South Africa holds the most unique and distinctive seabird community. Added to its continental assemblage, being a mix of 'Benguela' endemics and huge diversity of migratory species, are the 26 species that breed at the sub-Antarctic Prince Edward islands in the South Indian Ocean.

Notable hotspots

The small body size of the larid-dominated seabird assemblages in SWIO tropical waters has hampered research into migratory behaviours. This is largely the result of weight constraints for tracking devices (Passos *et al.* 2010 and references therein), which until relatively recently could only be placed on larger species (e.g. Afanasyev 2004). A second constraint is, somewhat ironically, their good conservation status. Expensive remote sensing studies have necessarily focused on species of the highest conservation concern. However, enough is known about foraging ranges during breeding to identify the waters around important breeding colonies as *prima facie* marine IBAs (e.g. Kappes *et al.* 2010).

Le Corre (in press) has summarized current understanding of migratory behaviour of birds in the tropical SWIO. Frigatebirds from Aldabra and Europa range widely, primarily northwards, and into the Maldives area. White-tailed tropicbirds also range extremely widely outside the breeding season, with a hotspot that overlaps with the non-breeding distribution of Barau's Petrel, in the central tropical Indian Ocean.

BirdLife International has used tracking data in the Global Procellariiform Tracking Database to analyse the degree of overlap between tracked populations of procellariiform seabirds in the Indian Ocean and longline fishing effort (ACAP 2007). Subsequent analyses focusing on seabirds from the French islands (Delord and Weimerskirch 2009, 2010, 2011) have confirmed that the entire SWIO area from 25°S southwards is heavily utilized by a diversity of threatened seabirds. Attempts have been made to refine the areas into 'hotspots' for the purposes of identifying areas where species vulnerable to bycatch from tuna longline fishing are at highest risk (Inoue *et al.* 2011). However, scientists at the Indian Ocean Tuna Commission's 2011 meeting of the Working Party on Ecosystems and Bycatch concluded that no reasonable grounds existed for identifying any smaller area than south of 25˚S as a hotspot (IOTC-WPEB07 2011).

Most vulnerable species

None of the typical SWIO tropical species is currently of global conservation concern. However, the two Reunion-endemic petrel species are of high conservation concern, as are most of the larger procellariiform seabirds that breed in or visit the SWIO. The African Penguin and Cape Gannet are the most threatened coastal South African species in the SWIO region.

Interaction with fisheries and issues of bycatch

There are two general and a third very specific negative interactions between seabirds and fisheries in the SWIO. Incidental capture or entanglement with gear, including in longline, trawl and gillnet fisheries, have received a large amount of attention. This is in part due to the physical evidence of negative interactions, in the form of dead birds, which makes the connection between fishing and seabird mortality impossible to ignore. The second risk is more insidious: loss of foraging opportunities due to depleted tuna stocks (Dankwerts *et al.* 2014). The third, direct competition with fisheries targeting low trophic level fish, is difficult to quantify and globally there are few examples (Cury *et al.* 2011).

Fisheries can cause reductions in food through overfishing or competition for the same prey. While direct impacts of overfishing on seabirds can be difficult to prove, there is evidence of overfishing of tuna and tuna-like stocks in the SWIO region (numerous reports on the IOTC website www.iotc.org). Many terns, tropicbirds and noddies, common in tropical and subtropical regions, forage in association with large predatory fish such as tuna (Ramos 2000, Le Corre *et al.* 2012). The tunas drive small forage fish species to the surface, bringing them within the range of seabirds. If the abundance of tuna is reduced through overfishing, these and other seabird species will not be able to forage as successfully (Le Corre *et al.* 2012). The species in the Afrotropical region most likely to be affected by this are the tropicbirds, boobies, frigatebirds, noddies, and Bridled *Sterna anaethetus* and Sooty *S. fuscata* terns (Dankwerts *et al.* 2014).

Red-footed Booby, Seychelles. (Photo: Ross Wanless)

DIRECT SEABIRD MORTALITY FROM FISHERIES INTERACTIONS

Seabirds are characterised as being late to mature and slow to reproduce. For example, many albatrosses do not breed before they are ten years old (e.g. Weimerskirch 1992; Wanless *et al.* 2009). Most seabirds lay a single egg each year, few can lay replacement clutches, and some albatross species produce at most one chick every second year. To compensate for this unusually low fecundity, seabirds are amongst the most long-lived birds, with natural adult mortality typically very low. These traits make adult mortality from anthropogenic sources potentially damaging for population viability, as even small increases in mortality can result in population decreases (Weimerskirch and Jouventin 1987; Finkelstein *et al.* 2008; Wanless *et al.* 2009). To illustrate this, consider the case of the endemic Amsterdam Albatross *Diomedea amsterdamensis* population, which is currently listed as Critically Endangered and breeds only on Amsterdam Island, in the southern Indian Ocean. The population (estimated to a maximum of 180 adults in the world) will decrease if there is an additional mortality of just five adult birds per year (Weimerskirch *et al.* 1997; Weimerskirch 2009).

Fisheries bycatch is the single greatest threat facing many populations of seabirds which breed or visit the western Indian Ocean on a regular basis (Weimerskirch *et al.* 1997; Nel *et al.* 2002; Anderson *et al.* 2011). Longline fisheries globally are responsible for contributing to the poor conservation status of many Procellariiformes (Anderson *et al.* 2011). Albatrosses, in particular, are under extreme pressure with 15 of the 22 species threatened with some level of extinction (and the remaining five species listed as near-threatened). On the positive side, the rich and abundant seabird assemblages in the tropical waters of the SWIO region are largely immune to direct, incidental mortality from longline fishing (or other types of entanglement with fishing gear). The foraging strategy common to virtually all tropical seabirds is to pursue live prey, and so the dead, drifting bait on longline hooks is of no interest to them. This contrasts with the procellariiform foraging strategy, which involves scavenging of dead, floating items (e.g. post-spawning squid). This pre-adapts Procellariiformes to find baited longline hooks extremely effectively.

Seabird bycatch is unnecessary, unintentional and in most cases, largely preventable (Gilman *et al.* 2005). In fact, it not only has disastrous consequences for the birds, but may render certain fishing operations less efficient – for example in longline fishing, when bait loss to scavenging seabirds and seabird captures occupying hooks that would otherwise be available to catch the exceptionally high-value target fish (Brothers *et al.* 1999; Bull 2007). Several simple and effective solutions have been developed that can reduce seabird bycatch significantly in longline and trawl fisheries (Gilman *et al.* 2005; FAO 2009).

Evidence from areas where seabird bycatch was formerly high but has been reduced (e.g. CCAMLR and South Africa) has shown that currently there is no single measure that can effectively reduce seabird bycatch (Waugh *et al.* 2008; Petersen *et al.* 2009). It is important to employ, simultaneously, a suite of measures (Bull 2007; ACAP 2011). Best practice for mitigation measures as recommended by ACAP (Agreement on the Conservation of Albatrosses and Petrels) includes night setting, appropriate deployment of well designed 'bird scaring lines', and properly weighted lines that ensure that baits sink below the reach of diving seabirds quickly (ACAP 2011). These recommendations apply to pelagic and demersal longlines, although the technical specifications for measures differ with gear type. Encouragingly, the Indian Ocean Tuna Commission (IOTC) followed recommendations from its Science Committee, and at their 2012 meeting adopted a binding resolution for all longline vessels operating south of 25°S to use two of the three measures.

Seabird fatalities in trawl fishing arise from three sources: net captures (diving birds swimming into the path of the open trawl net and being drowned), net entanglements (birds becoming entangled with the net) and cable strikes. Strikes against the net sonde, or sensor cable, were identified in the early 1990s (Bartle 1991), leading to the banning of the use of net sonde cables in several fisheries (e.g. CCAMLR 1998). Negative interactions with trawl net cables (or warps) have only been recognized and quantified relatively recently (Sullivan *et al.* 2006; Watkins *et al.* 2008). However, due to the sheer scale of the fishing effort of many trawl fisheries, comparatively low rates of fatal interaction can still multiply up to very substantial total mortalities. In South Africa, seabird mortalities were estimated to be 18,000 birds per year (Watkins *et al.* 2008). Bird scaring lines were introduced in 2006, and have proven to be almost completely effective in eliminating warp strikes in South Africa (Maree *et a*l. 2014). In sharp contrast, trawling operations in the tropical reaches of the SWIO have a negligible direct impact on seabirds. This is because trawling is mostly confined to shrimp trawling which seldom if ever records seabird bycatch and moreover, trawling is prohibited in all the small island states of Seychelles, French *Eparses* and the Mascarenes – all areas of high seabird abundance. However, the development of new trawl fisheries should be assessed for risks to seabirds before being authorised.

A third capture fishery technique that is of unknown scale and unquantified risk to seabirds in the region is gillnet fishing. Gillnet fishing is known to pose a huge risk to diving seabird species elsewhere (Melvin *et al.* 1999; Darby and Dawson 2000), and is assumed to pose similar risks within the SWIO. Large-scale driftnets (>2 km long) were banned by the United Nations from use on the high seas, but several coastal fishing nations in the northern Indian Ocean are known to fish in contravention of this ban (IOTC-WPEB07 2011), and any developments along this line in the SWIO region should be monitored and curtailed. That said, few breeding seabird species in the region have diving foraging behaviour that renders them highly susceptible to gillnet fishing.

Recommendations

Understanding where seabirds concentrate at sea is a precursor to implementing at-sea conservation actions and spatial protection. The Nairobi Convention has endorsed the concept of marine IBAs as a tool to assist in spatial conservation planning, and IBAs have been used extensively in defining the Convention on Biological Diversity's 'Ecologically or Biologically Significant Areas' (EBSA) programme.

Recommendation*: *Marine IBAs should be identified and integrated into national and regional fisheries planning (where appropriate, and without necessarily indicating no fishing in IBAs) and marine protected area networks. South West Indian Ocean Fisheries Commission (SWIOFC) should include EBSAs and marine IBAs (national and in the high seas) as sites of concern which require additional caution when considering fishing activities and possible fishing impacts on marine ecosystems and species.

There is a widespread misperception that negative interactions between seabirds and fisheries are primarily the domain of longliners. Two other fishing impacts within the SWIOFP area are of concern. Gillnet fishing poses very significant risks to seabirds elsewhere (Zydelis *et al.* 2009) and should be investigated where diving birds (in particular Socotra Cormorant and all shearwaters) occur. The second is the risk of population decreases of tropical seabirds from reduced numbers of commensal species – primarily tunas and cetaceans (Dankwerts *et al.* 2014).

Recommendation*: *SWIOFC should collaborate with the IOTC secretariat to assess possible impacts of tuna stock depletions on tropical seabird species.

Fairy Tern, Seychelles. (Photo: Ross Wanless)

REGIONAL OBSERVER SCHEMES

Independent, on-board fishery observer programmes are globally recognized as the best, and in many cases the only way to collect reliable information about fishing impacts on target and non-target stocks (e.g. Tuck 2011; Tuck *et al.* 2011). They are also crucial for collecting information about the degree of use and for assessing the effectiveness of various seabird bycatch mitigation measures. A shortcoming of some regional observer schemes is that they fail to require the submission of data to a centralized database (Wanless and Small 2011). This restricts the utility of such schemes in providing useful, region-wide, ecosystem-level data that fisheries managers and RFMOs can access readily for managing fisheries impacts. Elsewhere, such as within the CCAMLR region, all fishing vessels are required to carry at least one independent scientific observer at all times, and the observer data are centrally managed. This has allowed CCAMLR to respond quickly and effectively to a range of issues, including seabird bycatch, which has now been reduced to negligible levels thanks to 100% compliance with conservation measures (CCAMLR 1998; Waugh *et al.* 2008).

***Recommendation*: SWIOFC should initiate a regional scientific observer programme for all sizeable fisheries under its ambit.**

ON-BOARD COLLECTION OF SEABIRD ABUNDANCE AND DISTRIBUTIONAL INFORMATION

Seabirds are frequently the most visible indicators of productive marine areas. At sea, fishermen commonly use seabird flocks to locate schools of target fish. Understanding seasonal and spatial patterns in seabird abundance, and how these might shift with climate change and altered fishing practices or fishing areas, is of great scientific interest. However, tracking studies are necessarily limited in scope due to financial and logistical constraints. At-sea atlas data from observers on board fishing vessels or research cruises is a valuable, relatively low-cost option for collection large volumes of coarse atlas data, and has been used already to identify marine IBAs elsewhere (e.g. Amorim *et al.* 2009). This would require dedicated training of a few observers, as at-sea identification of flying seabirds is a specialist skill. Nevertheless, the scale of fishing operations in the SWIO region affords tremendous potential for voluminous and valuable at-sea data collection.

***Recommendation*: Observer training courses should deliberately identify individuals with an aptitude for seabird identification and methodological rigour, and train them in AS@S data collection and accession systems – see databases section for a description of this project.**

Conclusion

Most conservation efforts for seabirds relating to mitigating impacts from fisheries will require concerted and coordinated approaches. Seabirds are the most international of all birds, spending more time than any other bird group in international waters, which are by definition beyond national jurisdictions. Most species within the WIO are migratory or dispersive outside the breeding season to some extent, and can be expected to cross national boundaries and enter into international waters.

The meta-population dynamics of the more widespread and commoner seabirds in the WIO region are poorly understood, and losses of breeding colonies or subpopulations in one area cannot necessarily be compensated for by healthy colonies or subpopulations elsewhere. Fortunately, seabirds are the most conspicuous components of above-water marine biodiversity, making them easier to monitor than virtually any other group of marine animals. Secondly, they are obligate terrestrial breeders, returning predictably to colonies to lay eggs and raise their young. This facilitates more accurate counting and estimation of productivity (and other vital rates) than most marine species with which marine scientists and stock assessors are accustomed to working.

Coordinated monitoring of seabirds at colonies and at sea will serve multiple trans-boundary diagnostic analyses, providing that data are suitably reliable and accessible. It is incumbent on nations and intergovernmental organisations such as SWIOFC to monitor and assess the impacts of capture fisheries on non-target associated and dependent species, including seabirds. The known and likely impacts of fisheries on seabirds described above provide a *prima facie* case for contributing to regional/international seabird data collection protocols (see databases below). However, as already noted, seabirds are highly conspicuous, and are dependent on or indicators of many of the target species in SWIO fisheries. Therefore monitoring their patterns of abundance and distribution, as well as other parameters (such as breeding participation, adult body condition, chick provisioning rates, etc.) can provide important corroborative evidence or early warnings of adverse marine conditions that may impact negatively on important commercial or artisanal fisheries.

BirdLife International's Important Bird Areas programme, which includes marine IBAs, is listed as a key contributor to many objectives in the Strategic Action Plan (SAP). The IBA programme speaks to coastal zoning objectives, the identification of critical habitats and development of management approaches, regional monitoring of and evaluations for critical habitats, and through the various databases that BirdLife International runs, the management of regional information.

Known databases

- **BirdLife International Datazone**
  http://www.birdlife.org/datazone/home
  This searchable, online database contains information, maps and reports on the conservation status of all 10,000 of the world's bird species, as well as site descriptions of >10,000 Important Bird Areas. The marine atlas http://www.birdlife.org/marine is a work in progress, but has several hundred marine IBAs already identified.

- **The Global Procellariiform Tracking Database**
  http://www.seabirdtracking.org
  This is a central store for seabird tracking data from around the world. Data can be searched and viewed (subject to owner's permissions) within the site, but access to actual tracking data is restricted within a request process. There are plans to expand this to include tracking data from all seabirds, or to make the site fully interoperable with other seabird tracking and environmental/habitat (e.g. chlorophyll-a and SST) databases.

- **BirdLife International seabird foraging range database**
  http://seabird.wikispaces.com/home
  This is an online, database compilation of seabird ecology and foraging ranges. Its stated purpose is to use this information to help identify marine Important Bird Areas, inform Protected Area designation and input to marine spatial planning.

- **World Seabird Union**
  http://seabirds.net
  This site was under construction at the time of writing, but intends to become the central portal for seabird information, as well as the primary repository for some important databases, such as a seabird colony register, a seabird monitoring database and possibly a survey database. It also has an interactive map displaying seabird study metadata, with the intention that it becomes global and comprehensive.

- **Wetlands International/Ramsar sites database**
  http://ramsar.wetlands.org/Database
  This site provides information of all wetlands of international importance. It is a searchable database, fully accessible through the internet with a password protected data entry system, and a reporting system for public use. However, the quality of data publically available is generic, non-specific and of limited utility.

- **Indian Ocean Tuna Commission (IOTC)**
  http://www.iotc.org/English/data.php
  The Secretariat of this tuna commission maintains databases on nominal catch (from 1950), discards (not available for download), catch and effort (from 1998), and other statistics. All documents submitted to the various working parties and meeting reports are also available from this site.

- **The Agreement on the Conservation of Albatrosses and Petrels (ACAP)**
  http://www.acap.aq
  The data portal on this site links to comprehensive assessments of all the ACAP species, islands and breeding sites, Regional Fisheries Management Organisations and reference literature.

- **Atlas of Seabirds at Sea (AS@S)**
  http://seabirds.saeon.ac.za
  An open-access online database of at-sea survey data, including digitized records starting in the 1950s and continuing to the present. The protocols and data sheets are available online, and the system follows a simple and very flexible data collection principle. All data on this site are freely downloadable.

- **The Scientific Committee on Antarctic Research (SCAR)**
  http://www.scarmarbin.be
  This is a website containing data, including seabird distributional data, primarily of Antarctic relevance, but extending into the southern Indian Ocean.

White-tailed tropicbird, Seychelles. (Photo: Ross Wanless)

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11.
ELASMOBRANCHS (SHARKS AND RAYS)

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Previous page: Silky shark, *C. falciformis*. One of the most common bycatch shark species in the open-ocean purse seine fishery associated with floating objects. Photo by Chris Fallows, www.apexpredators.com.

11. ELASMOBRANCHS (SHARKS AND RAYS)

A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean

Jeremy Kiszka[1] and Rudy van der Elst[2]

Abstract

An overview of available information on sharks and rays in the Southwest Indian Ocean (SWIO) is presented, highlighting their dynamics, role in fisheries and conservation status. Despite their prominence , little directed research and assessment has been undertaken with the exception of studies in KwaZulu-Natal (South Africa), largely attributable to historic problems of shark attack. Additional drivers of research have focussed on charismatic species with tourist value.

Elasmobranchs are targeted or taken as bycatch in a range of SWIO fisheries, including longline, purse seine, pelagic drift net and especially shrimp trawling with high impact on endemic species. Some 188 species have been recorded by 39 nations totalling a catch of > 100,000t in 2012. However, FAO records reveal that shark catches in the western Indian Ocean have almost halved from a peak of 180,000t in 1996.

Analysis of records for coastal waters of 11 SWIO countries provides insight into the scale of fisheries and conservation status of elasmobranchs in different regions. Available information on shark behaviour, ecology, local distribution, aggregations, nursery areas and migrations is interrogated. Significant information gaps remain with knowledge on the ecology, biology and fisheries for elasmobranchs highly fragmented; disconcerting in the light of declining catches in the SWIO. Available data is generally inadequate for the assessment and management of stocks. However, new smart tag technology and genetic profiling is expanding the information on elasmobranchs. In addition, some mitigation measures have been implemented to minimise elasmobranch bycatch through the installation of bycatch reduction devices (BRDs) in several trawl fisheries. A start has also been made with the FAO-promoted National Plans Of Action for sharks (NPOA), with several countries having produced initial reports to underpin the conservation and management of sharks.

Introduction

Elasmobranchii is one of the two subclasses of cartilaginous fish in the class Chondrichthyes, the other being Holocephali (chimaeras). They occur in all oceans, from coastal to oceanic waters, from the surface to depths of more than 3,000 meters (Priede *et al.* 2006). Elasmobranchs range from planktivores to apex predators and exhibit every reproductive mode known in vertebrates, from egg laying to placental viviparity (Shelson *et al.* 2008). Most elasmobranchs (sharks and rays) and the related chimaeras are characterised by low fecundity and productivity, slow growth, late age at maturity, large size at birth, high natural survivorship and a long life. Such biological characteristics have serious implications for the sustainability of shark and ray fisheries (Kiszka & Heithaus 2014). Not surprisingly, these species are dependent on a stable environment, and generally have limited capacity to sustain and recover from heavy fishing pressure.

Among the 1,160 species of cartilaginous fishes known, 188 have been recorded in the Southwest Indian Ocean region (SWIO). Except for South Africa (especially the coast of KwaZulu-Natal province), little effort has been made to assess the status of sharks and rays in the SWIO, although some species have been more investigated than others in the region, notably the larger and emblematic species such as the whale shark (*Rhincodon typus*) and the reef manta ray (*Manta alfredi*).

This chapter provides an overview of available information on the status, fisheries (including directed exploitation and incidental catches, or bycatch) and management of elasmobranchs in the SWIO.

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Regional biodiversity and critical habitats for elasmobranchs in the Southwest Indian Ocean (SWIO)

This section highlights the level of knowledge on diversity and status of elasmobranchs in national waters of the SWIO countries. Generally, information on elasmobranchs is poor in most areas, except for the east coast of South Africa, where research was stimulated largely in response to a spate of shark attacks on bathers in the region. The Annex lists the species that have been recorded in the region, which includes more than 30 endemic species.

COUNTRY OVERVIEWS

South Africa (KwaZulu-Natal)

The most extensive research on the taxonomy, diversity, ecology and behaviour of elasmobranchs in the SWIO has been conducted in South Africa. Research on elasmobranch taxonomy and ecology in South Africa was initiated in the 1960s at the Oceanographic Research Institute by Davies (1964), Bass *et al.* (1973, 1975 a, b, c, 1976) and Wallace (1967 a, b, c). While their research publications remain relevant today, subsequent studies at the KwaZulu-Natal Sharks Board (KZNSB) have enriched the baseline information substantially. Their role in protecting the province's bathing beaches from shark attack for the past 40 years has allowed them to document relative abundance (including inter-annual and seasonal), breeding, feeding ecology and behaviour of sharks in this region. From 1980 to 2010, 216 peer-reviewed papers on elasmobranch ecology, taxonomy, distribution, and abundance have been produced in South Africa (Escobar-Porras & Sauer 2011), a large proportion of papers being based on data generated from net catches made by the KZNSB. The relative occurrence of the most common species caught in the nets is presented in Table 1.

From 1978 to 2003, the population status of 14 species of sharks caught in the KZNSB nets was investigated (Dudley & Simpfendorfer 2006). Catch rates of four species (*Carcharhinus leucas*, *Carcharhinus limbatus*, *Sphyrna lewini* and *Sphyrna mokarran*) showed a significant decline, as did the mean or median length of three species (*Carcharhinus amboinensis*, *C. limbatus* and female *Carcharodon carcharias*). The potential impact of the shark nets was assessed to be high for at least three species (*C. leucas, Carcharhinus obscurus* and *Carcharias taurus*), because of their very low intrinsic rates of population increase (Dudley & Simpfendorfer 2006). Holden (1977) and van der Elst (1979) had earlier concluded that the inshore species of sharks were most susceptible to reduction in numbers through shark netting off KwaZulu-Natal.

Shark abundance and diversity is seasonally influenced by the "Sardine Run", a winter influx of shoals of South American pilchards (*Sardinops sagax*) from the southwest during the austral winter. This spectacular event attracts large numbers of top predators, including seabirds, marine mammals and elasmobranchs to the KwaZulu-Natal coast. The effect of the Sardine Run on shark catches off the coast of KwaZu-

Table 1: Mean annual shark catches in KwaZulu-Natal Sharks Board nets from 2006 to 2010. (Source: http://www.shark.co.za/catchstatistics)

Species		***Mean number of animals caught***		***Percent released***	***Mortality*** (No. of animals)
		Caught	*Released*		
Great white	*Carcharodon carcharias*	28	3	10.7	25
Short-fin mako	*Isurus oxyrinchus*	4.8	0.8	16.7	4
Tiger	*Galeocerdo cuvier*	51.4	18.8	36.6	32.6
Raggedtooth	*Carcharias taurus*	62.8	14.6	23.2	48.2
Common thresher	*Alopias vulpinus*	0.2	<0.1	<0.1	0.2
Bigeye thresher	*Alopias superciliosus*	0.2	<0.1	<0.1	0.2
Pelagic thresher	*Alopias pelagicus*	0.0	<0.1	<0.1	<0.1
Bull (Zambesi)	*Carcharhinus leucas*	15	2.8	18.7	12.2
Pigeye	*Carcharhinus amboinensis*	5.2	0.6	11.5	4.6
Dusky	*Carcharhinus obscurus*	138	19.8	14.3	118.2
Sandbar	*Carcharhinus plumbeus*	4.6	0.2	4.3	4.4
Copper	*Carcharhinus brachyurus*	9.6	0.6	6.3	9
Blacktip	*Carcharhinus limbatus*	67.4	10.2	15.1	57.2
Spinner	*Carcharhinus brevipinna*	54.6	3.4	6.2	51.2
Great hammerhead	*Sphyrna mokarran*	0.6	<0.1	<0.1	0.6
Scalloped hammerhead	*Sphyrna lewini*	64	0.2	0.3	63.8
Smooth hammerhead	*Sphyrna zygaena*	34.4	0.6	0.7	33.8
Unidentified hammerheads	*Sphyrna* spp.	1.2	0.2	16.7	1
Snaggletooth	*Hemipristis elongatus*	0.6	<0.1	<0.1	0.6
Blue	*Prionace glauca*	0.2	<0.1	<0.1	0.2
Species unknown		3.6	0.8	22.2	2.8
Total		***546.4***	***76.6***	***14***	***469.8***

lu-Natal is particularly significant in June and July, with the presence of copper (or bronze whaler) sharks (*Carcharhinus brachyurus*) being strongly associated with sardine shoals. Spinner sharks (*Carcharhinus brevipinna*) and scalloped hammerhead sharks (*S. lewini*) are normally caught in greater numbers in summer than in winter, but they appear to shift their spatial distribution seasonally to feed on sardines (Dudley & Cliff 2010a).

The most charismatic shark species in South Africa, the great white shark (*C. carcharias*) is common, especially in the vicinity of seal colonies (notably Cape fur seals (*Arctocephalus pusillus*) in the Cape region, and has been caught regularly in KZNSB nets (Cliff *et al.*1989). Based on tagging data, the first estimate of great white shark population size off eastern South Africa was 1,279 individuals (95% CI, 839-1,843 sharks; Cliff *et al.*1996). Between 1978 and 2003, 35.8 white sharks were caught annually in the nets (SD=13.5).

From 1984 to 2009, distribution and movement of two hammerhead shark species (*S. zygaena* and *S. lewini*) along the east coast of South Africa were investigated using sport fisher tagging data (Diemer *et al.* 2011). Recapture rates by anglers varied from 1.9% for *S. lewini* to 1.5% for *S. zygaena.* Coastal areas in Transkei have been identified as of importance to juvenile and subadult hammerhead sharks year-round (Bass *et al.* 1975b; Diemer *et al.* 2011).

In the Aliwal Shoal Marine Protected Area and on the nearby Protea Bank, sharks are periodically very abundant and are of major economic importance. Commercial and recreational line fishers endure negative impacts of high levels of predation by sharks of their catches (Mann 2011), primarily involving blacktip sharks (*C. limbatus*). These aggregating sharks may well in part be attracted to fisher activities associated with the capture of certain seasonal shoaling species such as the geelbek (*Atractoscion aequidens*). Catches in the shark nets do not mirror this periodic increase, confirming that these aggregations are indeed localised. (Dudley & Cliff *et al.* 2010b). Also common in this area are tiger (*Galeocerdo cuvier*) and ragged-tooth (*C. taurus*) sharks which support a viable tourism industry based on divers and underwater shark encounters (Dicken & Hosking 2009). The coast of KwaZulu-Natal is a major area for ragged-tooth sharks in South Africa. Pregnant females spend the early part of their gestation in the warmer waters of northern KwaZulu-Natal and possibly southern Mozambique. After parturition further south off the Eastern Cape, many of the females migrate back to KZN (Dicken *et al.* 2006).

Whale sharks occur along the entire South African eastern seaboard with occasional strandings as far south as Cape Town. In the 1990s, whale shark studies were initiated with a comprehensive review of strandings as well as aerial surveys with sightings of 95 and 49 individuals south of Durban (Beckley *et al.* 1997). From 2001 to 2002, the occurrence of the whale shark was further investigated off KZN although only eight whale sharks were seen, with a sighting rate of 0.21 sharks per 100km of coastline. Another 13 surveys were completed during the summers of 2003/2004 and 2004/2005 and a total of 30 sharks were sighted, with a mean sighting rate of 0.69 sharks per 100 km of coastline. The density of sharks was highest in the far north where it averaged 1.05 sharks per 100km between January and May (Cliff *et al.* 2007). Clearly, whale shark abundance is variable in this region.

One group of elasmobranchs of great concern is the sawfishes, family Pristidae, which have been severely depleted globally (Kyne *et al.* 2013) and are now possibly extinct in South African waters (Everett *et al.* in press). Two species are known to occur in the SWIO: *Pristis pristis* and *Pristis zijsron*, both listed as Critically Endangered (IUCN Red List, www.iucnredlist.org). Reasons for their decline include (but are probably not limited to) entanglement in fishing nets and habitat degradation. It appears that sawfish populations have likewise been depleted in other countries of the region. Sawfishes are probably one of the most threatened of the elasmobranchs in the SWIO region.

Mozambique

The highest elasmobranch diversity in the SWIO region has been recorded from Mozambique waters, with 108 species (73 sharks and 35 rays; reviewed by Kiszka *et al.* 2009a). Fishery-dependant data provide the basis for preliminary information on the relative abundance of sharks in this country. From 2006 to 2010, fishery observer data from the longline fishing boats were collected, and sharks amounted for 11% of the catches by number. Four species were mostly represented: *Carcharhinus sorrah*, *G. cuvier*, *Squalus megalops* and *S. lewini* (Palha de Sousa 2011). No dedicated research on sharks and rays has been undertaken in Mozambique, except on the largest and emblematic species, especially the reef manta ray (e.g. Marshall *et al.* 2009, 2011) and the whale shark (Brunnschweiler *et al.* 2009). In the 1980s, a number of surveys were carried out by both Soviet and German trawlers primarily to estimate the potential nominal catch of fish, crustaceans and molluscs. During these surveys, sharks were recorded and the most commonly caught species were *Carcharhinus falciformis*, *C. obscurus*, *Mustelus manazo* and *S. zygaena* (Sousa *et al.* 1997).

Sport fishers measure dusky shark before tagging and release. (Photo: Rudy van der Elst)

Based on research conducted in Mozambique, a revision of the genus *Manta* has been proposed (Marshall *et al.* 2009). Two species are currently recognised: the giant manta ray (*Manta birostris*) and the reef manta ray (*M. alfredi*). Off southern Mozambique, there is a major reef manta ray aggregation that has been investigated for several years. From 2003 to 2007, annual population size estimates ranged from 149 to 454 individuals and a super-population estimate of 802 individuals (Marshall *et al.* 2011). This species occurs all year round off Inhambane, but higher concentrations are observed from November to January, during the breeding season. Due to high site fidelity and small population size, reef manta rays are highly vulnerable to fisheries in Mozambique (Marshall *et al.* 2011). Around Pt. Tofo, near Inhambane in southern Mozambique, an important whale shark aggregation has been identified (Cliff *et al.* 2007). The animals gather year-round in a narrow corridor close to shore and the high sighting rates and accessibility of the sharks has led to the development of a tourism industry. Although the broader scale movement patterns and behaviour of these fish are unknown, the local population structure (81% males) suggests that these sharks constitute a sub-set of a larger population (Bunnschweiler *et al.* 2009).

Tanzania

Along the coast of Tanzania, at least 51 elasmobranch species have been recorded (Kiszka *et al.* 2009a). Despite the exploitation of sharks in Tanzania, especially off Zanzibar, very little is known on the distribution, diversity and abundance of elasmobranchs in this area. Interview surveys suggest the African angel shark (*Squatina africana*) is commonly caught although these data are limited in quantitative detail. For an in-depth view of local elasmobranch diversity see Shehe & Jiddawi (1997). The whale shark has been recorded seasonally off Zanzibar, especially from August to November (Rowat 2007). White sharks have also been recorded off the coast of Zanzibar (Cliff *et al.* 2000).

Kenya

A total of 41 species of elasmobranchs has been recorded from Kenya (Kiszka *et al.* 2009a). However, almost nothing is documented on their abundance and distribution in Kenyan waters. In November 1994, an aerial survey along the whole coast of Kenya documented the distribution of whale sharks and other large coastal sharks (Wamukoya *et al.* 1997). A total of 37 whale sharks and 15 individuals of other large shark species was recorded during the survey (63 rays of unknown species were also sighted). Noticeable concentrations of elasmobranchs were seen in Ungwana Bay and around the islands of Pate and Manda. Whale sharks appear evenly distributed but more common from July to May, with observed aggregations in the Kikambala-Malindi stretch (Wamukoya *et al.* 1997; Rowat 2007).

Union of the Comoros

Very little research has been specifically directed to the status of sharks and rays in the Comoros (islands of Anjouan, Mohéli and Grande Comoro). Nevertheless, a total of 27 species of elasmobranchs has been recorded around the Comoros (Kiszka *et al.* 2009a). Additionally, fishes of the deep demersal habitats (100-400m) have been investigated and eight species of sharks and rays (Squalidae, Scyliorhinidae, Odontaspididae, Rajidae, Torpedinidae and Narkidae) were recorded (Heemstra *et al.* 2006). Although no scientific information is available on the existence of major aggregations, a number of divers have reported the presence of aggregating reef sharks and rays off Mohéli (National Marine Park), especially off the southeast coast (mostly *Carcharhinus amblyrhynchos* and *Manta* cf. *alfredi*).

Mayotte (including Iris, Zélée and Geyser banks)

Several small-scale initiatives have been undertaken to assess the diversity and occurrence of elasmobranchs around the island of Mayotte and surrounding reef banks (Iris, Zélée and Geyser). Most diversity records have been recorded from a sighting network implemented in 2007 (Jamon *et al.* 2010). A total of 39 species has been recorded (Kiszka *et al.* 2009a), mostly reef-associated and pelagic sharks. No major shark or ray aggregations were identified around the island. However, in the austral winter, reef manta rays (*M. alfredi*) and scalloped hammerhead sharks (*S. lewini*) are commonly observed near steep reef slopes (Wickel *et al.* 2010). On reefs, *C. amblyrhynchos* and *Triaenodon obesus* are the most common species (Jamon *et al.* 2010). In offshore waters, based on pelagic longline data fished over slope areas, *C. falciformis* (CPUE, N/1000hooks = 3.94), *Prionace glauca* (CPUE = 3.28) and *S. lewini* (CPUE = 0.88) are the most common species (Kiszka *et al.* 2010). Adjacent to Mayotte, surveys have been undertaken on Iris, Zélée and Geyser banks to assess elasmobranch diversity (Chabanet *et al.* 2002; Wickel *et al.* 2010). It has been speculated that the Geyser Bank could constitute a nursery area for tawny nurse sharks (*Nebrius ferrugineus*) and that the Zélée Bank could be a nursery for *C. amblyrhynchos* (Jamon *et al.* 2010; Wickel *et al.* 2010).

French dispersed islands (Europa, Bassas da India, Juan de Nova, Glorieuses, and Tromelin)

Around the French scattered islands, little is known on the diversity and use of reef-associated habitats by sharks and rays. A research project, led by IRD (Institute of Research for Development, RequIEP: *Requins des îles Eparses*) was undertaken in 2011 around all of these islands. Elasmobranch diversity was found to be highly variable between islands, attributable in part to the high variability of observation effort: 8 species around Bassas da India, 7 around Europa, 16 around Juan de Nova, 14 around the Glorieuses and 3 around Tromelin (Kiszka *et al.* 2009a). Reef shark diversity, area use and relative abundance have been assessed during short-term diving and fishing surveys (van der Elst & Chater 2001; Kiszka *et al.* 2009b; Wickel *et al.* 2009). Nursery areas have been found in Bassas da India for *C. galapagensis* (Hammerschlag & Fallows 2005), Europa for *C. melanopterus* (Wickel *et al.* 2009) and Juan de Nova for *C. amblyrhynchos* (Kiszka *et al.* 2009). Juan de Nova appears to be the area with the highest reef shark abundance, the dominant species being *Carcharhinus albimarginatus*, *C. amblyrhynchos* and *N. ferrugineus* (Kiszka *et al.* 2009b).

Madagascar

A total of 83 species of elasmobranchs has been recorded around Madagascar, including 59 sharks and 24 ray species (Kiszka *et al.* 2009a). The bulk of information has been derived from fishery data. In the southwest, in the Toliara region, the most commonly caught elasmobranch species in coastal fisheries (using longlines and gillnets) are *Sphyrna* spp. cf. *lewini*, *C. amblyrhynchos*, *C. limbatus* or *C. melanopterus* and *G. cuvier* (McVean *et al.* 2006). In this region, there is some evidence of population declines due to overfishing for the shark fin market. Along the northwest coast, in the Nosy Be region, whale sharks seem relatively common, especially during planktonic blooms. Their abundance in the region seems particularly high between October and December (Jonahson & Harding 2007). In the northwest region (Boeny-Mahajunga area), shark communities appear slightly different with *C. amblyrhynchos*, *S. lewini*, *C. sorrah*, *L macrorhinus, T. obesus* and *R. acutus* being the most common species (Andriamanaitra 2004; Robinson & Sauer 2013). The scalloped hammerhead shark is still the most abundant species, but shows worrying signs of decline in the region (Andriamanaitra, 2004).

Seychelles

Around the Seychelles, 84 elasmobranch species have been recorded: 62 sharks and 22 rays (Kiszka *et al.* 2009a). In the 1990s, it was estimated that there was between 50,000 and 56,000t of shark biomass on the Mahé Plateau, with an additional 34,000t on the other banks (NPOA Seychelles 2007). However, very little is documented on the ecology of both coastal/reef-associated and oceanic sharks around the Seychelles. Around Aldabra, 10 species of reef sharks have been recorded (belonging to three families), with *C. melanopterus* and *N. acutidens* being the most abundant species inside the lagoon and *C. albimarginatus* the most common species along the outer slope of the reefs (Stevens 1984). Population densities calculated for *C. melanopterus* in some areas varied from 19 to 198 individuals per km^2 (Stevens 1984). While no recent data on elasmobranchs have been documented, recent shark attacks on Praslin have highlighted the need to better understand shark diversity and abundance in Seychelles.

Whale sharks are common around the Seychelles, especially around Mahé, with information on abundance, distribution and ecology of this species available. The earliest report of whale sharks in Seychelles dates back to 1756 (Lionnet 1984), and the first individual ever caught was also reported from these waters in 1805 (Smyth 1829). Whale sharks have been recorded from June to February in this area (Rowat 2007). Tracking data have shown sharks tagged around the Seychelles to migrate eastward towards Africa, then from there southward towards Mozambique, northward to Somalia and westward to Sri Lanka (Rowat & Gore 2007).

Using a combination of photo-identification and marker tags, from 2001 to 2007, a total of 552 individuals was identified (Rowat *et al.* 2009). Around Mahé, abundance estimates using mark-recapture models for 2004-2007 indicated there to be 348-488 sharks (95% CI). Existing data suggest that whale sharks are transient in the Seychelles, indicating the need for regional research initiatives (Rowat *et al.* 2009). Recently, spatial behaviour of sicklefin lemon sharks (*N. acutidens*) has been investigated in the Amirantes islands (Seychelles), showing that these sharks have a restricted home range, making them particularly vulnerable to anthropogenic impacts such as fishing (Filmalter *et al.* 2013).

Whale shark research in Mozambique. (Photo: Simon Pierce)

La Réunion

Until very recently, no dedicated studies had been undertaken to investigate the diversity, ecology and behaviour of sharks around La Réunion. However, the assessment of bycatch in the pelagic longline fishery and reef fish population studies provide a list of 51 species: 42 sharks and 9 rays (Kiszka *et al.* 2009a). As the number of attacks on bathers, especially surfers and divers, has increased, a dedicated research project on the ecology and behaviour of *G. cuvier* and *C. leucas* has been implemented by IRD, *Institut de Recherche pour le Développement*. However, no results are available yet. In the offshore region of the EEZ, based on pelagic longline surveys, 712 fishes were caught, including 107 elasmobranchs (Romanov *et al.* 2011). The most common elasmobranch species being *P. glauca* (62% of elasmobranch species) and *Pteroplatytrygon violacea* (31%). Other less common species included *I. oxyrinchus*, *C. longimanus*, *C. falciformis* and *S. zygaena* (Poisson 2011; Romanov *et al.* 2011).

Mauritius

No dedicated studies have been undertaken on sharks off Mauritius. A total of 60 elasmobranch species has been recorded, including 43 sharks and 17 rays (Kiszka *et al.* 2009a). No major shark or ray aggregations have been documented, except at “Rocher aux Pigeons”, where grey reef sharks (*C. amblyrhynchos*) were once numerous, especially before the 1990s. However, based on diver interviews, grey reef sharks are now rarely seen, presumably as a result of high fishing pressure (Kiszka *et al.* 2009a). Offshore, the two most commonly caught sharks in longlines are *I. oxyrinchus* and *P. glauca* (Mamode 2011).

SHARKS OF THE OPEN OCEAN IN THE SWIO: OVERVIEW OF BIODIVERSITY

Around 30 species of elasmobranchs spend much of their life away from land masses in oceanic waters (Pitkitch *et al.* 2008). The bulk of knowledge on oceanic sharks in the SWIO region has been derived from longline fishery data. From 1961 to 2009, 46 elasmobranch species/taxa were recorded in the catch of pelagic longliners in the Indian Ocean (Table 2). The most diverse group was the pelagic sharks represented by 28 species, dominated by the family Carcharhinidae with 15 species of the genus *Carcharhinus,* and by two mono-specific genera (*Galeocerdo* and *Prionace*). The number of species recorded has varied from 30 to 40 in the period 1960-80, declining to 22 in the catches of the 2000s (Romanov *et al.* 2010). However, this trend may be partially linked to misidentifications in early years of data collection. Taxonomic Uncertainty (TU), calculated as the percentage of the taxa recorded at a level higher than species, confirms improved identification with a lower value of TU in the last period: 2002-2009. If all species were precisely identified this index would be equal to 0 (Romanov *et al.* 2010).

The most abundant pelagic shark families in the SWIO are Lamnidae, Carcharhinidae and Alopiidae. Among Lamnidae, great white sharks are mostly confined to southern Africa but occasionally make incursions into tropical waters. Large adults have been recorded in the tropical western Indian Ocean, including Zanzibar, northern Madagascar, Mauritius, Kenya (Cliff *et al.* 2000) and on several occasions around Mayotte (Jamon *et al.* 2010). The short-fin mako shark (*Isurus oxyrinchus*) is the most abundant mackerel shark in the SWIO, and this area takes the highest catch rate for this species in the Indian Ocean (Smale 2008, Groeneveld *et al.* 2014). This species is rarely seen on the continental shelf. Between 1978 and 2003, annual catches of this species in KZNSB nets were low (mean=13.4; SD=4.5 sharks), and no trend in catch rate or size of sharks has been detected over the period (Dudley & Simpfendorfer 2006). However, the net catch rates have subsequently decreased to an average of 4.8 in recent years (Table 1), suggesting a possible population decline, similar to that reported in the offshore fisheries. Among requiem sharks (Carcharhinidae), *C. falciformis* and *P. glauca* are the most abundant species. *C. falciformis* is found in open waters, from near the surface to >3,000m (Compagno, 1984). *P. glauca* occurs closer to the surface but can range to depths of ~1000m, and is probably one of the most prolific shark species in the world. However, they are less abundant in equatorial waters and their abundance tends to increase with latitude, including in the SWIO (Nakano & Stevens 2008). All three species of thresher sharks (*Alopias pelagicus*, *A. vulpinus* and *A. superciliosus*) occur in the SWIO, but have probably declined over the decade (Romanov *et al.* 2010).

Table 2: Elasmobranch species recorded in Indian Ocean pelagic catches: 1961-2009 (from Romanov *et al.* 2010).

Order, family, *species*	***1961-1970***	***1971-1980***	***1981-1989***	***2002-2009***
Lamniformes				
Alopiidae				
Alopias pelagicus	x	x	x	x
Alopias superciliosus	x	x	x	x
Alopias vulpinus	x	x	x	x
Alopias spp.	x	x	x	x
Lamnidae				
Carcharodon carcharias	x			
Isurus oxyrinchus	x	x	x	x
Isurus paucus		x	x	x
Isurus spp.	x	x	x	
Lamna nasus		x	x	
Pseudocarchariidae				
Pseudocarcharias kamoharai		x	x	x
Carcharhiniformes				
Carcharhinidae				
Carcharhinus albimarginatus	x	x	x	x
Carcharhinus altimus	x			
Carcharhinus amblyrhynchoides		x		
Carcharhinus amblyrhynchos		x	x	x
Carcharhinus brachyurus		x		
Carcharhinus brevipinna		x	x	
Carcharhinus falciformis	x	x	x	x
Carcharhinus galapagensis		x		
Carcharhinus leucas	x	x	x	
Carcharhinus limbatus	x	x	x	
Carcharhinus longimanus	x	x	x	x
Carcharhinus melanopterus	x	x	x	x
Carcharhinus obscurus	x	x	x	
Carcharhinus plumbeus	x	x	x	x
Carcharhinus sorrah	x	x	x	
Carcharhinus spp.	x	x	x	
Galeocerdo cuvier	x	x	x	x
Prionace glauca	x	x	x	x
Sphyrnidae				
Sphyrna lewini	x	x	x	x
Sphyrna mokarran		x	x	x
Sphyrna zygaena	x	x	x	
Sphyrna spp.	x	x	x	x
Hexanchiformes				
Hexanchidae				
Hexanchus griseus			x	
Squaliformes				
Squalus spp.		x		
Unidentified squalids	x	x	x	x
Rajiformes				
Mobulidae				
Manta birostris	x	x		
Manta spp.		x	x	
Mobula spp.	x		x	x
Dasyatidae				
Pteroplatytrygon violacea	x	x	x	x
Dasyatis spp.		x	x	x
Taeniura lymna	x			
Rajidae	x			
Number of species/taxa recorded	30	40	34	22
Total number of individuals	2928	19312	3830	834
Taxonomic uncertainty	26.6	30	26.4	22.7

MIGRATORY ROUTES AND POPULATION STRUCTURE OF ELASMOBRANCHS

Several species of shark are known to undertake extensive migrations; some having been recorded to cross ocean basins. However, information on movements and migration of elasmobranchs in the SWIO region is still very limited. Most of the information that does exist on shark movements has been collected from fisheries taking bycatch in oceanic ecosystems or from studies of charismatic species, especially the whale shark. Movement patterns (including vertical and horizontal) have been documented for this largest of species. A whale shark tagged and tracked off southern Mozambique showed a highly directional movement across the Mozambique Channel and around the south of Madagascar, a distance of ~1,200km in 87 days. The animal explored both bathypelagic and epipelagic zones (Brunnschweiller *et al.* 2009). In the western Indian Ocean, purse-seine fishery observers report that whale sharks are found between 0°S and 10°S in January. In April and May, they seem to mainly occur between 10°S and 20°S, in the Mozambique Channel. Thereafter, the sharks seem to move in more northerly latitudes and by August, they span between 5°N to 5°S (Rowat 2007). From satellite telemetry data, tagged whale sharks around the Seychelles seem to be influenced by geostrophic currents (Rowat & Gore 2007). Depth recordings show that up to 53% of the time was spent in water shallower than 10m, but dives to depths of 750 – 1 000m were also recorded (Rowat & Gore 2007).

Some information has been documented for a few oceanic shark species, such as *C. falciformis*. Under the MADE project (Mitigating ADverse impacts of open ocean fisheries, www.made-project.eu), a number have been tagged using PAT (Passive Acoustic Transponders) and miniaturized PAT tags. Those tagged under FADs (Fishing Aggregating Devices), have shown they remained associated with the FAD for several days (mean association time with FAD: 5.19 days) but deep dives were recorded at night, believed to be foraging trips (Filmalter *et al.* 2011).

In a SWIOFP-funded study into the population structure of *I. oxyrinchus*, Groeneveld *et al.* (2014) reported on observer-collected data from pelagic longliners between 2005 and 2010, involving 5,819 specimens. Results indicate a demographically structured population with size increasing from temperate to subtropical waters. Reproductively active adults are more common in coastal waters suggesting a preference for pupping closer to the coast.

Information on genetic structure is accumulating and has generally been generated from larger scale studies such as on whale sharks (Castro *et al.* 2007) and scalloped hammerhead sharks (Duncan *et al.* 2006). In general and not surprisingly, large and migratory sharks show limited genetic structural diversity, even at large spatial scales, including at the global level. Based on global sampling of whale sharks, including 18 samples from the SWIO, only limited population division and no evidence for cryptic evolutionary partitions were found (Castro *et al.* 2007). However, significant haplotypes frequency differences were found between the Atlantic and the Indo-Pacific regions. Overall, whale shark population genetic structure highlights the need for development of broad international approaches for management and conservation of this and related vulnerable species (Castro *et al.* 2007).

Species with more sedentary behaviour may display disjunct distribution or reproductive philopatry at some levels of structure, as for example *S. lewini.* From genetic sampling at 20 nursery areas around the world, including the Seychelles and the east coast of South Africa, population subdivisions was seen to be pronounced. (Duncan *et al.* 2006). Although genetic discontinuity is primarily associated with oceanic barriers, site fidelity and philopatry can limit recruitment from other regions in otherwise widely distributed species. Overall, nursery populations linked by continuous coastlines have high connectivity, but oceanic dispersal by females appears to be rare (Duncan *et al.* 2006).

Oceanic Whitetip. (Photo: Julien Wickel)

Relationship with fisheries

Elasmobranchs interact in two main ways with fisheries, either as a targeted resource or as incidental bycatch. Sharks and rays are an increasingly important and valued resource with 39 nations reporting the capture of elasmobranchs in the WIO, totalling about 86,500t in 2009 (FAO 2012). To this must be added a substantial non-reported catch taken by IUU operations. In some countries specific elasmobranch fishery permits are issued for shark fisheries, and some of these are managed accordingly. For example, the soupfin shark (*Galeorhinus galeus*) fishery of South Africa, the demersal gill net fisheries for deep water squalids by Mozambique and Madagascar and artisanal shark fisheries in Seychelles (www.wiofish.org) are legally authorised fisheries.

The trend in declared landings of elasmobranchs is noteworthy. Notwithstanding the improvements and diligence in reporting, the past decade has seen a significant decline of total catches reported from the WIO as depicted in Figure 1. While the underlying causes may not be immediately clear, it seems that Asian nations fishing in the western Indian Ocean have reported the largest decline. That, despite the increased landings reported by African countries and the higher demand for and value of shark products (FAO 2012).

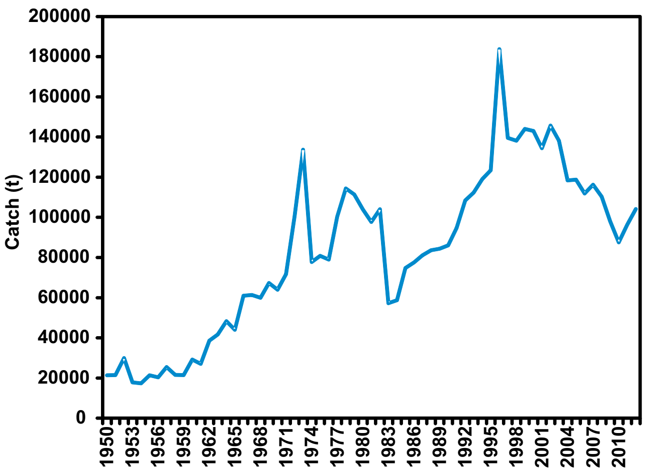


Figure 1. Reported total annual landings of elasmobranchs in the WIO (FAO Area 51) in tons (FAO 2012).

Bycatch of elasmobranchs features in several fisheries, both in coastal and in oceanic ecosystems. While in some cases this bycatch may provide food security and useful income, there is concern that in many cases this may have a negative impact on elasmobranch populations in the SWIO. This may be true for open ocean fisheries, both purse seine and longline, for low resilient coastal/reef-associated species and also for demersal elasmobranchs taken in trawls. Unfortunately, information is scarce and mostly derived from open-ocean fisheries.

COASTAL FISHERIES THAT TAKE ELASMOBRANCHS IN SWIO COUNTRIES

Here, we overview information by country on the exploitation and bycatch of elasmobranchs in the SWIO, especially in coastal waters and adjacent areas. The harvesting and bycatch of sharks in oceanic waters is treated separately. In 1996, TRAFFIC compiled a suite of reports that investigated the capture and trade in sharks around the world. One of the reports focussed on countries of the southeast Atlantic and SWIO. Although there have been substantial changes since that time, it does provide a useful baseline and point of reference (Marshall & Barnett 1996).

South Africa (East Coast region)

Sharks are caught along the coast of KwaZulu-Natal by the KZNSB as part of their bather protection programme. Indeed, since 1952, shark nets have been progressively introduced along the KwaZulu-Natal coastline. By December 2005, there were 38 installations comprising a total of 27.3km of netting (Dudley & Cliff 2010b). A typical shark net measures 213.5m long by about 6.3m deep, is manufactured from black multifilament polyethylene braid and is set about 400m from shore in 12–14m water depth (Dudley & Cliff 2010b). In the period 1970-1980 an average of 1,500 large elasmobranchs was caught in these nets annually. Progressively, there has been a reduction in this catch to levels of around 567 per annum, supplemented by some 15% released alive (Cliff & Dudley, 2011; www.shark.co.za). The relative occurrence of the most common large species is presented in Table 1. The high rate of capture of sharks and bycatch has prompted the KZNSB to implement a drum line capture system in favour of gillnets thereby further reducing mortality on several species of elasmobranchs as well as on marine mammals and sea turtles (Cliff & Dudley 2011).

Industrial fisheries in South Africa legally make moderate catches of elasmobranchs, taken in longline, trawl and line fisheries. Collectively these fisheries declared 1,710t of elasmobranchs in 2009, although this is combined for the east and west coast regions (Fishing Industry Yearbook 2010). These are legally harvested elasmobranchs that are declared and subject to management regulations. However, a number of fisheries take elasmobranchs as bycatch; not always fully declared or recorded. In the pelagic longline fishery, sharks dominate the bycatch. From 1998 to 2005, 26 species were reported caught in this fishery off South Africa. *P. glauca* and *I. oxyrinchus* were the most commonly caught species: 69.2% and 17.2%, respectively (Petersen *et al.* 2009). The catch per unit effort of these two species started to decrease since 2001 and 2000 respectively, accompanied by a decrease in average length for both species over the period 2002-2007 (Petersen *et al.* 2009). A number of other fisheries also catch sharks as bycatch, especially the demersal longline and the trawl fisheries that target Cape hake (*Merluccius capensis*). The overall catch rates are tabulated in Table 3.

Table 3. Catch rates of the four most common elasmobranch species taken by demersal industrial fisheries off the Cape south-west coast (after Petersen *et al.* 2008)

	Demersal longline			*Demersal trawl*
	% of total catch	Catch per 1000 hooks	Kg per 1000 hooks	Kg per nm^2
Squalus mitsukurii	12	10.5	31.5	68.32
Holohalaelurus regani	5.9	2.19	3.3	54.34
Scyliorhinus capensis	3.2	0.46	0.7	12.62
Raja straeleni	1.9	1.46	4.4	358.11

Off the KZN coast there is an industrial fishery for crustaceans with shallow inshore and deeper offshore elements. From 1989 to 1992, Fennessy (1994) analysed the elasmobranch bycatch of the inshore sector. He estimated that 44,600 elasmobranchs were caught in this fishery during the study period, estimated at 357 tons per year and including 26 species of which seven were endemic to the SWIO. Although a high, but variable proportion was returned alive to the water, the total elasmobranch catch was clearly substantial. Moreover, most individuals taken were juveniles. Dominant species were *Sphyrna lewini, Mustelus mosis, Halaelurus lineatus, Gymnura natalensis* and *Himantura gerrardi*. In a later study, Mkhize (2006) calculated elasmobranch catches in 2003 of the same fishery to be only 89 tons, partly attributable to much lower fishing effort. She documented 24 species of elasmobranch, contributing about 5% to the total discarded bycatch by number. Poor catch rates and market competition with cultured shrimp have effectively ceased operations since 2009 of this inshore fishery. It was estimated that the offshore deep-water shrimp trawl fishery discards about 901 tons of fish and invertebrates annually (2003 data). Of this 158 tons (18%) are elasmobranchs, represented by 17 species (Persad 2005). More recent observer data in both these shrimp fisheries has been collected (Tables 4 and 5; S. Fennessy/ORI, unpublished data) (see Chapters 2&3).

Table 4. Common elasmobranchs recorded by observers on 198 inshore (Thukela Bank) trawls from 2003-2006 (total fleet effort ~1000 trawls) (S. Fennessy/ORI, unpublished data).

Species	*Common name*	*No.*	*%*
Sphyrna lewini	Scalloped hammerhead shark	978	49.8
*Gymnura natalensis**	Diamond ray	302	15.4
Hymantura gerrardi	Brown ray	188	9.6
*Rhinobatos annulatus**	Lesser sand shark	113	5.8
Carcharhinus brevipinna	Spinner shark	67	2.7
Dasyatis thetidis	Thorntail ray	45	2.3
Mustelus mosis	Smooth hound shark	44	2.2
*Dasyatis chrysonata**	Blue ray	43	2.2
Pteromylaeus bovinus	Duckbill ray	35	1.8
Himantura uarnak	Honeycomb stingray	30	1.5
Other elasmobranchs		186	12.7

** endemic*

Table 5. Common elasmobranchs recorded by observers on 426 deep water trawls from 2003-2006 (total fleet effort ~6000 trawls) (S. Fennessy/ORI, unpublished data).

Species	*Common name*	*No.*	*%*
Squalus megalops	Spiny dogshark	3053	42.8
Holohalaelurus punctatus	Spotted catchark	573	8
Dalatias licha	Seal sharks	569	8
Pliotrema warreni	Sixgill sawshark	557	7.8
Squalus mitsukurii	Spiny dogshark	517	7.2
Cruriraja triangularis	Triangular legshark	423	5.9
Raja alba	Spearnose ray	400	5.6
Raja springeri	Roughbelly skate	319	4.5
*Squatina africana**	African Angel shark	145	2
Cephaloscyllium sufflans	Balloon shark	112	1.6
Other elasmobranchs		127	5.4

** endemic*

In addition to the industrial fisheries, there are commercial and recreational line fisheries which also take elasmobranchs, though most are released alive. In some cases commercial exploitation has taken place, notably for young dusky sharks (*C. obscurus*) (Dudley 2013) for food and for a variety of species for fins. However, these fisheries are managed and do not represent a threat *per se*. Over the years the attitude of fishers to killing unwanted elasmobranchs has changed so that in most cases the catch is released alive. Indeed, South Africa is well advanced in the development of a National Plan of Action (NPOA) for sharks.

Mozambique

It has been estimated that up to 60% of the Mozambican population is in some way dependent on marine resources. A wide variety of fisheries occur with licenses issued to domestic operators and especially to partnerships with foreign fishing companies. Table 6 reflects the number issued, although some licences may be dormant and thus inactive. The data also reveals a declining trend in license numbers, partly attributable to improved management and rationalization in these fisheries.

Table 6. Total semi- and industrial licences issued by ADNAP for Mozambique fisheries.

Fishing licences	*Peak*	*2011*
Inshore shrimp trawl	45 in 1980	13
Deep water shrimp trawl	90 in 1999	55
Purse seine	51 in 2007	34
Long line	110 in 2005	37
Linefish	43 in 2008	34

There are also a limited number of licensed gill net fisheries that capture line fish and sharks. Sharks are caught in virtually all Mozambican fisheries, either as target, or bycatch: discarded or retained. Elasmobranchs have been reported in industrial, semi-industrial and artisanal fisheries and by all types of boats using all types of gears in the full range of depth intervals, from the coastline to about 1,200m in depth (Sousa *et al.* 1997). In the late 1990s, a few semi-industrial directed shark fisheries using gillnets were established in the Maputo area as well as in Inhambane Bay and in the region of Vilankulos, especially targeting coastal/shelf-associated species (Sousa *et al.* 1997). However, these shark-directed fisheries appear to fluctuate and had effectively been reduced to two operators by 2010. Periodically, elasmobranchs are opportunistically targeted in certain places. One example was the intense pursuit of mantas at Ligogo in 2010, where a large number of mantas *Manta alfredi/birostris* and shorthorn devilrays *Mobula kuhlii* were caught in gillnets. As this site is near Inhambane and famed for top manta diving encounters, this created a local management problem.

Most of the elasmobranchs taken in Mozambique waters are part of a bycatch, with shrimp trawlers catching the most significant quantities. However, bycatch reduction devices (BRDs) have been tested in shrimp trawl fisheries in Mozambique. Fennessy & Isaksen (2007) showed that 75% of hauls with reduction grids caught fewer large rays than those without grids, while hauls using grids caught no large sharks at all. Overall, the Nordmøre grid successfully allowed the escape of larger elasmobranchs. Use of the grid, as well as a square-mesh panel sewn into the trawl, substantially reduced the bycatch without significantly reducing shrimp catches (Fennessy & Isaksen 2007).

Tanzania

Fisheries in Tanzania are largely artisanal, and include handline, longline and gillnet operations. In 2008, there were 7,342 and 7,155 small fishing vessels in Tanzania mainland and Zanzibar, respectively (MLFD/MALE 2008). Fishing for elasmobranchs has occurred for centuries, especially in Zanzibar, being mostly seasonal during austral summer. Sharks are important resources for Zanzibar, not only as a valuable and cheap source of dried meat, but more importantly also as a major source of income provided by fins (Schaeffer 2004). Bottom-set gillnets, which particularly target sharks and rays, vary in length up to 450m, with mesh sizes ranging from 20-40cm bar. Longlines are also used to harvest sharks (Barnett 1997).

In Zanzibar, a study on shark fisheries was conducted in April 2004 based on interview data from two landing sites in Stone Town (Schaeffer 2004). Data was gathered through observation of the type and number of sharks landed, fishing gear employed, and sale of shark products, particularly fins. A total of sixteen different shark species was identified during this study, although species identification was problematic. Most abundant species were *Carcharhinus macloti*, *R. acutus* and *C. amblyrhynchos*. *S. africana* and *C. obscurus* were other species mentioned as common in the catches (Schaeffer, 2004). The total catch of fish landed in Zanzibar declined from around 20,000t in the 1980s to about 10,000t in 1995. Shark landings statistics show a similar declining trend (Shede & Jiddawi 1997), although no more up-to-date information appears to be available. Besides a thriving artisanal sector, there is also an industrial inshore shrimp trawl fishery which is known to capture elasmobranchs as bycatch. However, this fishery was closed in 2008, in part due to a high level of turtle bycatch. At the time of closure a total number of 25 vessels was licenced although each year this is reviewed. This fishery is likely to resume operations in the near future, ostensibly with bycatch reduction devices in place.

Kenya

Kenyan fisheries include both artisanal and semi-industrial sectors, and are of major socio-economic importance. Artisanal fisheries are confined to shallow coastal waters but account for 90% of the annual total marine fish landed: 10,000-16,000t taken by about 10,000 fishers. A wide range of gears that can catch elasmobranchs is used by artisanal fishers, including gillnets, beach seines, shrimp trawls and longlines. In 2006, 28 artisanal landing sites were known to exist along the coast of Kenya (Kiszka *et al.* 2008).

There is a significant semi-industrial shallow water shrimp fishery in Ungwana Bay that has experienced high turtle mortalities and was closed accordingly for several years before using BRDs as a matter of course. Research trawling has indicated that these fisheries take an elasmobranch bycatch in moderate numbers, including *Himantura uarnak*, *Dasyatis pastinaca, Raja alba, Raja smithi, Squatina africana and Squalus aspes* (Kimani *et al.* 2010). Unfortunately, sharks taken by foreign pelagic operators and those explicitly directed at sharks, have not been documented (Marshall 1997). Nevertheless, there is an industrial fishery associated with harvesting shark and rays. Mombasa is the centre of a considerable shark fin and meat trade, with a number of dealers licensed to import and export shark fin products. For the period 1986 to 1990, Kenya exported a total of 139t of shark fins, which equates to an average of 28t per year (Marshall, 1997). Until recently, quantities of dried shark meat and fins were imported from Somalia (van der Elst, unpublished data). No recent estimates have been published, but the shark fin trade probably increased during the last two decades.

Union of the Comoros

Very little is known on shark use and exploitation in the Comoros. Fishing in the Comoros is entirely artisanal but licenses are awarded to commercial Asian and European longline and purse-seine fishing vessels. Coastal and artisanal fishing gears include handlines, beach seines, fish traps, and gillnets (Poonian *et al.* 2008). Gillnets targeting sharks have been reported (around 250m long, 2m deep with a bar mesh size of 30cm). However, the extent of their use is undocumented.

In 2009, a dedicated interview survey was conducted to assess the use, bycatch and exploitation of sharks and other elasmobranchs around the Comoros (Maoulida *et al.* 2009). Artisanal fishers were interviewed about the frequency of shark catches, species caught, gear used and market value. A number of shark species was found to be caught in Comorian waters, including *C. longimanus, S. lewini, G. cuvier* and *C. falciformis*.

On Grande Comoro (Ngazija), sharks were caught largely as bycatch, while on Anjouan, sharks were more often intentionally targeted. Shark meat was cheaper (USD 0.5-2 per kg) than other fish, such as tuna (USD 3-5 per kg); but fins and dried meat were an exception, reaching high values at market, up to USD 40 per kg and USD 5 per kg respectively. Local fishers valued sharks as an indicator of the presence of large schools of tuna; the most important fishery resource. Some 42% of the Anjouan fishers confirmed intentionally targeting sharks, indicating that this island should be a priority for elasmobranch fisheries management in the Comoros. Overall, sharks did not appear to be highly valued as a resource in the Comoros. However, the disproportionately high value of shark fins and increasing demand from overseas could result in rapid and unsustainable increases in shark catch (Maoulida *et al.* 2009).

Mayotte and French dispersed islands (Europa, Bassas da India, Juan de Nova, Glorieuses, Tromelin)

Fisheries around Mayotte are mostly artisanal and poorly developed. The most important fishing technique is handline, targeting reef and pelagic fish. In 2006, 1,092 small boats (including pirogues and small vessels less than 7m long) were recorded around the island (Direction des Affaires Maritimes, personal communication). Small seines are also used on the barrier reef to target small reef fish (only around 20 boats). Two small longliners also operate from Mayotte in the territorial waters, targeting billfish and tunas (Kiszka *et al.* 2010).

In a 2010 interview survey, data was collected on the by-catch, exploitation and use of elasmobranchs by small-scale coastal fisheries around Mayotte (Hamada, 2010). Up to 97% of respondents confirmed taking sharks as retained bycatch; meat being consumed but fins not collected. The most commonly caught species were *S. lewini*, *G. cuvier*, *C. amblyrhynchos* and *N. ferrugineus* (Hamada 2010).

In the domestic pelagic longline fishery, sharks make up 20.3% of catches but are generally discarded. The most commonly caught species are, in order of occurrence, *C. falciformis*, *P. glauca*, *S. lewini* and *C. longimanus* (Kiszka *et al.* 2010). Based on data collected during an observer programme (2009-2010), out of a total number of 166 sharks caught, 127 were discarded (76.5%). Most of them were released alive (88.2%), all others being discarded dead. The capture mortality of the sharks was recorded for 137 individuals: 16.1% were observed dead and 83.9% were alive (Kiszka *et al.* 2010).

Around the French scattered islands, no fisheries are allowed. However, illegal fishing occurs, especially around the Glorieuses islands (from Madagascar and possibly other countries, including from Asia) and it has been recently shown that sharks could be targeted, probably for fins (J. Kiszka, unpublished data, Figure 2). Illegal longline fishing boats from Sri Lanka have also been documented with shark fins around Glorieuses islands (*Préfecture des Terres Australes et Antarctiques Françaises*, personal communication).

Madagascar

In Madagascar, fisheries constitute a primary source of income for both coastal communities and foreign revenue for the national economy. The three main types of fisheries in Madagascar, are classified according to the power of vessels' engines: commercial (>50hp), artisanal (<50hp) and traditional (non-motorized). In 2006, 80 commercial longline and trawling vessels exploiting tunas, swordfish, sharks and shrimps were recorded (source: Ministry of Agriculture, Fisheries and Livelihoods). The artisanal fisheries mainly utilize gillnets to target elasmobranchs, fish and crustaceans. Traditional fisheries target a full range of resources, including elasmobranchs, cephalopods, sea turtles, echinoderms and fish in shallow coastal and as well as pelagic waters.

The industrial, artisanal and traditional shark fisheries of Madagascar have been the subject of studies dating back as far as 1930 (Petit 1930). Studies have been mostly undertaken in the north of the country and in the southwest (particularly the Toliara region (Andriamanaitra 2004; McVean *et al.* 2006). Here there is an active export market for the fins resulting from these fisheries, indicating a considerable social and economic importance in this impoverished region of Madagascar. In the Toliara region, results from a total of 1,164 fishing outing records, included at least 13 species of elasmobranchs, with an estimated total wet weight of over 123t. Hammerhead sharks *Sphyrna* spp. represented 29% of sharks caught by number and 24% of the total wet weight (McVean *et al.* 2006). There were 30 longline vessels registered by the ministry of fisheries in 2010, 60% operating along the west coast. Around 23% of their east coast catches comprise sharks, while this proportion is lower at 17% from the western waters. Trolling liners and encircling gillnets (which are called artisanal fisheries in Madagascar) catch sharks at quite low levels (1.13% for the east and 0.74 % for the west; Rahombanjanahary, 2011).

In some cases shrimp fishers have shifted their activity into pelagic fisheries by changing their vessels to small-scale longliners. In the period from 2008 to 2010, there were five such converted longliners; four fishing the west and one the east coast of Madagascar. Shark fisheries are showing signs of decline, possibly as a result of the decline of other established fisheries (Rahombanjanahary, 2011).

Figure 2: Dried shark meat in an illegal fishing camp, Glorieuses islands, April 2011 (*C. amblyrhynchos*). (Photo: Jeremy Kiszka)

Seychelles

There is a long history of shark fishing in Seychelles, considered to have been of significant socio-economic importance. Prior to WWII, sharks were caught as bycatch but retained and mostly dried for local consumption. At the end of the war, the market for dried shark meat was further developed. Consequently, fishing effort was applied across the entire Mahé plateau and its surrounds, the banks beyond and the Amirantes. However, in the late 1950s, the decline of large sharks around the central islands had been noted and by the end of the 1960s, large sharks were almost absent off Mahé (Smith & Smith 1969). A local semi-industrial long-line fishery was initiated in the mid-1990s to target swordfish and tuna; resulting in an increased shark bycatch. In the late 1990s, it was noted that some of the longline vessels were increasingly targeting and finning sharks in order to export this high-value commodity (Bargain 2001). The targeting of sharks increased dramatically when the Seychelles Government banned the export of swordfish (2003-2005) to the EU until issues regarding the cadmium content of the fish exceeding EU recommended levels were resolved in 2005.

Shark stocks of Seychelles have continued to be the subject of increasing exploitation with concern as to their sustainability and in particular the practice of "finning" in some fisheries. Three agencies are known to export fins to the Asian market (Seychelles NPOA 2007). The Ministry of Environment and Natural Resources (MENR) and the Seychelles Fishing Authority (SFA) initiated the process to develop a National Plan of Action for the Conservation and Management of Sharks (NPOA-sharks) to address these concerns (Seychelles NPOA 2007).

One of the most useful sources of information on the species composition of contemporary stocks is restricted to an interview-based stakeholder survey (Nevill 2005). This study highlights the fact that shark diversity in Seychelles coastal waters had decreased significantly (Nevill 2005). Diving with sharks represents a significant component of the tourism industry.

Galapagos shark, *Carcharhinus galapagensis*. A globally distributed pelagic species associated with oceanic islands. (Photo: Chris Fallows www.apexpredators.com)

La Réunion

Two main fisheries occur around La Réunion: longline and handline (coastal, reef-associated). Longlining occurs throughout the year in the EEZ by a fleet of around 30 vessels (2010), targeting tuna and swordfish. Handlines target reef fish, and around 300 boats have been recorded around the island (IFREMER, personal communication). Sharks are seldom targeted, and shark finning is prohibited in accordance with European regulations. Data from voluntary logbooks (5,884 longline sets) collected between 1997 and 2000 were analysed to assess the potential impact of the Réunion-based longline swordfish fishery on sharks (Poisson, 2011). Blue sharks represented between 75% and 88% of shark catches, with variable discard rates between species, ranging from low discards (2.6%) for *Isurus* spp. to high discards for blue shark (86.5%). Estimates by weight of the total catch of sharks (both retained and discarded) ranged from 7% to 9% of the total catch of the major target species caught by the fishery. Of concern is the decline of blue shark CPUE from 2.2 to 1.03 sharks per 1,000 hooks between 1998 and 2000 (Poisson 2011). As a result of a growing number of shark bites on surfers and bathers since 2011, drumlines are currently used to remove coastal sharks along the coast of La Réunion (particularly *C. leucas* and *G. cuvier*).

Mauritius

The Mauritian fleet consists of artisanal, semi-industrial and industrial operations. The artisanal fleet has 1,605 vessels, consisting of 7-9m long boats targeting mainly shallow-water demersal species in the lagoon and outer reefs. Some 1,620 fishers were registered in this fishery in 2010 (Sweenarain 2011). The semi-industrial fleet consists of four vessels, each less than 24m and mostly involved in the shallow-water demersal fishery on offshore reef banks, with some occasionally also involved in the pelagic fishery. The industrial fleet consists of three vessels longer than 24 meters. A small-scale FAD fishery is being developed in order to offset the depleted artisanal lagoon fish stocks, targeting mainly tuna around some 27 FADs.

Although elasmobranchs are seldom targeted around Mauritius, they are frequently taken as bycatch, both in coastal/small-scale and pelagic fisheries. Recently, the shark bycatch in all Mauritian fisheries was investigated (Mamode 2011). From 2006 to 2010, the shark bycatch was recorded in semi-industrial and industrial pelagic fishing boats, although without information on species composition. For the years 2009-2010 a total of 2,349t of sharks was transhipped at Port Louis. The main species of sharks landed from licensed and non-licensed fishing vessels calling at Port Louis consisted of blue (58.1%) and short-fin mako sharks (38.9%) (Mamode 2011).

OVERVIEW OF OPEN-OCEAN SHARK BYCATCH IN THE WIO

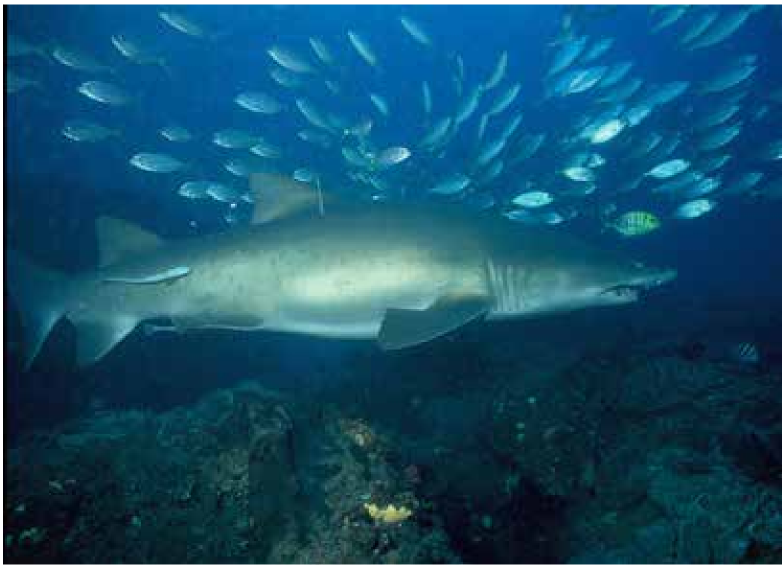
In the western Indian Ocean, longlines, purse seines and occasionally pelagic driftnets are used to harvest tuna, swordfish and elasmobranchs; either as target species or as bycatch. These fisheries are considered one of the most significant sources of shark mortality in the region. In 2009, 33 countries reported elasmobranch landings from the FAO fishing area 51, totalling 86,500t (FAO 2012). This represents about 12% of the total reported global elasmobranchs catch of 721,163t. Significantly, the western Indian Ocean elasmobranch catch is third highest of all the FAO fishing regions. The entire Indian Ocean accounts for the highest ocean catch of elasmobranchs. Although detailed information on shark catch and bycatch in the Indian Ocean is still limited, there have been improvements in data submission to the Indian Ocean Tuna Commission (IOTC) since the early 2000s. These records indicate that 15 species (belonging to 5 families) are regularly taken in the region's fisheries (Smale 2008). However, most of the elasmobranch landings in the IOTC region are still not identified to species and are grouped as "sharks". There are still too few observer programmes in the Indian Ocean and SWIO in particular, and little is known on trends in pelagic shark populations of the region, except from data collected in the South African pelagic longline fishery and the KwaZulu-Natal Sharks Board.

In the Indian Ocean, most shark carcasses are discarded but fins are collected. Overall, elasmobranch catches drastically increased in the western Indian Ocean (FAO fishing area 51), peaking in 1996, partly attributable to higher fishing effort directed at tuna. However, since that peak the reported landings of elasmobranchs subsided significantly as depicted in Figure 1 (Smale 2008). Three main shark families are taken in pelagic fisheries in the SWIO: Lamnidae, Alopiidae and Carcharhinidae.

Among the requiem sharks, *P. glauca*, *C. falciformis* and *C. longimanus* are the most commonly caught species. *C. falciformis* is distributed throughout the region (Fourmanoir 1961; Compagno 1984). Off the Maldives, this is the most important pelagic shark caught (70-80%; Anderson & Hafiz 2002). In the purse seine fishery, for the period 1986 to 1992, the annual bycatch was estimated at 944-2,270t of pelagic oceanic sharks and 53-112t of *Mobula* spp. and *Manta* spp. (Romanov 2002). For the period 2003-2009, silky sharks were the most common bycatch shark species by weight in the purse seine fishery associated with floating objects, as deduced from observer data on European vessels (Amandè *et al.* 2011). The highest catch rates were observed in the northern fishing grounds (2°N, 53°E), north of the Seychelles (Amandè *et al.* 2011). Fishing operations under FADs are characterized by significantly higher bycatch levels (4.3 sharks per set in FAD-associated tuna vs. 0.3 sharks in targeting of free shoaling tuna; Amandè *et al.* 2008).

An extensive and large-scale study on catches in the Taiwanese pelagic longline fishery in the Indian Ocean was conducted by Huang & Liu (2010). Observer data collected from 77 trips on Taiwanese longline vessels from June 2004 to March 2008 were used to estimate the scale of the bycatch. At least 40 species were recorded. Albacore, bigeye, yellowfin, and southern bluefin tuna were the major target species and comprised over 73.3% of the total retained catch. Major bycatch species were *X. gladius*, *P. glauca*, *Istiophorus platypterus*, *Brama brama*, and *Lepidocybium flavobrunneum* (Huang & Liu 2010). Highest bycatch rates were observed in the tropical Indian Ocean (between 10°N and 10°S, i.e. the bigeye tuna fishery), with, in order of occurrence, *P. glauca* (n=2,067 individuals), *C. falciformis* (n=621), *A. superciliosus* (n=439) and *I. oxyrinchus* (n=219) (Huang & Liu 2010). In the albacore tuna fishery, essentially occurring between 10°S and 25°S, bycatch rates were lower and *P. glauca* and *I. oxyrinchus* were the most common bycatch species.

Off South Africa, *P. glauca* is targeted in the pelagic shark-directed longline fishery and is a common bycatch in the tuna and swordfish directed fisheries. Of the total pelagic shark landings in South Africa, including east and west coasts, *P. glauca* comprised 35% of landed mass from 1998 to 2008 (Jolly *et al.* 2011). Recent results highlighted greatest *P. glauca* abundance during summer and autumn off the west coast of South Africa, and standardized CPUE for both fisheries suggests that *P. glauca* catch rates remained relatively stable from 1998 to 2008 (Jolly *et al.* 2011).



Raggedtooth shark, *Carcharias taurus*, shortly after being tagged on a KZN reef. (Photo: Geremy Cliff)

Management of shark fisheries and mitigation of bycatch in the SWIO

COASTAL FISHERIES

In the SWIO, very few mitigation measures have been implemented to minimise elasmobranch bycatch, except in some trawl fisheries where bycatch levels of elasmobranchs are the most significant. Various initiatives have been undertaken to reduce bycatch in shrimp trawl fisheries of the region (Fennessy *et al.* 2008). In Kenya, the use of TEDs (Turtle Excluder Devices), contributing to reduce elasmobranch bycatch, was legislated in 2003. In 2008, a draft discussion paper aimed at developing a shrimp fishery management plan was circulated to stakeholders. This plan includes gear modification, reduced fishing effort and zonation of the fishing grounds in order to reduce user-conflict (Fennessy *et al.* 2008). No concrete mitigation measures were implemented in Tanzania, while in Mozambique; legislation has required the compulsory use of TEDs since 2005. A number of experiments to test various BRD designs have been conducted jointly by South Africa and Mozambique. There are additional initiatives underway to investigate shrimp trawl gear technology including Turtle Excluder Devices (TEDs) (Fennessy *et al.* 2008). In South Africa, the use of Nordmøre grids provided good results, with a reduction by 60% of elasmobranch bycatch. Other legislated measures reducing bycatch in South Africa have also been implemented, including a mesh size limit (50mm), an inshore trawling distance limit of 0.5nm, and the prohibition of the sale of certain bycatch species (Fennessy *et al.* 2008). In Madagascar, a number of mitigation measures have been implemented to reduce bycatch in shrimp trawl fisheries, including mesh size restrictions, trawl gear size limits, closed seasons and areas, partial prohibition of nocturnal trawling, limited number of permits and zonation of effort. The use of TEDs was legislated in 2003 and enforced in 2005 (Fennessy *et al.* 2008).

Shark finning, Comoros. (Photo: Hendrik Sauvignet)

While the industry generally appears amenable to the ultimate implementation of these devices, the actual level of implementation of BRDs has been variable with encouraging levels of implementation in several fisheries, such as in Kenya and Tanzania. Improved legislation and heightened awareness are prerequisites.

OCEANIC FISHERIES

Managing wide ranging oceanic species is highly challenging. Fortunately, the IOTC has greatly improved data collection on shark and other bycatch species in the Indian Ocean. In addition, the number of reports on elasmobranch ecology, behaviour, bycatch and usage has significantly increased over the last ten years, highlighting the increasing interest to manage shark and ray populations in the region. However, information remains inadequate and the scale and extent of the shark bycatch in oceanic realm of the Indian Ocean is probably much higher than reflected in current data.

Baum *et al.* (2003) have suggested that shark populations have drastically declined in the Atlantic Ocean (75% of decline over 15 years). Overall the declining trend in the western Indian Ocean appears equally serious judging by FAO data presented in Figure 1. However, no information is at hand from the Indian Ocean to detect trends in individual shark populations, especially in the SWIO, except for South Africa. Indeed, pelagic shark longline records and shark catches made by the KwaZulu-Natal Sharks Board are the only reliable sources of information to assess long-term trends. As indicated earlier, several species appear to have been substantially depleted, such as hammerhead sharks (*Sphyrna* spp.). In the SWIO, the lack of capacity in specific countries to assess, manage and control access to their EEZ is also a major problem that needs to be addressed. Due to their life history traits, limiting their stock rebuilding potential, management plans for elasmobranchs are urgently needed in the Indian Ocean. It has been suggested that open ocean marine protected areas could assist shark populations. One management approach that is increasingly being considered is fisheries' closures (Grantham *et al.* 2008). In the South African pelagic longline fishery, three closure approaches were tested, suggesting that temporary spatial closures were the most cost effective and considerably reduced bycatch, while purely seasonal closures were ineffective (Grantham *et al.* 2008).

Technical modifications of gears have also been implemented in many fishing areas around the world. While the use of nylon leaders generally lead to lower shark bycatch rates and increase bigeye tuna catches (Ward *et al.* 2008), the use of circle hooks does not really lead to a decrease of bycatch (e.g. Yokota *et al.* 2006). In the SWIO region, the MADE project (Mitigating ADverse impacts of open ocean fisheries, www.made-project.eu) is investigating the effectiveness of certain mitigation measures to decrease shark bycatch, such as the use of "ecological FADs", the implementation of better practices on board vessels, the use of artificial baits or a better vertical distribution of hooks (Dagorn 2011). In addition, it has been recently shown that drifting FADs constitute a major source of mortality for silky sharks in the Indian Ocean (Filmalter *et al.* 2013). In this region, entanglement mortality of silky sharks is about 5-10 times that of other known bycatch shark species taken as bycatch from the region's purse-seine fleet. Estimates from this single ocean (480,000-60,000 individuals) rival those from all world fisheries combined (400,000-2 million individuals). This situation clearly requires immediate management decisions (Filmalter *et al.* 2013).

Member states of FAO that are targeting sharks in its fisheries have to compile a National Shark Assessment Report (SAR). The Seychelles has published their NPOA-Sharks in 2007. Amongst others, this report should take into account issues pertaining to biodiversity, conservation and the management of sharks. There is a shark management plan in South Africa which provides the basis for development of a National Plan of Action for the conservation and management of sharks in South African waters.

Gaps and recommendations

South African-based scientists have generated considerable information on elasmobranchs. In addition, credible information from KZN shark nets is also a useful data set that provides scientific knowledge on elasmobranchs, including on population trends. However, knowledge on the ecology, biology and fisheries of elasmobranchs in the SWIO region remains highly fragmentary and limited. Fortunately, there is an increase in research activities on open ocean sharks and the development of new initiatives in the region, especially under the auspices of IOTC and its active Working Party on Ecosystems and Bycatch (WPEB). Overall, research on sharks and rays has been limited to large and emblematic species, ignoring the assessments of smaller, less charismatic but equally threatened species. The biggest gap relates to assessment of elasmobranchs, their population dynamics and sustainability. There are very few models to assess elasmobranchs. The question posed is: how serious is the bycatch of elasmobranchs in specific fisheries? Which species are vulnerable and why? Such information is not available in most cases.

Here are some recommendations for research and management:

- ► Better reporting of shark bycatch, in all fisheries, including the use of semi-quantitative approaches in coastal/artisanal/small scale fisheries, having an impact on even less resilient species (e.g. reef sharks).

- ► Studies on population structure to define elasmobranch management units, at different temporal scales (from populations to individuals, from evolutionary to ecological/behavioural scales). Included should be telemetry on a regional basis (Kiszka & Heithaus 2014).

- ► Detailed assessment of shark finning in the SWIO region.

- ► Implementation of Shark Assessment Reports in all SWIO countries, and the development of NPOA-Sharks in all SWIO countries.

- ► Development of regional management plans for stocks which straddle international boundaries.

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Annex:
Draft list of elasmobranchs species recorded in the West Indian Ocean. Highlighted are endemic to SWIO.

Order	*Family*	*Genus*	*Species*	*Authors*	*IUCN Red list status**
SHARKS					
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*albimarginatus*	Rüppell (1837)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*altimus*	Springer (1950)	DD
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*amblyrhynchos*	Bleeker (1856)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*amboinensis*	Müller & Henle (1839)	DD
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*brachyurus*	Günther (1870)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*brevipinna*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*falciformis*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*galapagensis*	Snodgrass & Heller (1905)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*humani sp. nov.*	White & Weigmann (2014)	NE
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*leucas*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*limbatus*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*longimanus*	Poey (1861)	VU
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*macloti*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*melanopterus*	Quoy & Gaimard (1824)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*obscurus*	Lesueur (1818)	VU
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*plumbeus*	Nardo (1827)	VU
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*sealei*	Pietschmann (1913)	NT
Carcharhiniformes	Carcharhinidae	*Carcharhinus*	*sorrah*	Müller & Henle (1839)	NT
Carcharhiniformes	Carcharhinidae	*Galeocerdo*	*cuvier*	Péron & LeSueur (1822)	NT
Carcharhiniformes	Carcharhinidae	*Loxodon*	*macrorhinus*	Müller & Henle (1839)	LC
Carcharhiniformes	Carcharhinidae	*Negaprion*	*acutidens*	Rüppell (1837)	VU
Carcharhiniformes	Carcharhinidae	*Prionace*	*glauca*	Linnaeus (1758)	NT
Carcharhiniformes	Carcharhinidae	*Rhizoprionodon*	*acutus*	Rüppell (1837)	LC
Carcharhiniformes	Carcharhinidae	*Scoliodon*	*laticaudus*	Müller & Henle (1838)	NT
Carcharhiniformes	Carcharhinidae	*Triaenodon*	*obesus*	Rüppell (1837)	NT
Carcharhiniformes	Hemigaleidae	*Hemipristis*	*elongata*	Kluzinger (1871)	VU
Carcharhiniformes	Hemigaleidae	*Paragaleus*	*leucolomatus*	Compagno & Smale (1985)	DD
Carcharhiniformes	Proscyllidae	*Ctenacis*	*fehlmanni*	Springer (1968)	DD
Carcharhiniformes	Proscyllidae	*Eridacnis*	*radcliffei*	Smith (1913)	LC
Carcharhiniformes	Proscyllidae	*Eridacnis*	*sinuans*	Smith (1913)	LC
Carcharhiniformes	Pseudotriakidae	*Pseudotriakis*	*microdon*	Brito Capello (1868)	DD
Carcharhiniformes	Scyliorhinidae	*Apristurus*	*indicus*	Brauer (1906)	NE
Carcharhiniformes	Scyliorhinidae	*Apristurus*	*longicephalus*	Nakaya (1975)	DD
Carcharhiniformes	Scyliorhinidae	*Cephaloscyllium*	*sufflans*	Regan (1901)	LC
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*boesemani*	Springer & D'Aubrey (1972)	DD
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*clevai*	Seret (1987)	NE
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*lineatus*	Bass, D'Aubrey & Kistnasamy (1975)	DD
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*lutarius*	Springer & D'Aubrey (1972)	DD
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*natalensis*	Regan (1904)	DD
Carcharhiniformes	Scyliorhinidae	*Halaelurus*	*quagga*	Alcock (1899)	DD
Carcharhiniformes	Scyliorhinidae	*Haploblepharus*	*edwardsii*	Schinz (1822)	NT
Carcharhiniformes	Scyliorhinidae	*Haploblepharus*	*fuscus*	Smith (1950)	VU
Carcharhiniformes	Scyliorhinidae	*Haploblepharus*	*kistnasamyi*	Human & Compagno (2006)	CR
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*grennian*	Human (2006)	NE
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*favus*	Human (2006)	EN
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*melanostigma*	Norman (1939)	DD
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*punctatus*	Gilchrist (1914)	EN

Order	*Family*	*Genus*	*Species*	*Authors*	*IUCN Red list status**
Carcharhiniformes	Scyliorhinidae	*Holohalaelurus*	*regani*	Gilchrist (1922)	LC
Carcharhiniformes	Scyliorhinidae	*Poroderma*	*africanum*	Gmelin (1789)	NT
Carcharhiniformes	Scyliorhinidae	*Poroderma*	*pantherinum*	Müller & Henle (1838)	DD
Carcharhiniformes	Scyliorhinidae	*Scyliorhinus*	*capensis*	Müller & Henle (1838)	NT
Carcharhiniformes	Scyliorhinidae	*Scyliorhinus*	*comoroensis*	Compagno (1988)	DD
Carcharhiniformes	Sphyrnidae	*Sphyrna*	*lewini*	Griffith & Smith (1834)	EN
Carcharhiniformes	Sphyrnidae	*Sphyrna*	*mokarran*	Rüppell (1837)	EN
Carcharhiniformes	Sphyrnidae	*Sphyrna*	*zygaena*	Linnaeus (1758)	VU
Carcharhiniformes	Triakidae	*Galeorhinus*	*galeus*	Linnaeus (1758)	VU
Carcharhiniformes	Triakidae	*Hypogaleus*	*hyugaensis*	Miyosi (1939)	NT
Carcharhiniformes	Triakidae	*Mustelus*	*manazo*	Bleeker (1854)	DD
Carcharhiniformes	Triakidae	*Mustelus*	*mosis*	Hemprich & Ehrenberg (1899)	DD
Carcharhiniformes	Triakidae	*Mustelus*	*palumbes*	Smith (1957)	DD
Carcharhiniformes	Triakidae	*Scylliogaleus*	*quecketti*	Boulenger (1902)	VU
Carcharhiniformes	Triakidae	*Triakis*	*megalopterus*	Smith (1839)	NT
Heterodontiformes	Heterodontidae	*Heterodontus*	*ramalheira*	Smith (1949)	DD
Hexanchiformes	Hexanchidae	*Heptranchias*	*perlo*	Bonnaterre (1788)	NT
Hexanchiformes	Hexanchidae	*Hexanchus*	*griseus*	Bonnaterre (1788)	NT
Hexanchiformes	Hexanchidae	*Hexanchus*	*nakamurai*	Teng (1962)	DD
Hexanchiformes	Hexanchidae	*Notorynchus*	*cepedianus*	Peron (1807)	DD
Lamniformes	Alopiidae	*Alopias*	*pelagicus*	Nakamura (1935)	VU
Lamniformes	Alopiidae	*Alopias*	*superciliosus*	Lowe (1840)	VU
Lamniformes	Alopiidae	*Alopias*	*vulpinus*	Bonnaterre (1788)	VU
Lamniformes	Lamnidae	*Carcharodon*	*carcharias*	Linnaeus (1758)	VU
Lamniformes	Lamnidae	*Isurus*	*oxyrinchus*	Rafinesque, 1810	VU
Lamniformes	Lamnidae	*Isurus*	*paucus*	Guitart (1966)	VU
Lamniformes	Lamnidae	*Lamna*	*nasus*	Bonnaterre (1788)	VU
Lamniformes	Mitsukurinidae	*Mitsukurina*	*owstoni*	Jordan (1898)	LC
Lamniformes	Odontaspididae	*Carcharias*	*taurus*	Rafinesque (1810)	VU
Lamniformes	Odontaspididae	*Odontaspis*	*ferox*	Risso (1810)	VU
Lamniformes	Odontaspididae	*Odontaspis*	*noronhai*	Maul (1955)	DD
Lamniformes	Pseudocarchariidae	*Pseudocarcharias*	*kamoharai*	Matsubara (1936)	NT
Orectolobiformes	Ginglymostomatidae	*Nebrius*	*ferrugineus*	Lesson (1831)	VU
Orectolobiformes	Ginglymostomatidae	*Pseudoginglymostoma*	*brevicaudatum*	Günther (1867)	VU
Orectolobiformes	Hemiscylliidae	*Chiloscyllium*	*plagiosum*	Anonymous [Bennett] (1830)	NT
Orectolobiformes	Rhincodontidae	*Rhincodon*	*typus*	Smith (1828)	VU
Orectolobiformes	Stegostomatidae	*Stegostoma*	*fasciatum*	Hermann (1783)	VU
Pristiophoriformes	Pristiophoridae	*Pliotrema*	*warreni*	Regan (1906)	NT
Squaliformes	Centrophoridae	*Centrophorus*	*granulosus*	Bloch & Schneider (1801)	VU
Squaliformes	Centrophoridae	*Centrophorus*	*lusitanicus*	Bocage & Capello (1864)	VU
Squaliformes	Centrophoridae	*Centrophorus*	*moluccencis*	Bleeker (1860)	DD
Squaliformes	Centrophoridae	*Centrophorus*	*niaukang*	Teng (1959)	NT
Squaliformes	Centrophoridae	*Centrophorus*	*secheyllorum*	Baranes (2003)	DD
Squaliformes	Centrophoridae	*Centrophorus*	*squamosus*	Bonnaterre (1788)	VU
Squaliformes	Centrophoridae	*Deania*	*calcea*	Lowe (1839)	LC
Squaliformes	Centrophoridae	*Deania*	*profundorum*	Smith & Radcliffe (1912)	LC
Squaliformes	Centrophoridae	*Deania*	*quadrispinosum*	McCulloch (1915)	NE
Squaliformes	Dalatiidae	*Dalatias*	*licha*	Bonnaterre (1788)	NT
Squaliformes	Dalatiidae	*Euprotomicrus*	*bispinatus*	Quoy & Gaimard (1824)	LC
Squaliformes	Dalatiidae	*Heteroscymnoides*	*marleyi*	Fowler (1934)	LC
Squaliformes	Dalatiidae	*Isistius*	*brasiliensis*	Quoy & Gaimard (1824)	LC

Order	***Family***	***Genus***	***Species***	***Authors***	***IUCN Red list status****
Squaliformes	Dalatiidae	*Squaliolus*	*laticaudus*	Smith & Radcliffe (1912)	LC
Squaliformes	Echinorhinidae	*Echinorhinus*	*brucus*	Bonnaterre (1788)	DD
Squaliformes	Etmopteridae	*Etmopterus*	*bigelowi*	Shirai & Tachikawa (1993)	LC
Squaliformes	Etmopteridae	*Etmopterus*	*brachyurus*	Smith & Radcliffe (1912)	NE
Squaliformes	Etmopteridae	*Etmopterus*	*compagnoi*	Smith & Radcliffe (1912)	DD
Squaliformes	Etmopteridae	*Etmopterus*	*gracilispinis*	Krefft (1968)	LC
Squaliformes	Etmopteridae	*Etmopterus*	*lucifer*	Jordan & Snyder (1902)	LC
Squaliformes	Etmopteridae	*Etmopterus*	*pusillus*	Lowe (1839)	LC
Squaliformes	Etmopteridae	*Etmopterus*	*sensotus*	Bass, D'Aubrey & Kistnasamy (1976)	LC
Squaliformes	Somniosidae	*Centroscymnus*	*coelolepis*	Bocage & Capello (1864)	NT
Squaliformes	Somniosidae	*Centroselachus*	*crepidater*	Bocage & Capello (1864)	LC
Squaliformes	Somniosidae	*Zameus*	*squamulosus*	Günther (1877)	DD
Squaliformes	Squalidae	*Cirrhigaleus*	*asper*	Merrett (1973)	DD
Squaliformes	Squalidae	*Squalus*	*acanthias*	Linnaeus (1758)	VU
Squaliformes	Squalidae	*Squalus*	*lalannei*	Baranes (2003)	DD
Squaliformes	Squalidae	*Squalus*	*megalops*	Macleay (1881)	DD
Squaliformes	Squalidae	*Squalus*	*mitsukurii*	Jordan & Snyder (1903)	DD
Squaliformes	Squalidae	*Squalus*	*uyato*	Rafinesque (1810)	NE
Squatiniformes	Squatinidae	*Squatina*	*africana*	Regan (1908)	DD
RAYS					
Rajiformes	Anacanthobatidae	*Anacanthobatis*	*marmoratus*	von Bonde & Swart (1923)	DD
Rajiformes	Anacanthobatidae	*Anacanthobatis*	*ori*	Wallace (1967)	DD
Rajiformes	Dasyatidae	*Dasyatis*	*brevicaudata*	Hutton (1875)	LC
Rajiformes	Dasyatidae	*Dasyatis*	*chrysonata*	Smith (1828)	NE
Rajiformes	Dasyatidae	*Dasyatis*	*microps*	Annandale (1908)	DD
Rajiformes	Dasyatidae	*Dasyatis*	*thetidis*	Ogilby (1899)	DD
Rajiformes	Dasyatidae	*Himantura*	*draco*	Compagno & Heemstra (1984)	NE
Rajiformes	Dasyatidae	*Himantura*	*fai*	Jordan & Seale (1906)	LC
Rajiformes	Dasyatidae	*Himantura*	*granulata*	Macleay (1883)	NT
Rajiformes	Dasyatidae	*Himantura*	*imbricata*	Bloch & Schneider (1801)	DD
Rajiformes	Dasyatidae	*Himantura*	*jenkinsii*	Annandale (1909)	LC
Rajiformes	Dasyatidae	*Himantura*	*leoparda*	Manjaji-Matsumoto & Last (2008)	VU
Rajiformes	Dasyatidae	*Himantura*	*uarnak*	Forsskål (1775)	VU
Rajiformes	Dasyatidae	*Neotrygon*	*kuhlii*	Müller & Henle (1841)	DD
Rajiformes	Dasyatidae	*Pastinachus*	*sephen*	Forsskål (1775)	DD
Rajiformes	Dasyatidae	*Pteroplatytrygon*	*violacea*	Bonaparte (1832)	LC
Rajiformes	Dasyatidae	*Taeniura*	*lymna*	Forsskål (1775)	NT
Rajiformes	Dasyatidae	*Taeniura*	*meyeni*	Müller & Henle (1841)	VU
Rajiformes	Dasyatidae	*Urogymnus*	*asperrimus*	Bloch & Schneider (1801)	VU
Rajiformes	Gymnuridae	*Gymnura*	*natalensis*	Gilchrist & Thompson (1911)	DD
Rajiformes	Gymnuridae	*Gymnura*	*poecilura*	Shaw (1804)	NT
Rajiformes	Hexatrygonidae	*Hexatrygon*	*bickelli*	Heemstra & Smith (1980)	LC
Rajiformes	Myliobatidae	*Aetobatus*	*flagellum*	Bloch & Schneider (1801)	EN
Rajiformes	Myliobatidae	*Aetobatus*	*narinari*	Euphrasen (1790)	NT
Rajiformes	Myliobatidae	*Aetomylaeus*	*vespertilio*	Bleeker (1852)	EN
Rajiformes	Myliobatidae	*Manta*	*alfredi*	Krefft (1868)	VU
Rajiformes	Myliobatidae	*Manta*	*birostris*	Walbaum (1792)	VU
Rajiformes	Myliobatidae	*Mobula*	*eregoodootenkee*	Bleeker (1859)	NT
Rajiformes	Myliobatidae	*Mobula*	*japanica*	Müller & Henle (1841)	NT
Rajiformes	Myliobatidae	*Mobula*	*kuhlii*	Müller & Henle (1841)	DD
Rajiformes	Myliobatidae	*Mobula*	*tarapacana*	Philippi (1892)	DD

Order	Family	Genus	Species	Authors	IUCN Red list status*
Rajiformes	Myliobatidae	*Mobula*	*thurstoni*	Loyd (1908)	NT
Rajiformes	Myliobatidae	*Myliobatis*	*aquila*	Linnaeus (1758)	DD
Rajiformes	Myliobatidae	*Pteromylaeus*	*bovinus*	Geoffroy Saint-Hilaire (1817)	DD
Rajiformes	Myliobatidae	*Rhinoptera*	*javanica*	Müller & Henle (1841)	VU
Rajiformes	Plesiobatidae	*Plesiobatis*	*daviesi*	Wallace (1967)	LC
Rajiformes	Rajidae	*Bathyraja*	*smithii*	Müller & Henle (1841)	DD
Rajiformes	Rajidae	*Cruriraja*	*andamanica*	Lloyd (1909)	DD
Rajiformes	Rajidae	*Cruriraja*	*parcomaculata*	von Bonde & Swart (1923)	NE
Rajiformes	Rajidae	*Cruriraja*	*triangularis*	Smith (1964)	NE
Rajiformes	Rajidae	*Dipturus*	*campbelli*	Wallace (1967)	NT
Rajiformes	Rajidae	*Dipturus*	*crosnieri*	Séret (1989)	VU
Rajiformes	Rajidae	*Dipturus*	*johannisdavisi*	Alcock (1899)	DD
Rajiformes	Rajidae	*Dipturus*	*lanceorostratus*	Wallace (1967)	DD
Rajiformes	Rajidae	*Dipturus*	*springeri*	Wallace (1967)	DD
Rajiformes	Rajidae	*Dipturus*	*stenorhynchus*	Wallace (1967)	DD
Rajiformes	Rajidae	*Fenestraja*	*maceachrani*	Séret (1989)	DD
Rajiformes	Rajidae	*Leucoraja*	*wallacei*	Hulley (1970)	LC
Rajiformes	Rajidae	*Okamejei*	*heemstrei*	McEachran & Fechhelm (1982)	NE
Rajiformes	Rajidae	*Raja*	*miraletus*	Linnaeus (1758)	NE
Rajiformes	Rajidae	*Rajella*	*leopardus*	von Bonde & Swart (1923)	LC
Rajiformes	Rajidae	*Rostroraja*	*alba*	Lacepède (1803)	EN
Rajiformes	Rhinobatidae	*Rhina*	*ancylostoma*	Bloch & Schneider (1801)	VU
Rajiformes	Rhinobatidae	*Rhinobatos*	*annulatus*	Müller & Henle (1841)	LC
Rajiformes	Rhinobatidae	*Rhinobatos*	*holcorhynchus*	Norman (1922)	DD
Rajiformes	Rhinobatidae	*Rhinobatos*	*leucospilus*	Norman (1926)	DD
Rajiformes	Rhinobatidae	*Rhinobatos*	*ocellatus*	Norman (1926)	DD
Rajiformes	Rhinobatidae	*Rhinobatos*	*zanzibarensis*	Norman (1926)	NT
Rajiformes	Rhinobatidae	*Rhynchobatus*	*djiddensis*	Forsskål (1775)	VU
Pristiformes	Pristidae	*Anoxypristis*	*cuspidata*	Latham (1794)	EN
Pristiformes	Pristidae	*Pristis*	*pristis*	Linnaeus (1758)	CR
Pristiformes	Pristidae	*Pristis*	*zijsron*	Bleeker (1851)	CR
Torpediniformes	Narcinidae	*Benthobatis*	*moresbyi*	Alcock (1898)	DD
Torpediniformes	Narcinidae	*Electrolux*	*addisoni*	Compagno & Heemstra (2007)	CR
Torpediniformes	Narcinidae	*Heteronarce*	*garmani*	Regan (1921)	NE
Torpediniformes	Narcinidae	*Narcine*	*insolita*	Carvalho, Séret & Compagno (2002)	DD
Torpediniformes	Narcinidae	*Narcine*	*oculifera*	Carvalho, Compagno & Mee (2002)	NE
Torpediniformes	Narcinidae	*Narcine*	*rierai*	Lloris & Rucabado (1991)	DD
Torpediniformes	Narcinidae	*Narke*	*capensis*	Gmelin (1789)	DD
Torpediniformes	Torpedinidae	*Torpedo*	*fuscomaculata*	Peters (1855)	DD
Torpediniformes	Torpedinidae	*Torpedo*	*sinuspersici*	Olfers (1831)	DD

*IUCN RED LIST STATUS ABBREVIATIONS	
Extinct in the wild	EW
Critically endangered	CR
Endangered	EN
Vulnerable	VU
Near threatened	NT
Least concern	LC
Data deficient	DD
Not evaluated	NE

12.
VULNERABLE TELEOST FISHES

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Previous page: Endangered humphead wrasse. Photo by Dennis King.

12. VULNERABLE TELEOST FISHES

A review of fisheries' impacts on threatened species in the Southwest Indian Ocean

Rudy van der Elst[1]

Abstract

The West Indian Ocean (WIO) is rich in fish diversity with some 2,200 species, equal to about 14% of the global total of marine fish species, grouped into 270 families representing 83% of all the fish families known. High levels of endemism at 13%, coupled with vulnerable features such as slow growth, limited distribution and declining populations place a number of species at risk. While traditional fish stock assessments deal with harvested fish stocks, it is often the less common but vulnerable species that require special attention. The identification of such species at risk is not straightforward and can best be done by interrogating several sources of information. The IUCN red data for marine fishes lists 1,058 marine fish species of concern in the WIO. Of these, 232 are elasmobranchs and 824 teleost fishes. Amongst the latter are 97 families dominated by coral reef species, including the larger Serranidae and Labridae. Combining the IUCN categories *critical, endangered* and *vulnerable* into a "threatened" category, supplemented with information from Cites as well as vulnerable species identified in WIOFish, results in a list of 12 species explicitly of concern to SWIOFP fisheries. The inadequate level of protection afforded by countries to some of these species raises concern about their future viability. Line and gillnet fisheries are especially implicated and in several cases the targeting of spawning aggregations and remote spawning refugia increases concern. It is recommended that a regional SWIO list of threatened marine fish species is compiled and adopted as a basis for collective action.

Biodiversity of teleost fishes in WIO

The Indo-West Pacific region has the greatest diversity of fishes of all the oceans' eight biogeographic regions. Embedded in this is the West Indian Ocean (WIO) with some 2,200 species, about 14 % of the global total of marine fishes (Smith and Heemstra 1986; Nelson 2006). The fish species found in the WIO can be grouped into 270 families, representing some 83% of all the fish families known. This richness is due to the large variety of habitats and oceanographic conditions of the region (van der Elst *et al.* 2005; UNEP 2009). On a national scale, the diversity of fishes is also considerable. For example, Tanzania's national marine fish species list may reach 1,000 species (Benbow 1976), that of the Seychelles over 1,000 species and, at a smaller scale, 552 species of fish for the Grand Reef at Toliara alone in south-west Madagascar (Gaudian *et al.* 2003). Mozambique has about two thousand species of marine fish with at least 307 species of linefish, La Réunion boasts 885 species (Letouneur *et al.* 2004) while the South African list is also around 2,500, including West Coast species. Many of these species are transboundary and shared between the SWIOFP countries. The West Indian Ocean marine fish assemblage includes many remarkable and iconic fishes, ranging from the world's "oldest" fish the coelacanth *Latimeria chalumnae* to the world's largest, the whale shark *Rhincodon typus*. The origin of the region's ichthyofauna is diverse, with about ½ considered to be Indo-Pacific (Smith & Heemstra 1986), about 13% endemic to the WIO and the rest made up of species that are global or original migrants from different regions as shown in Table 1.

Table 1. Origin of fish species found in the West Indian Ocean region. After Smith & Heemstra 1986.

Origin	*Percent*
Indo-Pacific	50
Atlantic	3-4
Southern ocean	<1
Global deep sea	29
Cosmopolitan	4
Endemic	13

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The distribution of this diversity of fishes in the WIO is not necessarily uniform. There are regions of higher diversity, such as the East African coast, Madagascar and India and also regions of relatively low diversity, such as the Arabian Gulf, with its shallow seas, high salinity and temperature fluctuation from 10ºC to 35ºC (Cohen 1973; Randall 1995). Significantly, there are also regions of high endemism. The Red Sea and Arabian Gulf, with their restricted opening and relative isolation from other seas have levels of endemism around 15%. Endemic species have also been recorded from several islands, especially belonging to the butterfly-, damsel and angelfish families (McAllistar *et al.* 1994). A surprisingly high level of endemism is also found off southern Mozambique and South Africa, with 227 endemic species (13% of its marine ichthyofauna) (Smith & Heemstra 1986). This endemism is largely attributable to five main families as reflected in Table 2.

Brindle bass, *Epinephelus lanceolatus.* Photo: Dennis King

Table 2. Main groups of endemic fishes found off SE Africa.

Family	*Common name*	*No. of species*
Clinidae	Klipfishes	38
Gobidae	Gobies	28
Sparidae	Seabreams	25
Scylliorhinidae	Catsharks	11
Batrachoideidae	Toadfishes	7

The reason for this high level of endemism in South Africa can be attributed to the unique environment of the southern tip of continental Africa. This is the only coastal region in the West Indian Ocean that has a temperate climate with distinctly different environmental conditions in association with the Agulhas large marine ecosystem (Beckley *et al.* 2002.) Some of the endemics in the West Indian Ocean may be glacial relics, meaning that they were once more widespread during the Pleistocene (Randall 1995). In some cases, upwelling systems may have contributed to their isolation, such as off South Africa, Oman and Somalia. There is also evidence of disjunct distribution of fishes, such as the croaker, *Argyrosomus hololepidotus* (Griffiths & Heemstra 1995). Surveys have suggested anti-tropical distribution of several inshore species that have been found off Puntland in Somalia and KwaZulu-Natal in South Africa, but not in between these latitudes. Examples of this are the elf *Pomatomus saltatrix,* the blacktail *Diplodus sargus,* the Cape fur seal *Arctocephalus pusillus* and the Natal rock lobster *Panulirus homarus*. (Mann & Fielding 2000.)

Despite the extensive fish collections made, and the major studies undertaken in the West Indian Ocean over the years, the ichthyofauna remains poorly understood. Very few countries of the region have national collections, most specimens are housed in northern hemisphere museums and the institutional support for ichthyology and taxonomy has declined. Hence the precise numbers of species found in the region and the levels of endemism will continue to vary as new species are added, synonyms recognised and errors corrected. For example, the notable ichthyologist Jack Randall added 52 new species based on collections he made during several surveys in the seas off Oman (Randall 1995). Most of the large and comprehensive ichthyofauna surveys were published before the 1960s and the more recent studies have been focussed on individual families or specific sites, such as those in Mozambique (Gell & Whittington 2002) and Kenya (Mwatha *et al.* 1998; McClanahan *et al.* 1996). There are, however, two notable exceptions, namely the five-volume FAO species' guide to the West Indian Ocean (Fischer and Bianchi 1984) and the comprehensive Smith's Sea Fishes, edited by Smith and Heemstra (1986). A further major contribution is imminent when "Fishes of the West Indian Ocean" is published by Heemstra and Heemstra.

Species under threat

Fishes of the WIO region are variably at risk. These risks may be attributed to various causes, including ecosystem and/or habitat destruction, climate change and of course as a result of fishing. In the case of fisheries, the risks imposed can be either as a result of directly targeting, incidental by-catch or impact on the species' environment. Whatever the case, some species are more vulnerable than others and these require identification and protection. The identification of such species at risk can be done on the basis of several different criteria. Included are issues such as declining populations, limited distributions, endemism, slow turn-over life cycles, reduced distribution range, high mortality rates, etc. While traditional fish stock assessments should be able to deal with harvested fish stocks, it is often the less common but vulnerable species that require special attention. There are several approaches, including the IUCN Red List system as well as national conservation programmes.

IUCN RED LIST SYSTEM

One system that encapsulates vulnerability is the IUCN Red List. Although the Red List system was initially developed for terrestrial use as an indication of the risk of extinction of individual species, it has progressively been improved and expanded since Version 1 in 1991, to Version 3.1 released in 2001. The suite of criteria used to evaluate species includes: population size, maturity levels, reductions and continued declines in abundance, extreme fluctuations, severely fragmented populations, range and area of occupancy, location in relationship to risk and quantitative assessments. Evaluations are conducted by a network of species specialists who assess the status of species based on the best expertise and information available. The data that supports the IUCN Red List system is the IUCN Species Programme, a centralized database and species information service which is publicly available via a searchable database. The records of all plants and animals listed in the Red List Categories are accessible, including marine fishes. Marine fishes present specific challenges for the Red List system as marine fishes invariably "have a much larger population size and a greater (potential) dispersal capability provided by the presence in many of pelagic larval life history phases" than terrestrial animals (Sadovy *et al.* 2013). This suggests that extinction is extremely remote. In the case of marine fishes there are specialist groups dealing with families of fishes, including Serranidae, Labridae and Sparidae. This process is guided by a set of rules that assist in defining the level of risk. Notwithstanding, the system does provide a useful framework for assessing threats and thus Red List categories should be considered as "flags of threat" which are an index of endangerment rather than an absolute risk of extinction of a particular species (Issac & Mace 1998; Mace *et al.* 2008). Indeed, no marine fishes have been listed as extinct in the wild. More details of the Red List criteria can be obtained from the IUCN website. Accordingly, the following categories are identified (Table 3). Based on the IUCN red data listing for marine fishes there are presently a total of 1058 marine fish species listed in the Red List for the WIO. Of these, 232 are Chondrichthyes, 2 are hagfishes and 824 are teleost fishes. Amongst the latter are 97 families dominated by coral reef species as shown in Figure 1 *(*see next page*)*.

Included in this list is a total of 17 (3.4%) listed as "threatened" comprising either Critical= 2; Endangered=3 or Vulnerable=12. Of these, six are shallow water and not threatened directly by industrial/commercial fisheries, while the remaining 11 are variably taken in fisheries in the SWIOFP region, mostly by line. In contrast, there are 57 species of elasmobranch listed (24% of total) as "threatened" comprising Critical=8; Endangered=8 and Vulnerable=41. This higher proportion signifies the higher levels of risk associated with elasmobranchs as well as the greater effort and progress made by the respective specialist group. One further species that is red-flagged listed as Critical is the coelacanth *Latimeria chalumnae*, belonging to the class Sarcopterygii.

Table 3. Red List categories as defined by IUCN.

Extinct in the wild	EW	A taxon is Extinct in the Wild.
Critically Endangered	CR	A taxon is Critically Endangered when the best available evidence indicates that it is considered to be facing an extremely high risk of extinction in the wild.
Endangered	EN	A taxon is Endangered when the best available evidence indicates that it is considered to be facing a very high risk of extinction in the wild.
Vulnerable	VU	A taxon is Vulnerable when the best available evidence indicates that it is considered to be facing a high risk of extinction in the wild.
Near Threatened	NT	A taxon is Near Threatened if it does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Least Concern	LC	A taxon is Least Concern if it does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.
Data Deficient	DD	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.
Not Evaluated	NE	A taxon is Not Evaluated when it is has not yet been evaluated against the criteria.

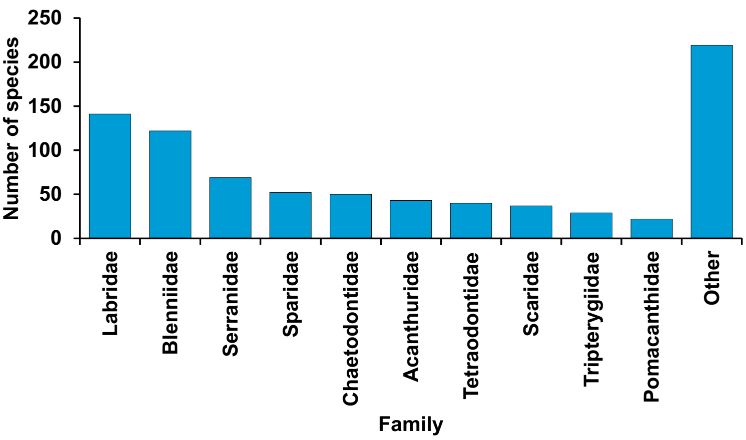

Figure 1. Distribution of the number of species red-flagged for the main WIO teleost fish families (IUCN).

Table 4. The twelve non-elasmobranch WIO species that have been red-flagged as "threatened".

Latimeria chalumnae	Coelacanth	CR
Thunnus maccoyii	Southern bluefin tuna	CR
Argyrosomus hololepidotus	Madagascar kob/croaker	EN
Cheilinus undulatus	Humphead wrasse	EN
Epinephelus marginatus	Dusky grouper	EN
Bolbometopon muricatum	Bumphead parrotfish	VU
Epinephelus albomarginatus	Captain fine	VU
Epinephelus gabriellae	Gabriella's grouper	VU
Epinephelus lanceolatus	Brindle bass	VU
Plectropomus areolatus	Spotted coral trout	VU
Plectropomus laevis	Black-saddled coral grouper	VU
Thunnus obesus	Big eye tuna	VU

Table 5. Distribution and level of protection of species relevant to SWIOFP that are IUCN red-flagged or listed under national regulation. F= fully protected; P=partial, N= no protection, ?=uncertain. Blue indicates presence. *= source of listing.

		Red	Cites	Nat[2]	RSA	MOZ	TANZ	KEN	SEY	FRN/ EPRS	MAU	MAD	COM	SOM
Coelacanth	*Latimeria chalumnae*	*	*	*	F	F	F	F				N	F	
Southern bluefin tuna	*Thunnus maccoyii*	*			?							N		
Madagascar kob	*Argyrosomus hololepidotus*	*										?		
Humphead wrasse	*Cheilinus undulatus*	*	*	*		N	N	N	N	P	N	N	N	
Dusky grouper	*Epinephelus marginatus*	*			P	N					0			
Bumphead parrotfish	*Bolbometopon muricatum*	*				N	N	N	N	P	N	N	N	N
Captain fine grouper	*Epinephelus albomarginatus*	*		*	P	?								
Gabriella's grouper	*Epinephelus gabriellae*	*												N
Brindle bass	*Epinephelus lanceolatus*	*		*	F	F	N	N	N	P	N	N	N	N
Spotted coral trout	*Plectropomus areolatus*	*								P		N		N
Black-saddled grouper	*Plectropomus laevis*	*				N	N	N	N	P	N	N	N	
Big eye tuna	*Thunnus obesus*	*			N	N	N	N	N	N	N	N	N	N
Natal wrasse	*Anchichoerops natalensis*			*	F	N								
Potato bass	*Epinephelus tukula*			*	F	F	N	N	N	N	N	N	N	N
Seventyfour	*Polysteganus undulosus*			*	F	F								

2. Information contributed by Component 5 national focal points.

CITES: CONVENTION IN TRADE OF ENDANGERED SPECIES

This convention is designed to monitor and manage the trade in endangered species. Species are allocated to lists based on their threatened status. Appendix I lists those that are severely under threat and may not be traded whereas Appendix II limits and controls trade for the listed species. While a number of marine fish species are listed, only two are relevant to SWIOFP: *Cheilinus undulatus* (Appendix II) and *Latimeria chalumnae* (Appendix I).

NATIONAL SPECIES CONSERVATION LISTS

In addition to the *red-flagged* species, individual SWIOFP countries have also identified species in their ichthyofauna that require special protection. While some of these species are endemic and may apply to one country only, others are transboundary and shared by more than one country. An amalgamated list of such specially protected species is given in Table 5, thus a reflection of fish species considered to be threatened and in need of special protection. In some cases species are partially protected by marine protected areas while in others they are fully protected and may not be landed at all. The table reflects that aside from the coelacanth there is considerable room for improved regional collaboration in the protection of red-flagged non-elasmobranch fishes. In most cases the red-flagged species are not even listed in national management regulations.

Fisheries that harvest listed species

There are a number of fisheries that may target some of the red-flagged species. In many cases this is an incidental catch but in some cases the red-flagged species represent a specific target. Potentially, several sources of information could indicate whether such red-flagged species are taken and at risk in the WIO. These range from formal international databases to scientific studies.

FAO RECORDS

Each year countries of the WIO submit their catch statistics to the FAO in Rome. These records are assembled into a database which provides insight into the region's fisheries landings by species, group, country and region. Several of the red-flagged species are taken in large numbers and hence reflected in the FAO fisheries landings data for the WIO (area 51).

The fact that no more vulnerable species are reported to the FAO data does not mean that *red-flagged* species are not caught. For example, several species of *Epinephelus* are *red-flagged*, but these have not been identified to species level and are reported as Serranidae or *Epinephelus* spp, the latter accounting for about 35,500 mt in the WIO in 2012. The

Table 6. Landings of red-flagged species declared to FAO in 2009 comparing WIO to global.

Species	Capture per region (t)		Reporting nations (WIO)
	Global	WIO = Area 51	
Argyrosomus hololepidotus	18,055	14	South Africa
Argyrosomus regius	7,284	0	n/a
Argyrozona argyrozona	371	0	n/a
Bolbometopon muricatum	150	150	Saudi Arabia
Cephalopholis hemistiktos	250	250	Saudi Arabia
Cheilinus undulatus	984	0	n/a
Epinephelus coioides	8,152	8,152	Iran, UAE
Epinephelus fuscoguttatus	50	50	Saudi Arabia
Epinephelus marginatus	1,157	0	n/a
Epinephelus polylepis	470	470	Bahrain, Saudi Arabia
Lophius vomerinus	6,786	0	n/a
Makaira nigricans	38,446	6,896	16 nations
Petrus rupestris	2	0	n/a
Plectropomus areolatus	410	410	Saudi Arabia
Plectropomus leopardus	20,699	0	n/a
Plectropomus pessuliferus	340	340	Saudi Arabia
Thunnus alalunga	256,082	15,355	21 nations
Thunnus albacares	1,352,204	295,405	28 nations
Thunnus maccoyii	9,243	1,251	6 nations
Thunnus obesus	450,546	71,573	23 nations

reporting of *A. hololepidotus* is a specific issue of confusion. *A. hololepidotus* is endemic to the southeast coast of Madagascar (Griffiths & Heemstra 1995) and known to be severely restricted and declining. Those listed as *A. hololepidotus* from elsewhere are either *A. japonicus* or other *Argyrosomus* species.

Blacksaddle grouper, *Plectropomus laevis*. Photo: Dennis King

WIOFISH DATABASE

WIOFish was first conceived in 2000 as part of an IUCN initiative under the Jakarta Mandate of the CBD. It was noted that despite the importance of the WIO as a region of great marine biodiversity and as an essential source of food security for millions of people, very few of the region's fisheries had been formally identified and described, especially the small-scale fisheries. In response it was decided to identify and document all fisheries of the region focussing on small-scale and artisanal fisheries. WIOFish has evolved into a viable information system with the following primary objectives:

- to identify and describe each unique fishery type found in the WIO coastal regions and to capture such information into a freely accessible database of annotated fishery profiles for all fisheries of the region;
- to annually update this information and to facilitate public web-based access to the data through an interactive web-based system that allows for comprehensive access and a wide range of reporting routines;
- to report annually on the "status" of the fisheries, including risk profiles and management needs, via a semi-quantitative scoring system;
- to foster development of small-scale fisheries co-management systems through the sharing of information and access to common information sources;
- to use WIOFish as a mechanism to maintain a permanent regional partnership between national fishery nodes in the main WIO countries.

WIOFish is a partner programme involving most of the SWIOFP member states. While the WIOFish database is not a statistical fisheries database, it is a repository for as much descriptive information as possible about each fishery that is currently operating or has operated in the western Indian Ocean. This includes information related to threatened species. By 2012, a total of 260 fisheries had been documented reflecting fisheries in Comoros, Seychelles, Kenya, Tanzania, Mozambique, South Africa, Mauritius and Madagascar. Analysis of the WIOFish database indicates that 108 species considered as domestically threatened were taken in 40 different fisheries. These included elasmobranchs (16), sea turtles (5), marine mammals (6), sea cucumber (13), molluscs (19), prawn (8), lobster (5), corals (2), crab (1) and 33 species of teleost fish, inclusive of the coelacanth. These species are thus in addition to the Red List *flagged* species as reflected in Table 7.

Table 7: Species listed as threatened by WIOFish countries in addition to those red-flagged by IUCN.

Scientific Name	***English Name***	***Fishery Name***	***Area***
Acanthopagrus berda	Goldsilk seabream, Picnic seabream	Hook & line, shore, estuarine (rec)	South Africa
Atractoscion aequidens	Geelbek croaker	Hook & line, vessel, commercial	South Africa
Cephalopholis argus	Peacock hind	Diving, speargun, fish	Kenya
Cephalopholis boenak	Brownbarred rockcod	Diving, speargun, fish	Kenya
Cephalopholis leopardus	Leopard rockcod	Diving, speargun, fish	Kenya
Cephalopholis miniata	Coral hind	Diving, speargun, fish	Kenya
Cephalopholis sonnerati	Tomato hind	Diving, speargun, fish	Kenya
Cephalopholis taeniops	Bluespotted seabass	Diving, speargun, fish	Kenya
Cephalopholis urodeta	Duskyfin rockcod	Diving, speargun, fish	Kenya
Cetoscarus bicolor	Bicolour parrotfish	Diving, speargun, fish	Comoros
Chrysoblephus anglicus	Englishman seabream	Hook & line, small boat & motor, charter/party; Hook & line, vessel, commercial	South Africa
Ctenochaetus striatus	Striated surgeonfish	Diving, speargun, fish	Comoros
Epinephelus caeruleopunctatus	Whitespotted rockcod	Diving, speargun, fish	Kenya
Epinephelus coioides	Orange-spotted grouper	Diving, speargun, fish	Kenya
Epinephelus fasciatus	Blacktip grouper	Diving, speargun, fish	Kenya
Epinephelus fuscoguttatus	Blotchy rockcod	Diving, speargun, fish	Kenya
Epinephelus longispinis	Streakyspot rockcod	Diving, speargun, fish	Kenya
Epinephelus malabaricus	Malabar grouper	Diving, speargun, fish	Kenya
Epinephelus merra	Honeycomb grouper	Diving, speargun, fish	Kenya
Latimeria chalumnae	Coelacanth	Hook & line, handline, fish; Small nets, gill nets, sharks & rays	Comoros; Madagascar
Lichia amia	Leerfish	Hook & line, paddleski, fish	South Africa
Mulloidichthys flavolineatus	Yellowstripe goatfish	Other, dynamite, fish	Comoros
Parupeneus indicus	Indian goatfish	Other, dynamite, fish	Comoros
Pomadasys commersonnii	Smallspotted grunter	Hook & line, shore, estuarine (sub); Traps, staked, fish	South Africa
Pomatomus saltatrix	Bluefish	Small nets, cast net, fish/prawns	South Africa
Pterocaesio tile	Dark-banded fusilier	Other, dynamite, fish	Comoros
Rhabdosargus sarba	Goldlined seabream	Hook & line, shore, estuarine (sub); Traps, staked, fish	South Africa
Scarus ghobban	Yellowscale parrotfish	Diving, speargun, fish	Comoros
Scomberomorus commerson	Narrow-barred Spanish mackerel	Small nets, gill nets, sharks & rays	Madagascar
Siganus argenteus	Streamlined spinefoot	Small nets, gillnets & cast nets, fish & shrimps	Madagascar
Siganus stellatus	Brown-spotted spinefoot	Diving, speargun, fish	Comoros
Thunnus obesus	Bigeye tuna	Industrial nets, purse seine, tuna; Small nets, gill nets, sharks & rays	Madagascar
Umbrina ronchus	Slender baardman	Diving, speargun/no SCUBA, fish	South Africa

Specific fisheries' interactions

Certain fisheries are more prone to harvesting r*ed-flagged* species. Some are discussed.

TROPICAL ARTISANAL AND SEMI-INDUSTRIAL LINEFISHING

Linefishing in association with reefs often targets Serranidae and Labridae. This can include the capture of *red-flagged* species, especially *E. tukula, E. lanceolatus, E. albomarginatus, P. laevis, P. areolatus, C. undulatus* and *B. muricatum* as well as *L. chalumae.* These are all slow growing and *k*-selected species, rendering them vulnerable so that they seldom occur on reefs that are or have been intensely fished (Sadovy *et al*. 2013). However, on the more remote reefs these species may still be prevalent. For example, remote and inaccessible hotspots such as Bassas da India and other atolls and islands are refugia for such species. Occasional visits by fishers lead to the capture of such species (Figures), as shown in the images taken of a commercial linefish catch at Bassas da India some years ago (van der Elst *et al.* 2009). This presents a problem as such refugia may well represent an important source of spawning stock. Similarly, most of these *red-flagged* reef species were also recorded on Geyser Reef by Chabenet *et al.* (1996). Smith & Smith (1963) also reported the presence and capture of these species at several locations in the Seychelles while Polunin (1987) refers to a similar fish assemblage at Aldabra, especially *C. undulatus*. Visual observations by the author at Aldabra revealed a considerable number of *B. muricatum* (> 50) in the main Aldabra channel in 1995.

In some line fisheries that operate in deeper water, the capture of coelacanths has been reported. This is especially true of areas around volcanic islands with steep slopes and narrow shelf regions so that the fisheries operate in deep water.

Figure 2: Two vulnerable serranids *(P. laevis & P. areolatus)* taken by fishers at Bassas da India.

The best example is that of the Comoros where coelacanths are not infrequently caught. Coelacanths have also been reported from Mozambique and Kenya caught by trawler. In the late 1990s and early 2000s there was a sudden increase in coelacanth catches with reports from Tanzania, Zanzibar and Madagascar. In most of these cases the specimens were caught using hook and line, except for Tanzania where deep set gillnets were used (Ngatunga 2003; Nikaido 2011).

Figure 3: Coelacanths caught in Tanzania. (Photo: TAFIRI)

GILL NETTING

There are at least 15 different gill net fisheries in the WIO reported in WIOFish (WIOFish 2012). Many of these have the potential to capture *red-flagged* species. Most notable is the Seychelles gillnet fishery for humphead parrotfish *B. muricatum*. This is a local artisanal fishery without any obvious restrictions. The catch is sold fresh or frozen as a popular local food, although this fishery conflicts with diving tourists. Fishers involved are subsidised to the extent that they have fuel subsidies and social security benefits. Few of the other gill net fisheries report detailed catch information although a synopsis of these fisheries gives useful insight, as tabulated opposite (Table 8).

Table 8. List of WIO gill net fisheries with those that reported capture of red-flagged species to the WIOfish data.

Country	*Fishery*	*Critical*	*Vulnerable*	*Near threatened*
Comoros	Small nets, gill nets bottom, fish			
	Small nets, gill nets surface, fish			
	Small nets, gillnets – surrounding, fish			
Kenya	Small nets, bottom gill net, sharks/rays/fish			
	Small nets, gillnets, crustaceans			
	Small nets, surface gill net, sharks/rays/fish			*Thunnus albacares*
Madagascar	Small nets, gill nets, sharks & rays	*Latimeria chalumnae*	*Thunnus obesus*	*Epinephelus malabaricus, Thunnus alalunga, Thunnus albacares*
	Small nets, gillnets & cast nets, fish & shrimps			
	Small nets, gillnets surface, fish			
Mauritius	Small nets, gill net, Fish			
Mozambique	Small nets, bottom gillnet, artisanal			
	Small nets, gillnet, shrimp			
	Small nets, gillnet, small pelagic			
Seychelles	Small nets, bottom gill net, slipper lobster			
	Small nets, gill net, humphead parrot fish (Filanbaz)		*Bolbometopon muricatum*	
	Small nets, gill nets, sharks			
	Small nets, pelagic gill net, mackerel			
South Africa	Small nets, surface gill net, sharks			
Tanzania	Small and large mesh nets, bottom gill net			*Thunnus albacares*
	Small nets, surface (drift) gill net, pelagics			*Thunnus albacares*
	Small nets, surrounding net (Zuwio)			

SPORT AND TOURIST FISHERIES

Sport fishing and tourism are important economic drivers in the WIO region. While many sport fishers and tourist operators are increasingly adopting conservation approaches in their angling, there is a new trend towards accessing the more exotic and remote species. In some cases this leads to the targeting of *red-flagged* species and accessing remote biodiversity hotspots. Specific examples include fishing trips to Bassas da India, a French atoll located in the mid-Mozambique Channels. A web search lists a great many ventures to fish at this site and promotes the capture of *red-flagged* species. Similar ventures to the Seychelles' remote outer islands such as Farquahar and Mauritius' remote St Brandon are increasingly popular. In some cases these trips are reported on in fishing magazines, further promoting the catching of *red-flagged* fish, including *C. undulatus*, *B. muricatum, E. lanceolatus and E. tukula*. While in some cases the catch is released, this is not always true and threatened species may be taken without any management controls or reporting. These isolated hotpots are considered to be refugia of such *red-flagged* species and are thus especially important for their future survival (van der Elst & Chater 2009). Notwithstanding their remoteness, it is incumbent on the authorities to manage and protect these sites as envisaged under the French "Isles Eparses" programme.

AQUARIUM AND ORNAMENTAL SPECIMEN COLLECTIONS

There is a variable level of live fish collecting in the WIO for aquariums, both for private collectors as well as for public aquaria. While such fisheries and their associated trade can be quite lucrative, in most cases they are poorly controlled and monitored. Where records are kept, these pertain mostly to trade statistics referring to "mixed" species. However, it is clear that coral reef fishes predominate in these fisheries. Although industrial fisheries in the SWIO region do not target such species, the suggestion that aquarium collecting may represent an alternative livelihood to offset depleted industrial fisheries needs to be made with caution. In some cases specimens are taken as bycatch in trawl fisheries that have ornamental value. Examples include the puffers such as *Diodon hysterix* which are dried and inflated, at times made into lamp shades. Without a scientific basis such resources should not be targeted and developed as alternative sources of income. Public aquaria also make collections in the WIO region. Although the quantities may appear modest, rare species are more in demand. For example the pursuit of endangered sawfish (*Pristis* sp) should be prohibited. It is recommended that the Pan African Association of Zoos, Aquaria and Botanical Gardens (PAAZAB) be encouraged to take a lead in this regard.

Individual species profiled

While exploitation of marine species is known to be the dominant factor in causing declines in populations (Dulvy *et al*. 2003), certain life history traits can exacerbate species' vulnerability. Larger species that mature late and produce fewer offspring are more susceptible to population decline than species with high fecundity (Sadovy *et al*. 2013). Table 7 provides a synopsis of the main reference points that contribute to the species' vulnerability.

Table 9: Key life history parameters for some species of concern including red-flagged species (primarily sourced from www.fishbase.org).

Name	Distribution	Habitat	Fisheries Impact	IUCN listing	Cites listing	L mat (cm)	L max (cm)	Mean pop doubling time in yrs	Vulnerability index
Latimeria chalumnae	IP	Deep reef ledges	Artisanal fisheries	CR	I	150	170-183	> 14	86/100
Cheilinus undulatus	IP	Reef associated	Live food & aquarium	EN A2bd+3bd	II	52?	229	4.5 - 14	74/100
Epinephelus marginatus	Atlantic; SWIO& Med	Reef associated	Linefish	EN A2d	n/a	47	150	4.5-14	72/100
Epinephelus tukula	IP	Reef associated	Linefish	LC	n/a	99	200	>14	71/100
Epinephelus lanceolatus	IP	Reefs & brackish lagoons	Linefish, aquarium	VU A2d	n/a	129	270	>14	74/100
Epinephelus albomarginatus	SWIO	Reef associated	Linefish	VU A2d	n/a	Unknown	100	4.5-14	50/100
Epinephelus areolatus	IP	Sea grass; reefs	Linefish Aquaculture	LC	n/a	23	47	1.4 - 4.4	36/100
Epinephelus gabriellae	NWIO	Rocky bottom	Artisanal	VU Blab(v)	n/a	Unknown	70	1.4 - 4.4	26/100
Plectropomus laevis	IP	Reef associated	Linefish	VU A2d+4d	n/a	60	125	>14	55/100
Polysteganus undulosus	SWIO	Reef associated	Linefish	n/a	n/a	33	100	1.4 - 4.4	45/100
Anchichoerops natalensis	SWIO	Reef edges	Linefish	LC	n/a	Unknown	75	4.5 - 14	45/100
Bolbometopon muricatum	IP	Reefs & lagoons	Linefish & aquarium	VU A2d	n/a	Unknown	130	4.5 - 14	67/100
Thunnus obesus	Pantropical	Oceanic	Industrial fisheries	VU A2bd	n/a	100-125	250	4.5 - 14	56/100
Thunnus maccoyii	Global	Oceanic	Industrial fisheries	CR A2bd	n/a	120-130	245	4.5 - 14	67/100
Argyrosomus hololepidotus	Endemic to Madagascar	Estuarine & offshore	Diverse fisheries	EN B1ab+2ab	n/a	Unknown	200	>14	77/100

Relevance to SWIOFP

Clearly there are vulnerable and endangered species implicated in a number of SWIO fisheries. In some cases these represent a serious threat – such as the targeting of iconic species in remote locations where they may represent a remnant spawning stock. In most cases the capture of red-flagged species is not seen as a matter of concern by management agencies, except perhaps the coelacanth. Similarly, the capture of elasmobranchs is not generally viewed in the light of their red-flagged status. It is thus proposed that, under the joint auspices of the Nairobi Convention and the SWIOFC, a list of species is drawn up which reflects a collated red-flagged species list for the WIO and which countries are encouraged to report on capture and be managed accordingly.

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13.
BIODIVERSITY HOTSPOTS

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Previous page: A trio of Aldabra giant tortoises. Photo by Bernadine Everett.

13. BIODIVERSITY HOTSPOTS OF THE SOUTHWEST INDIAN OCEAN

Their location and primary features

Bernadine Everett[1] and Rudy van der Elst[1]

Abstract

Within the Southwest Indian Ocean there are specific geographic sites that are considered as biodiversity hotspots. These sites are areas that may be vulnerable to fishing pressure, of importance to the region's biodiversity or provide the means to monitor fisheries' impacts on the environment. A total of 59 hotspots were identified for the region which are key areas for various marine fish, sea turtles, seabirds and/or marine mammals. While this list is by no means complete, it is a start to identifying and describing these critical areas for the region.

Introduction and background

The Southwest Indian Ocean (SWIO) is characterised by high biodiversity which can be attributed to the diversity of habitats available to marine organisms. These include mangrove forests, estuaries, seagrass meadows, coral reefs, soft sediments and inshore banks, deep incised canyons, sea mounts, and a dynamic oceanic realm. In many cases these habitats support fisheries, either targeting species within those habitats or harvesting species that have some dependence on these habitats. Such fisheries may affect the intricate interactions between species and the very habitats on which they are reliant for their survival. Disruptions to the ecology of ecosystems may be through the removal of specific species, the removal of non-targeted species (bycatch) or through physical alteration to the habitat.

For comprehensive management of fisheries through ecosystem approaches, it is necessary to have knowledge of the extent and distributions of the various components of the ecosystems where the fisheries operate and to understand the interactions of the species involved with each other and with their environment. However, apart from the general distribution of these critical ecosystems in the WIO, there are specific sites which can be identified as special, called "hotspots". Although different definitions can be applied, in this case a hotspot is defined as a spatially well-defined and predictable site or zone with biological features that:

1. may render it periodically or permanently vulnerable (and relevant) to fisheries;
2. appropriately reflects the nature and status of its particular ecosystem and functions as a regional biodiversity assessment reference site;
3. could function as a proxy for monitoring fisheries impacts on specific vulnerable groups (e.g. turtles, piscivorous seabirds and mammals)
4. for protected sites fisheries data from unexploited (virgin) stocks provide key biological reference points.

Included are turtle nesting and foraging sites, areas of abundance of vulnerable species, nesting seabird populations, fish aggregating and nursery areas and areas of high biodiversity as well as sites that generate particular environmental goods and services, including for fisheries.

This chapter provides an overview of hotspots in the WIO that were identified from several sources, including sites highlighted by national focal points to the biodiversity component of SWIOFP as reflected in the Data Gap Analysis (van der Elst et al 2009). Other sites were identified by the EAME process and are included here. The hotspots presented here are by no means a complete list but a start at identifying, describing and hopefully protecting all the critical hotspots of the region.

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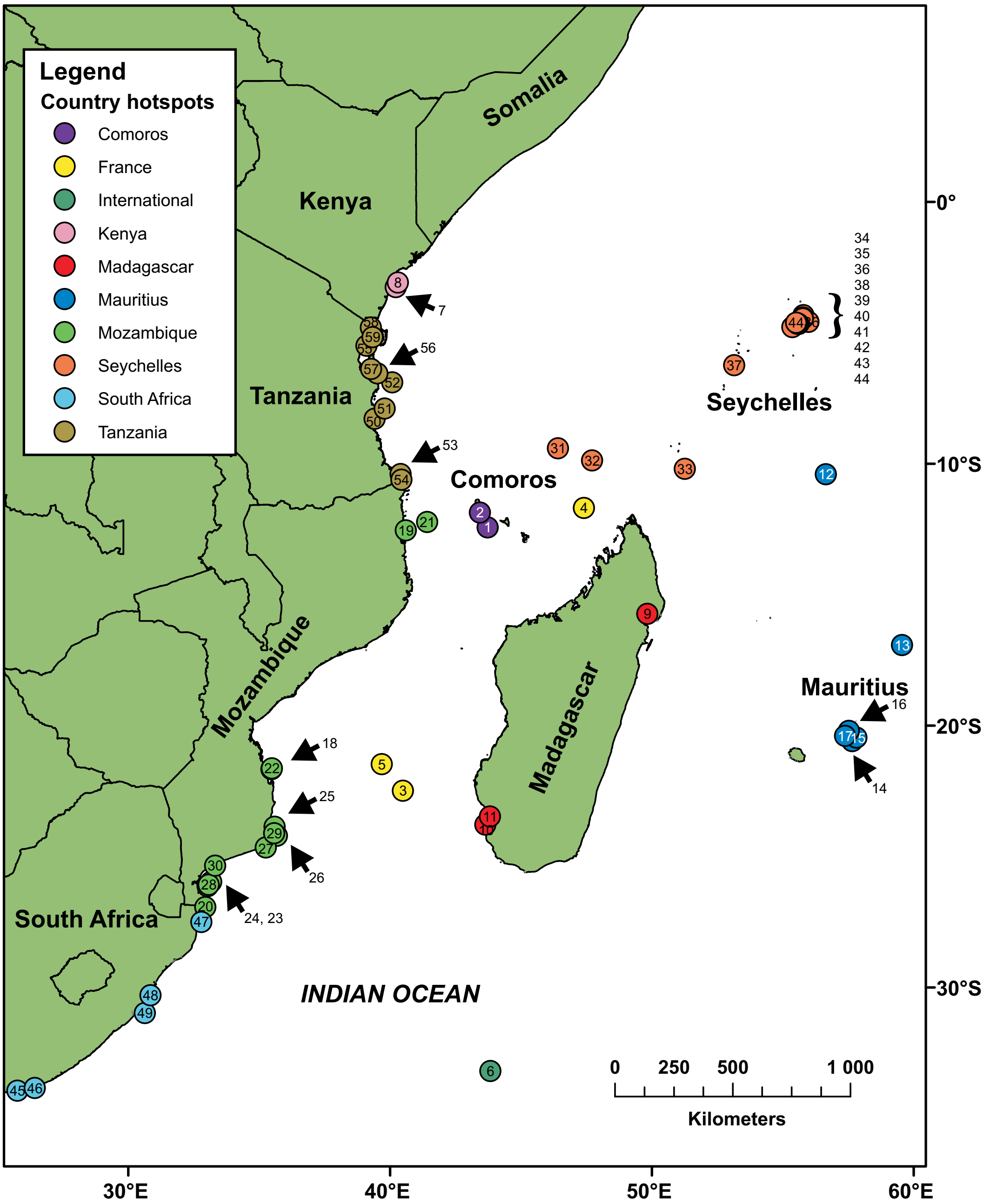
Hotspots

Each of the hotpots is described by country and each is given a reference number that facilitates reference to the relevant area on the map. A regional overview map is provided in Figure 1 below. The species refered to in the text are listed with their respective scientific names in the Annex.

Figure 1: Regional map of biodiversity hotspots in the WIO.



1: Mohéli, Comoros; 2: Gombessa Reserve, Comoros; 3: Europa Island, France; 4: Glorieuse, France; 5: Bassas d'India, France; 6: Walters Shoal, International; 7: Malindi Bay, Kenya; 8: Ungwana Bay, Kenya; 9: Helodrano Antongila Bay, Madagascar; 10: Nosy Ve, Madagascar; 11: Grand Reef, Madagascar; 12: Agalega, Mauritius; 13: St Brandon, Mauritius; 14: Gris gris, Mauritius ; 15: Le Bouchon, Mauritius ; 16: Rivulet Terre Rouge Bird Sanctuary, Mauritius; 17: West coast, Mauritius; 18: Bazaruto, Mozambique; 19: Quirimbas, Mozambique; 20: Ponta Do Oura, Mozambique; 21: Saint Lazarus Bank, Mozambique; 22: Ponta don Carlos, Mozambique; 23: Barreira Vermelha, Mozambique; 24: Baixo Denae, Mozambique; 25: Tofo Beach, Mozambique; 26: Paindane (Jangamo), Mozambique; 27: Zavora, Mozambique; 28: Inhaca Island, Mozambique; 29: Manta Reef, Mozambique; 30: Praia do Bilene, Mozambique; 31: Aldabra, Seychelles; 32: Cosmoledo, Seychelles; 33: Farquhar, Seychelles; 34: Aride, Seychelles; 35: Cousin, Seychelles; 36: Fregate, Seychelles; 37: Desnoeufs, Seychelles; 38: Curieuse, Seychelles; 39: Grand Anse, Seychelles; 40: Anse Manon, Seychelles; 41: St Anne, Seychelles; 42: Point Matoopa, Seychelles; 43: L'ilot, Seychelles; 44: Glacis, Seychelles; 45: Saint Croix Island, South Africa; 46: Bird Island, South Africa; 47: iSimangaliso Wetland Park, South Africa; 48: Aliwal Shoal, South Africa; 49: Protea Banks, South Africa; 50: Rufiji Delta, Tanzania; 51: Mafia Island, Tanzania; 52: Latham Island, Tanzania; 53: Mnazi Bay, Tanzania; 54: Ruvuma Estuary, Tanzania; 55: Maziwe Island, Tanzania; 56: Menai Bay, Tanzania; 57: Chumbe Island, Tanzania; 58: Moa Bay, Tanzania; 59: Pemba Channel, Tanzania.

SEYCHELLES

A total of 14 hotspots were identified and are described below.

Name & location	**Aldabra – Seychelles – Ref = 31**
Habitat	Coral atoll; land area = 155.4 km^2; lagoon = 224 km^2
Primary features	High levels of avifauna endemism reflecting evolutionary processes; largest giant tortoise population; major seabird and green turtle nesting sites; rich marine mammal diversity, unexploited stocks of red-flagged fishes, including blackfin reef sharks.
Primary threats	Coral bleaching; invasive rats, cats & goats, tourism.
Monitoring potential	Turtle nesting; seabird nesting; coral transects; vulnerable fish populations.
Conservation status	Fully protected; IUCN category I.
Strategic relevance to SWIOFP	• No fisheries permitted. • Continued protection of stocks of threatened fishes and sharks. • Reference site for long-term monitoring of turtles and seabirds as proxy for regional fisheries impact. • Reference site for biological data from non-exploited fishes.

Aldabra is a raised coral atoll located at 9°24'S 46°22'E and belongs to the Aldabra Group, one of the island groups of the Outer Islands of the Seychelles (Carpin 1998). It is more than 1,100 km from Mahé, the principal island of the Seychelles. Most of the land surface is comprised of ancient coral reef (~125,000 years old) which has been repeatedly raised above sea level. Erosion of the reef has left characteristic *champignon* outcrops.

The atoll is a unique example of an oceanic island ecosystem in which evolutionary processes remain highly apparent and visually active within its rich biota. Discrete insular communities have developed due to the extensive size, morphology and isolation of the atoll which resulted in a high occurrence of endemicy among the species that make up the ecosystem. Since there is minimal human impact on the atoll, the full complexity of the ecological processes can be fully and clearly observed (UNESCO 2011).

The atoll is the second largest in the world by land area, after Kiritimati (Christmas Island) in the Pacific Ocean. It is 34 km long, 14.5 km wide, and, in places, up to 8 meters above sea level. It has a land area of 155.4 km^2 (Prŷs-Jones & Diamond 1984). It consists of a ring of four larger islands which make up 95% of the total land area. These are South Island (Grand Terre, 116.1 km^2), Malabar or Middle Island (26.8 km^2), Polymnieli or Polymnie Island (4.75 km^2) and Picard or West Island (9.4 km^2). There are also forty smaller islands and rocks, all inside the lagoon, except a few very small islets at the West Channels between South and Polymnie Islands, the largest of those being Îlot Magnan. The largest islands inside the lagoon are Île Michel (Michael Island) in the east and Île Esprit (Spirit Island) in the west. The islands consist of consolidated coral limestone uplands, sand dunes and beaches based on the remains of a coral reef. Most of the land lies lower than 10 m above sea level. The central lagoon measures 224 km^2 in area, of which roughly two thirds are exposed during low tide. The lagoon links to the ocean through narrow channels, none of which are wider than 600 m.

Aldabra has a complex assemblage of plants with 31 endemic species. An evergreen fringe of grey, black, Indian and red mangroves occur in the intertidal area around the lagoon. Three less abundant species of mangrove are white-flowered apple, canonball and cedar mangroves (Hnatiuk & Merton 1979). The higher areas are covered with a pemphis scrub of which the dominant plant is a marine species called *Pemphis acidula.* It is a thick coastal shrub which is salt-tolerant and grows on highly dissected rocks (Prŷs-Jones & Diamond 1984). The lower outer areas of the islands, which are home to the giant tortoises, are covered by a mixture of trees, shrubs, herbs and grasses where no single species dominates.

The atoll has the world's largest population of Aldabra giant tortoises numbering some 100,000 individuals (Bourn *et al.* 1999). It is also known for the coconut crab, the world's largest land crab. Notable is a population of blackfin reef sharks, especially in the shallow lagoon, as well as manta rays and endangered humphead wrasse and green humphead parrotfish. Some 6,000 green turtles nest on Aldabra's beaches annually while the endangered hawksbill turtles nest in lower numbers. Loggerhead turtles and leatherback turtles also occur but do not nest here (Frazier 1984).

Endemic birds of the atoll include the Aldabra brush warbler, Abbott's sunbird, Aldabra fody, Aldabra drongo and the Aldabra rail (Sinclair & Langrand 2003) which along with Madagascar's white throated rail, are the last surviving flightless birds of the Indian Ocean region (Skerrett 1999). Aldabra provides good breeding grounds for numerous seabirds including red-footed boobies, greater and lesser frigatebirds, white-tailed and red-tailed tropicbirds and swift, bridled, black-naped and white terns.

Aldabra has two species of bats that are both endemic to the atoll: Paulian's triple leaf-nosed bat and the Aldabra flying fox (Goodman & Ranivo 2008, Racey & Nicoll 1984). All other terrestrial mammals are introduced species. These include goats, cats and rats. From February 1973 until February 2007, a total of 14 marine mammal species have been recorded around the atoll. These were: spinner dolphin, common bottlenose dolphin, Blainville's beaked whale, short-finned pilot whale, sperm whale, killer whale, Curvier's beaked whale, common dolphin, spotted dolphin, false killer whale, Risso's dolphin, melon-headed whale, humpback whale and dugong. Most of these mammals are irregular visitors to Aldabra with the exception of the spinner dolphins which are thought to be resident (Hermans & Pistorius 2008). Aldabra is the only locality in the Seychelles where there has been more than one sighting of dugong (Muir *et al.* 2004). Dugong have only been sighted irregularly in the lagoon which is surprising considering that the atoll seems to provide an ideal habitat for them with very little human disturbance (Hermans & Pistorius 2008). Dugongs do, however, have the ability to move large distances (Muir *et al.* 2004) and it is doubtful that the animals seen at Aldabra are residents. It is more likely that the animals move from northern Madagascar to Aldabra during the southeast monsoons (Hermans & Pistorius 2008). Nevertheless the atoll does provide dugongs with a sheltered stopover.

The Aldabra Atoll was declared a UNESCO World Heritage Site in 1982. The atoll is legally protected under national Seychelles legislation and is managed by the Seychelles Islands Foundation, with daily operations guided by a management plan. The remoteness of the atoll limits human interference which contributes to the protection of the biological and ecological processes (UNESCO 2011).

Opportunities for fisheries-related regional monitoring are considerable and include seabird populations, sea turtle nesting, coral cover and the abundance of vulnerable fish species such as humphead wrasse and green humphead parrotfish. As there is no fisheries activity at Aldabra, biological evaluation of natural fish populations can generate valuable data on biological reference points of several species of fish.

Name & location	**Cosmoledo – Seychelles – Ref = 32**
Habitat	Coral atoll; land area = 5.2 km^2; lagoon = 145 km^2
Primary features	Globally important bird nesting site; spawning aggregations of vulnerable groupers; green turtle nesting sites.
Primary threats	Coral bleaching; invasive rats, cats & goats, tourism.
Monitoring potential	Turtle nesting; seabird nesting; coral transects; vulnerable fish population aggregations.
Conservation status	Fully protected; IUCN category I.
Strategic relevance to SWIOFP	• No fisheries permitted. • Protection of spawning aggregations of threatened groupers. • Reference site for long-term monitoring of piscivorous seabirds and turtles as proxy for regional fisheries impact.

Cosmoledo is an atoll of the Aldabra Group and belongs to the Outer Islands of the Seychelles located at 9°42'S 47°36'E. It is situated on one of the peaks of a volcano that rises from the sea floor at 4 000 – 4 400 m below the surface. The atoll is 14.5 km long and 11.5 km wide. The total land area is about 5.2 km^2, while the lagoon measures 145 km^2 in area. The atoll is composed of 8 individual islets and numerous cays along the rim. The peripheral reef encloses a shallow lagoon which opens to the south via two large channel systems (Bayne *et al.* 1970).

The vegetation of Cosmoledo is similar to that of Aldabra. There are three main types: raised reef-rock vegetation which includes species of pembris, bully trees, fig trees and climbing milkweeds; sand and dune vegetation comprised of fan-flowers, soldierbush and bay cedars as well as coconuts, grasses sedges, herbs and vines. She-oak woodlands are found on the dunes along with fan-flowers and bay cedar scrub. The final type is the mangrove vegetation composed of six species: white, red, black, white flowered apple, cannonball and Indian mangroves (Bayne *et al.* 1970).

BirdLife International has designated Cosmoledo as an Important Bird Area due to its value as a centre of biodiversity. The atoll has globally significant populations of the masked booby, the red-footed booby, and the sooty tern. There are also populations of terrestrial birds with forms that are endemic to the Aldabra group but the taxonomy requires molecular examination for confirmation. The atoll is currently uninhabited but the birds are impacted on by the presence of species (cats and rats) introduced by previous inhabitants (Rocamora 2003).

Cosmoledo, like some other localities in the Seychelles, has periodic spawning aggregations of fish (Robinson *et al.* 2004). These are primarily camouflage and brown-marbled grouper. The aggregations off Cosmoledo were noted to occur in November and December with the possibility of occurring as late as February (Aumeeruddy & Robinson 2006). The predictable nature of spawning aggregations in both time and space makes them highly vulnerable to over-exploitation (Sadovy *et al.* 1994). Closed seasons and closed areas have been proposed to protect spawning aggregations in the Seychelles but these are awaiting promulgation of the Seychelles Fisheries Act and the finalisation of a programme on spawning aggregations (WIOMSA 2011).

Name & location	**Farquhar Atoll – Seychelles – Ref = 33**
Habitat	Coral atoll with high sand dunes; land area = 7.5 km^2; lagoon = 165 km^2
Primary features	Major bird colonies including sooty terns; aggregating site of spawning groupers.
Primary threat	Fisheries targeting aggregations of threatened groupers.
Monitoring potential	Turtle nesting; seabird nesting; vulnerable fish population aggregations.
Conservation status	No fisheries protection.
Strategic relevance to SWIOFP	• Protection of spawning aggregations of threatened groupers. • Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact- especially sooty tern nests.

The Farquhar Atoll is part of the Farquhar Group of islands and is located at 10°11'S 51°07'E about 770 km from Mahé and is the most southerly part of the Seychelles. Farquhar is a low-lying flat, roughly circular atoll of 10 islands surrounding a shallow lagoon which dries extensively at low tide. The total area of the atoll, including the large lagoon, is 170.5 km^2 and the total land area is only 7.5 km^2. Farquhar is notable for its high sand dunes, some of which reach to over twenty metres in height. The main group of islands form a long curve which describes the eastern side of the atoll. The largest of these islands are Ile du Nord and Ile du Sud, with the smaller Manaha islands between them. Farther south is Goelette Island and to the west is the small group of islands called Trois Îles (Stoddart & Poore 1970).

Goelettes is the island in the atoll with the most importance ornithologically. There is a large breeding colony of sooty terns with upwards of 200,000 breeding pairs while black-naped terns also use the island as a nesting area. Other breeding species include red-footed booby, striated heron, western cattle egret, grey heron, brown noddy and common white tern. Non-breeding great and lesser frigatebirds roost on the island. The lagoon also supports migratory waders which may sometimes include large numbers of crab plovers and ruddy turnstones. The atoll regularly has reports of more than 20,000 waterbirds (Rocamora & Skerrett 2001).

Like Cosmoledo, Farquhar atoll is an area where fish aggregate for spawning. Large aggregations of camouflage grouper and the brown marbled grouper occur in December and January (Robinson *et al.* 2008). The marbled coral grouper was also found to aggregate at the atoll. No formal protection exists for these spawning aggregations from unsustainable fishing but fishers have refrained from targeting the aggregations for some years (Robinson *et al.* 2008). Closed seasons and fishery reserves have been proposed to stakeholders as management options.

Name & location	**Aride – Seychelles – Ref = 34**
Habitat	Granitic island area = 0.72 km^2 with old guano deposits.
Primary features	Major seabird colonies of nine key species; important hawksbill nesting site.
Primary threat	Climatic.
Monitoring potential	Existing research in place; turtle nesting; seabird nesting.
Conservation status	Fully protected IUCN I.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact- especially sooty tern nests. • General biodiversity and ecological reference site.

Aride is located at 4°10'S 55°40'E and is the northernmost granite island of the Seychelles Archipelago. It is 1.73 km long and 0.5 km wide with an area of 0.72 km^2. It is a simple ridge of precambrian granite that reaches a height of 134 m above sea level near the western side. On the southern side there is an area of low-lying flat land composed of geologically recent beach deposits cemented together with guano (Warman & Todd 1984).

Aride hosts approximately one million breeding seabirds from nine species making it one of the most important colonies of the Indian Ocean. Species occurring include: Seychelles brush-warbler, roseate, sooty and common white terns, brown and lesser noddies, wedge-tailed and tropical shearwater, and white-tailed tropicbird. In addition bridled terns and red-tailed tropicbirds also nest on the island but in smaller numbers. Non-breeding great and lesser frigatebirds flock over the island in numbers up to 4 600 (Rocamora & Skerrett 2001).

Hawksbill turtles nest at the top of the single beach on Aride during the northwest monsoon (November to March), while green turtles are occasionally seen off Aride but have not nested there for many years (Warman & Todd 1984).

In 1979 Aride was declared a Special Reserve by the Seychelles Government. This afforded the fauna, flora and habitats of the island protection from any disturbance or destruction. The island has been scientifically monitored since 1984 and has an ongoing research programme administered by professional full time scientists (ICS 2011).

Name & location	**Cousin – Seychelles –Ref= 35**
Habitat	Granitic island area= 0.28 km^2 with indigenous woodland.
Primary features	Most important hawksbill turtle nesting site; endemic land birds (Seychelles brush-warbler); seabird colonies include wedge-tailed shearwater & noddies.
Primary threats	Coral bleaching; climate.
Monitoring potential	Hawksbill turtle nesting; bird counts and seabird nesting; coral transects.
Conservation status	Fully protected IUCN I.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of hawksbill turtles. • General biodiversity and ecological reference site.

Cousin is a very small (0.28 km^2) and low granitic island fringed by coral and which lies 2 km west of Praslin Island at 4°20'S 55°40'E. The island was bought in 1968 and managed as a wildlife sanctuary by the International Council for Bird Preservation (now BirdLife International) to save the Seychelles brush-warbler. It was declared a Special Reserve in 1975 giving it legal protection under the Seychellois legislation (Rocamora & Skerrett 2001).

Cousin has a large plateau that extends over most of the island which is covered with indigenous mature woodland. The most abundant plant species are cabbage trees, noni and wooden bat trees. A rocky hill rises up in the southern part of the island to 69 m (Rocamora and Skerrett 2001).

The island is one of the sites of highest ornithological interest in Seychelles. It is significant for its seabirds and endemic land birds. From May to September each year there is a large colony of breeding seabirds on Cousin mostly dominated by the lesser noddy. There are also smaller numbers of the brown noddy. During the northwest monsoon, wedge-tailed shearwaters form an important breeding colony on the granite hill while common white terns, white-tailed tropic birds, bridled terns and tropical shearwaters breed all year round. Great and lesser frigatebirds can be seen in large flocks flying above the island or roosting in the trees (Rocamora & Skerrett 2001).

Cousin is the most important breeding site for hawksbill turtles in the western Indian Ocean. The turtles emerge during the northwest monsoon and the nesting 'season' spans from August to March each year. Within the Seychelles, hawksbills typically, and unusually for this species, nest diurnally making them more at risk to disturbance and predation. They have, however, received protection since 1968 allowing them to make an eight-fold increase in nesting numbers (Allen *et al.* 2010).

In 1994, Cousin's coral reefs were dominated by live massive and branching corals which were complex in structure but there was a major decline in live coral cover in 1998 as a result of the global bleaching event. This was followed by an ongoing decline in structural complexity (Ledlie *et al.* 2007). Coral cover has declined further and a subsequent increase in macroalgal cover has occurred.

Name & location	**Frégate – Seychelles – Ref = 36**
Habitat	Granitic island area = 2.19 km^2.
Primary features	Formerly major bird nesting island; progressive destruction of indigenous vegetation.
Primary threats	Alien vegetation; human impact; rats & cats.
Monitoring potential	Seabird re-colonization.
Conservation status	Privately owned tourist resort with good conservation plan; sport fishing is allowed.
Strategic relevance to SWIOFP	• General biodiversity and ecological reference site for recolonization. • Sport fishing for threatened species

Frégate Island is a small privately owned granite island located at 04°35'S; 55°56'E. It is comprised of two hills and two low-lying plateaus (Robertson & Todd 1983, Rocamora & Skerrett 2001). Almost all the natural vegetation was removed from the island in the 19th century to make way for agriculture but this did not prove economical and the introduced vegetation was left to grow wild.

The rich, phosphatic soils found on the plateaus suggest that historically the island hosted large colonies of breeding seabirds but these have mostly become extinct. They have been relentlessly subjected to the impacts of human habitation for over a century, including the removal of the indigenous forest, the introduction of cats and, more recently, rats (Burger & Lawrence 2000). The lesser noddies and the common white terns are the most numerous of the remaining seabirds, while there are small numbers of the white-tailed tropicbird and the sooty tern. There are a number of vagrant species which visit the island all year but the most frequent non-breeding visitor is the ruddy turnstone. In addition to birds on Frégate Island, the islet off the south-east of Frégate, L'îlot Frégate, hosts small numbers of breeding bridled terns and brown noddies (Rocamora & Skerrett 2001).

As Frégate Island is privately owned it does not benefit from legislated protection by the Seychellois government. The current owner has, however, been implementing good conservation strategies to return the island to a natural environment. Programmes have been undertaken to eradicate the cats and rats as well as to re-establish native trees in parts of the forest (Burger & Lawrence 2000). With these programmes accomplished the island should become more hospitable to breeding seabirds.

Name & location	**Desnoeufs – Seychelles – Ref = 37**
Habitat	Reef island; circular with coral fringe and sandy beaches; area = 0.35 km^2.
Primary features	Sooty tern nesting; green and hawksbill turtle nesting.
Primary threat	Sooty tern egg harvest.
Monitoring potential	Sooty tern nests ; hawksbill turtle nesting.
Conservation status	Partially protected.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact- especially sooty tern nests. • Reference site for long-term monitoring of hawksbill turtles as proxy for regional fisheries impact. • General biodiversity and ecological reference site.

This island lies at the southern end of the Amirantes chain at 06°14'S 53°32'E. It is a more-or-less circular island with a high rim surrounding a central depression (Rocamora & Skerrett 2001). It is a reef island surrounded by a narrow peripheral reef but where both island and reef sit on an extensive and relatively shallow and gently sloping rock platform covered in rubble, sand and seagrass beds (Hagen *et al.* 2010).

Green turtles (Frazier 1975) and hawksbill turtles nest on Desnoeufs' beaches (Rocamora & Skerrett 2001).

It is thought that Desnoeufs once had the largest colony of sooty terns in the Seychelles and estimates have placed numbers at around one million pairs. These birds still occur in a large colony on the island but in substantially lower numbers. Other birds on the island include wedge-tailed shearwaters, tropical shearwaters, bridled terns, brown noddies, lesser noddies, masked boobies, common white terns and western cattle egrets (Rocamora & Skerrett 2001, Hagen *et al.* 2010).

Desnoeufs is the only island in the Seychelles where seabird egg harvesting is legal and from 1944 to 1964 an average of 770 000 sooty tern eggs were harvested each year. There was some realisation early on that egg harvesting needed to be restricted to ensure sustainability and the first closed season was introduced in 1933. Between 1956 and 1965 egg harvesting was only permissible every alternate year. Currently egg harvesting occurs annually but closed areas have been introduced. An area of approximately 0.166 km^2 on the western side of the island has been designated as a strict Nature Reserve from which no eggs may be collected. Furthermore, the harvesting crate size has been reduced so that only 400 eggs are collected per crate rather than 750 eggs as the old size allowed. All harvesting is monitored by staff members from the Department of Agriculture. Nevertheless, cropping levels remain high (Hagen *et al.* 2010).

Name & location	**Curieuse – Seychelles – Ref = 38**
Habitat	Granitic island with beaches and coral fringe; land area= 2.86 km^2.
Primary features	Coral diversity and resilience; hawksbill turtle nesting; fish spawning aggregations.
Primary threats	Climate; fishing.
Monitoring potential	Fish aggregations; coral diversity.
Conservation status	Fully protected land.
Strategic relevance to SWIOFP	• Key fish aggregations need protection. • Reference site for long-term monitoring of hawksbill turtles as proxy for regional fisheries impact. • Fisheries bycatch of turtles managed. • High coral diversity vulnerable to bleaching.

Curieuse is the fifth largest of the granite islands in the Seychelles and is located at 4°17'S 55°43'E, one kilometre from Praslin Island. It has a total area of 2.86 km^2 and rises at its highest point to 172 m above sea level. Almost 5 km of beach is available for turtles to nest (Mortimer *et al.* 1996; Obura & Abdulla 2005); especially hawksbill but some green turtles also use the site. The green turtles nest all year with peaks from June to September while the hawksbill turtles nest from September to February. Turtles have received legal protection on Curieuse since 1978 but with varying levels of success (Mortimer *et al.* 1996).

Curieuse has granitic and coralline reef habitat. Of the 16 families and 67 genera of hard corals found in the Seychelles, 10 families and 23 genera are found on the Curieuse reefs (Engelhardt 2002). Following the global coral bleaching event in 1997/8, the live coral cover was reduced to below 10% on most of the granitic islands of the Seychelles including Curieuse. However, the diversity of coral species seemed largely unaffected with similar numbers of genera and species being found during surveys conducted after the event (Turner *et al.* 2009).

Name & location	**Sainte Anne – Seychelles – Ref = 41**
Habitat	Granitic island with beaches and coral fringe; land area= 2.19 km^2.
Primary features	Key hawksbill turtle nesting site.
Primary threats	Reclamation and siltation.
Monitoring potential	Fish populations.
Conservation status	Fully protected national park.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of hawksbill turtles as proxy for regional fisheries impact. • Fisheries bycatch of turtles managed. • MPA status provides key data on unexploited fish populations. • General biodiversity and ecological reference site.

Sainte Anne Island is 4 km off the east coast of Mahé at 4°36'S 55°30'E and has abundant tropical vegetation. It is the largest (2.19 km^2) of six islands in Ste Anne Marine National Park of the Seychelles. The island is 2 km long and 1 km wide. The highest peak on Sainte Anne is 205 m above sea level (Mair & Beckley 2001).

Saint Anne Island has the highest number of hawksbill turtles that nest on its beaches making it one of the most important nesting areas in the granitic islands of the Seychelles (Mortimer 1984). A monitoring programme of the turtles has been in operation since 1981 and although the turtles have had legal protection since 1979, enforcement of the regulations has been of varying success (Mortimer *et al.* 1996). Some green turtles have been recorded nesting on the beaches of Sainte Anne Island but these have been very few (Mortimer 1984).

Name & location	**Mahé – Seychelles (whale shark sites)**
Habitat	Granitic island located on plateau; beaches and coral fringe; mountainous; land area= 152 km^2.
Primary features	Whale sharks.
Primary threats	Tourism, reclamation and dredging; development.
Monitoring potential	Whale sharks.
Conservation status	Subjected to conservation regulations.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of whale sharks a proxy for regional fisheries impact on this species.

Mahé is the largest and most heavily populated island of the Seychelles. It consists of granitic hills and mountains that rise steeply out the ocean. The island is 27 km long and 8 km wide with a total area of 152 km^2. The highest peak rises to 905 m above sea level (Mair & Beckley 2001). Mahé is centrally located on a shallow plateau, approximately 60 m deep. The strong trade winds that blow from the south-east from June to October result in upwelling of cold, nutrient rich water. This gives rise to localized plankton productivity events which are accompanied by the appearance of whale sharks (Rowat & Gore 2007).

Whale sharks have been recorded from the waters around Seychelles since 1756 (Lionnet, 1984). In 1996 a pilot monitoring programme was undertaken off Mahé Island and numerous whale sharks were found, 21 of which were tagged (Rowat 1997). Further research was carried out using tagging techniques to establish the movement patterns of these whale sharks. A total of 211 sharks were tagged off Mahé from 2001 to 2006. It was confirmed that these sharks travelled long distances across much of the Indian Ocean (Rowat & Gore 2007). While there has never been a commercial whale shark fishery in the Seychelles, the potential effects of targeted fisheries in other areas within the region (e.g. India) give cause for concern and a regional management plan is required to protect these sharks (Rowat 2007).

MADAGASCAR

A total of three hotspots were identified in Madagascar.

Name & location	**Antongil Bay – Madagascar – Ref = 9**
Habitat	Large bay.
Primary features	Humpback whales; dolphins.
Primary threat	Fisheries.
Monitoring potential	Marine mammals.
Conservation status	Whale sanctuary.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of marine mammals, especially humpack whales as proxy for regional fisheries impact. • Bycatch of marine mammals to be managed.

Antongil Bay, situated on the north east coast, is the largest bay in Madagascar. It is a shallow, semi-protected bay that extends approximately 80 km inland from the mouth and is approximately 30 km wide (Cerchio *et al.* 2008). The Bay provides refuge to significant marine resources and is heavily utilized by traditional, artisanal and industrial fisheries (Doukakis *et al.* 2008).

Humpback whales visit Antongil Bay from June to October and the highest concentrations occur from July to early September (Rosenbaum *et al.* 1997). Based on the whales' behaviour that is widely accepted to indicate breeding activity it is assumed that the whales utilise Antongil Bay as a breeding area. Females with young calves are also regularly observed (Rosenbaum et al. 1997). The whales seem to use the Bay as a short stopover point. Individuals have been recorded having short residency times and highly significant consistency in timing of their return visits to the Bay (Cerchio *et al.* 2008).

Bottlenose dolphins and spinner dolphins are commonly encountered in Antongil Bay (Vely *et al.* 1995; Rosenbaum *et al.* 1997). While of international conservation importance these species are not locally threatened (Cooke 1998).The Baie d'Antongil – Saint Marie Island Humpback Whale Sanctuary has been proposed to cover an area of 70 000 km^2 but has not been declared as yet. There are, however, three smaller marine reserves within the Masoala National Park. These are the Itampolo, Masoala and Tanjona Reserves (Hoyt 2005).

Name & location	**Nosy Ve – Madagascar – Ref = 10**
Habitat	Small coastal island; land area= 1 km^2.
Primary features	Tropicbirds.
Primary threats	Human disturbance; artisanal fisheries.
Monitoring potential	Bird nestings.
Conservation status	Terrestrial fully protected as nature reserve; heavy artisanal fishing pressure surrounds.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact – especially red-tailed tropic birds.

Nosy Ve is a small island, off the town of Anakao located 30 km south of Toliara in the south west of Madagascar and 3 km offshore at 23°38'57.81"S and 43°36'14.13"E. It is 1.4 km long and 350 m across at its widest point with a total area of about 1 km^2 (Frontier-Madagascar 2003a).

The island is home to the most southern colony of nesting red-tailed tropicbirds. The first two breeding pairs were spotted on the island in 1980 and since then the numbers have continued to increase. This species is the most pelagic of the tropicbirds and they are usually seen soaring high over the water and feeding by plunge-diving after fish (Morris & Hawkins 1998). They nest under bushes on the ground which makes them extremely susceptible to predation particularly by small mammals such as rats (Frontier-Madagascar 2003a). Nosy Ve previously had a rat infestation problem but the rats were eradicated in 2000 and the island has been clear of them ever since (Frontier-Madagascar 2003a).

Green turtles were known previously to nest on Nosy Ve but none has been observed nesting there since 1986. Turtles have been discouraged from using Nosy Ve as a nesting site through three factors: the adult turtles have been caught for meat, the eggs have been dug up and eaten and the females have been disturbed on their passage to the island by the use of Petromax lamps and flash lights during squid fishing activities around the island (Lilette 2006).

Nosy Ve is uninhabited as it is considered a sacred ancient burial site. In 1998, the island was declared a special reserve under the local *Dina* (social conventions) and is managed by the Fikambanana Miaro sy Mampandroso an'I Nosy Ve (FI.

MI.MA.NO). *Dina* has been endorsed by the Malagasy government and is enforceable. The marine section of the reserve, called the Aquarium, is, however, very small (0.04 km^2) and does not include the fringing reef and lagoon along the coast of the mainland where extensive harvesting takes place. The surrounding coral has been severely damage by fishing. FI.MI. MA.NO is also not very experienced with respect to sustainable management which means that the *Dina* is not always respected (Frontier-Madagascar. 2003b).

Name & location	**Grande Récif – Madagascar – Ref= 11**
Habitat	Large coral barrier reef; >20km^2.
Primary features	Rich coral assemblage.
Primary threats	Climatic; fisheries; waste management.
Monitoring potential	Long-term coral data are available.
Conservation status	Not protected; heavily fished.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of reef condition subject to fisheries and development. • General biodiversity and ecological reference site.

The Grande Récif is situated at 23°26'16"S and 43°39'E opposite Toliara off the south west coast of Madagascar. It is an 18 km long barrier reef that is completely separated from the shore. It varies in width from 1.1 km to 2.9 km. The reef is divided into three large groupings: the outer reef, the reef flat which emerges at low tide and the inner slope and lagoon (Gabrié *et al.* 2000).

The reef is highly productive with three principal components: the hard-ground communities, the coral sand communities and the coral fish communities. The hard-ground communities have been classified into the photophilous sessile community consisting mainly of anthozoans (Pichon 1978); the extremely diverse skiophilous sessile community that has approximately 1 000 species of fauna and flora (Vasseur 1977, Vasseur 1981); the borer community (Peyrot-Clausade & Brunel 1990); and the mobile cryptofauna of hard grounds (Peyrot-Clausade 1977).

The Grande Récif is mostly highly degraded but there are some smaller areas such as the outer slopes that are in better condition. Causes of reef degradation are localised coral bleaching, a reduction in the water clarity in the reef lagoon, a reduction in the depth of the oxygenated zone of coral sands as a result of excess organic matter, the proliferation of green algae which changes to brown algae in winter, modifications in the hydrodynamic conditions on the reef flat and the scattering of coral debris over a large area. Furthermore the reef is highly susceptible to the effects of sedimentation, pollution (sewage, agricultural chemicals and domestic garbage) and long-term over-exploitation of the marine environment. All of these factors have left the reef in a critical state (Gabrié *et al.* 2000). The reef has been a research site for Universities of Marseilles and Toliara for decades, based at the nearby research station.

KENYA

An important regional hotspot complex was identified and decribed: the bays of Malindi and Ungwana.

Name & location	**Malindi-Ungwana Bay – Kenya – Refs = 7 & 8**
Habitat	Large shallow soft bottom bay; opposite Tana River.
Primary features	Sawfish; relic dugong populations.
Primary threats	Trawl fisheries; river input and climate change.
Monitoring potential	Fisheries; bycatch.
Conservation status	Under fisheries management.
Strategic relevance to SWIOFP	• Trawl fisheries management using bycatch reduction devices and turtle excluder devices. • Monitoring of bycatch in shrimp fisheries. • Protection for critical sawfish species. • Mangrove fish nurseries need protection. • River flow links to fisheries. • Reference site for long-term monitoring of dolphins and dugong as proxy for regional fisheries impact. • Fisheries bycatch of turtles managed.

The Ungwana bay, extends from 2°59'23"S 40°14'27"E to 2°33'40"S 40°36'30"E. To its south lies the smaller Malindi Bay extending south to 3°13'9.07"S 40°7'0.81"E and both bays together form the Malindi–Ungwana Bay complex (Fulanda *et al.* 2011). The bays are shallow with water depths ranging 12-18 m between 1.5-6 nm offshore. Beyond 7 nm the depth rapidly decreases to 100 m and deeper (Alverson 1974, Iversen 1984). The wide continental shelf (15-60 km) and the inflow of the Athi River in the south and the Tana River in the north provide rich fishing grounds both inshore and offshore. The coastline is characterised by fringing reefs and there are occasional coral outcrops in the bay (Iversen 1984, Fulanda 2003). The extensive mangrove forests include the only significant Kenyan stands of looking-glass, cannonball and black mangroves which are considered threatened (Wass 1995) and a further seven mangrove species (WWF EAME 2004). The mangrove forests play an important role as they provide protected areas for fish and shellfish nurseries that nourish the rich fisheries of Ungwana Bay (Ng'weno 2008).

The Tana River Delta provides a suitable habitat for the highly endangered green and narrow sawfish (Ng'weno 2008). Both species are listed on CITES Appendix 1. Sawfish are particularly susceptible to capture by net fisheries due to the entanglement of their rostrums in nets. Habitat degradation is yet another threat to their existence.

Common, Indo-Pacific humpback, spinner, pantropical spotted and Indo-Pacific bottlenose dolphins were identified in the Ungwana Bay during an aerial survey conducted in 1994 (Wamukoya et al. 1996). Dolphins are fairly common in the Bay and are susceptible to being caught in the fishing gears used by both the artisanal and commercial fishers.

Large numbers of dugongs were last reported off the Kenyan coast in the late 1960s and only low numbers have been recorded since. During an aerial survey conducted in 1994 a total of 16 dugongs were sighted and all of them were in the Malindi-Ungwana Bay (Cockcroft *et al.* 1994). The Tana River delta, situated in Ungwana Bay, is one of the few places in Kenya where dugongs have been sighted recently (KWS 2010). Dugongs have been heavily exploited for their meat, oil, skin and medicinal/aphrodisiac products. They are also caught as bycatch in fishing nets, or hit by power boats operating in their habitat. While legislative protection is in place in much of the region, enforcement is inadequate (UNEP 1998). One of the biggest challenges dugong face is habitat destruction through the physical impacts of fishing gears like the trawl nets, increased siltation resulting from the rivers and increased pollution such as sewage and agricultural chemicals.

The green, loggerhead, olive ridley, leatherback and hawksbill turtles all occur in Kenyan waters. The green and hawksbill turtles nest along the entire coastline but the green turtle is more common (Mbendo *et al.* 1998). The distribution and extent of the olive ridley, loggerhead and leatherback turtles' abundance is unknown but the olive ridley was reported to be localised in Ungwana Bay (Frazier 1975). Like the dugongs, turtles face multiple challenges in Ungwana Bay including the destruction or modification of habitat, exploitation for meat and eggs, the use of non-selective gear that capture them as bycatch such as beach seines and dynamite, pollution of the environment by way of sedimentation, sewage and other effluents, sand mining which disturbs their nesting beaches and ineffective law enforcement of the regulations set to protect them (Mbendo *et al.* 1998). Turtles were also caught as bycatch in the inshore trawl fishery as the turtles foraged in the bay where the trawlers operate. This fishery remains a large threat to the turtles.

The bay and its habitats face numerous threats including over-exploitation of marine resources, physical damage to the environment by fishing gears, modifications in siltation due to upstream changes to the rivers entering the bay and increases in pollution including sewage, industrial and agricultural effluent. Furthermore an area of more than 50 km^2 of mangroves was converted for solar salt works and aquaculture (Abuodha & Kairo 2001). Despite all the threats, it is estimated that 80% of the area is functionaly intact and that there is high natural recuperation in the bay due to its large area, the bay's complexity and adaptability (WWF EAME 2004).

TANZANIA

A total of 12 hotspot sites was identified, nine through the SWIOFP gap analysis process and others through the EAME.

Name & location	**Rufiji Delta, Mafia Island Complex – Tanzania – Ref = 50 & 51**
Habitat	Integrated complex of riverine delta, estuarine waters and offshore influence with corals and fishes. Highly diverse.
Primary features	Mangrove nurseries for fish and crustaceans; extensive seagrass beds; waterbirds; dugong, green turtle nesting; coelacanths; shrimp resources high coral diversity.
Primary threats	Climate change; fisheries; dynamite.
Monitoring potential	Fisheries, bird counts; turtle nests.
Conservation status	Partial protection; Mafia Island is an MPA.
Strategic relevance to SWIOFP	• General biodiversity and ecological reference site including fish populations. • Protection for critical sawfish species and coelacanths. • Mangrove fish nurseries protection. • River flow links to fisheries. • Reference site for long-term monitoring of dolphins, dugong, whale sharks as a proxy for regional fisheries impact. • Fisheries bycatch of turtles managed. • MPA status provides key data on unexploited fish populations.

The Rufiji Delta – Mafia Island Complex extends from the northern end of the Rufiji Delta south to include the Songo-Songo Archipelago and Kilwa Masoko and east to Mafia Island. It also extends approximately 25 km inland including all of the mangrove forest of the delta. The total area is about 9,500 km^2 (WWF EAME 2004). The complex is influenced by incursions of the high energy Indian Ocean waters to the east of Mafia Island and by the sheltered waters of the Rufiji Delta on the west which charges the area with sedimentary discharge. Due to all the islands, islets and reefs, it has a complex bathymetry which has resulted in a varied seascape. These factors have, together, produced a very diverse habitat with an associated high species richness (Rubens & Kazimoto 2003).

The Rufiji Delta is characterised by its mangroves which are the largest single forest of mangroves in East Africa (WWF EAME 2004). The most abundant mangrove species are red, white flowered apple and Indian mangroves, while white and black mangroves are much less abundant (Mwalyosi 1993). The mangroves support an extensive ecosystem due to their high productivity of detritus which is broken down by bacteria and fungi. They provide a safe haven or nursery area for the juveniles of many species of fish and crustaceans as well as being an important wintering area for migrating birds such as waders and terns.

The delta provides a good habitat for waterbirds and a survey undertaken in 2000 recorded a total of 40,160 waterbirds belonging to 62 species (Nasirwa *et al.* 2001). These numbers were considered a minimum because some birds hide in the mangroves and along upstream rivers and were therefore not counted. The birds on Mafia Island and surrounding islands were counted in 1989 with a resulting total of 11,878 waterbirds (Bregnballe *et al.* 1990).

Fringing reefs do not occur around the Rufiji Delta but Mafia Island has extensive reefs particularly in the south (Spalding *et al.* 2001). The reefs are reportedly in good condition and over 380 species of fish and 45 genera of corals have been recorded on them. Further south, the Songo Songo Archipelago also has some important reefs. Since these reefs are deeper and further from the shore they are less accessible and this has led to them remaining in good condition (Spalding *et al.* 2001). There are extensive seagrass beds in the area which have about 12 species of seagrass and 134 species of algae (Mahingika 2007).

The seagrass beds around the delta and Mafia Island provide a suitable habitat for a very small breeding population of dugongs. In 2010 there were six live sightings of dugongs, five in the Rufiji Delta and one off Mafia Island. Since 2004, when dugong monitoring started, a total of 38 animals have been recorded. Of these 22 were live sightings, 15 had drowned from capture in gillnets and one was washed up dead on a beach. These mammals are extremely vulnerable to fishing gears such as gillnets and dynamite. (West 2010).

Mafia Island is the most important turtle nesting site in Tanzania mostly for green turtles but hawksbill turtles nest there as well. In 2010, 50% of all recorded green turtle nests in Tanzania were on Mafia island producing 22,500 hatchlings. Turtles nest all year round but peak in May (West 2010). The green and hawksbill turtles, as well as loggerhead, leatherback and olive ridley turtles forage all year round in the waters surrounding Mafia Island and the delta (Rubens & Kazimoto 2003). There is unfortunately a high rate of turtle mortality in the Rufiji District due to intense fishing pressure and a high level of illegal activities including turtle harvesting (West 2010).

A population of whale sharks is to be found off Mafia Island where they are safe from harvesting as they are not targeted for their fins by the local fishers. Their presence was first noted by local fishers in the late 1980s and their numbers have been increasing since then. The sharks migrate over a wide range but their peak presence in Mafia is October to April (WIOMSA 2010).

The first coelacanth recorded in Tanzania was caught in the very southern part of the Rufiji-Mafia Complex at Songo Mnara on 8 September 2003. Six months later another coelacanth was caught in the same area (Nulens *et al.* 2011). These are the only two coelacanths reported from the complex.

The delta's aquatic system is of great importance to Tanzania's shrimp fisheries. The penaeid shrimps spawn at sea and the larvae move into the estuary where they find shelter and food. They return to the sea as sub-adults (Mwalyosi 1993). Shrimp fisheries in the delta catch 80% of Tanzania's prawn exports. (Gibbon 1996). Along with shrimp fisheries, there are other productive and profitable fisheries in the delta. Regularly caught are milkfish, mullets, anchovies, cobia, groupers, hairtails, trevallies, eels, queenfish, sea catfish, halfbeaks, goatfishes, needlefish, barracuda, sharks and rays. Lobsters, crabs, octopus, sea cucumbers and shells are also harvested. The complex is an extremely important artisanal and commercial finfish fishing ground and fishers come from Tanga, Dar es Salaam, Lindi and Mtwara to fish (Richmond *et al*. 2001). The region is believed to have sustained sawfish but no recent records exist of these vulnerable elasmobranchs.

For two decades parts of the complex were subjected to dynamite fishing which was outlawed in 1998. In addition the area has a long history of coral mining for lime production which in conjunction with the dynamite fishing has left the marine environment significantly damaged. This situation has been compounded by an increase in fishing activities particularly from the use of small mesh nets which catch juveniles and damage the substrate. Mafia Island received some protection after the establishment of the Mafia Island Marine Park in 1995. This park covers 820 km^2 of the southern part of the Mafia Island Archipelago and is a multiple-use marine park with a dense human population (WWF EAME 2004). In January 2005, the Rufiji Delta – Mafia Island Complex was declared a Ramsar wetland of international importance providing added protection to the whole ecosystem (ENS 2005).

Name & location	**Latham Island – Tanzania – Ref = 52**
Habitat	Small flat topped islet (0.03 km^2); rock and sand.
Primary features	Seabird nesting; pelagic fishes appear to aggregate here.
Primary threats	Lack of protection; fisheries.
Monitoring potential	Bird counts.
Conservation status	Nil.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact- especially sooty tern nests. • General biodiversity and ecological reference site including pelagic fish and shark populations.

Latham Island is situated approximately 66 km south-east of Dar es Salaam at 6°54'S, 39°56'E (Baker & Baker 2002). It is the exposed top of a seamount which rises only 3m above sea level (Gerhart & Turner 1978) and has an area of approximately 0.03km^2 (WWF EAME 2004). It is composed of rock, sand and guano and has very sparse vegetation (WWF EAME 2004). The seabed drops off steeply all around the island to a depth of approximately 300 m.

This island is of significant importance for seabirds of the East African region (Cooper *et al.* 1984) and it has been listed as an Important Bird Area for Tanzania (Baker & Baker 2002). A survey conducted in 2004 found 3,700 pairs of masked boobies. 320 pairs of swift terns, 4,400 pairs of sooty terns and 4,000 pairs of brown noddies representing 20%, 50%, <1% and 25% respectively of the overall populations of these birds (Crawford *et al.* 2006).

The area supports rich pelagic fish resources including dogtooth tuna, yellowfin tuna, wahoo, giant trevally, billfish and sharks such as whitetip reef, oceanic whitetip, mako, scalloped hammerhead and tiger sharks (Sport Fishing Tanzania 2010).

Currently there appears to be no management strategies in place for Latham Island. Although pressure on the island's resources is low at present, it is necessary to introduce some protection to minimise future impacts on the seabirds and fish stocks (WWF EAME 2004).

Name & location	**Mnazi Bay, Ruvuma Estuary – Tanzania – Ref = 53 & 54**
Habitat	Estuarine; extensive mangroves, seagrass beds and nurseries; several small islets; high coral diversity.
Primary features	Nurseries, turtle foraging and nesting.
Primary threats	Climate; fisheries.
Monitoring potential	General habitat mapping; fisheries bycatch; turtles.
Conservation status	Protected as MPA.
Strategic relevance to SWIOFP	• Critical seagrass habitat for turtle foraging needs protection. • General biodiversity and ecological reference site. • Protection for critical sawfish species. • Mangrove fish nurseries protection. • River flow links to fisheries. • MPA status provides key data on unexploited fish populations.

The Mnazi Bay, Ruvuma Estuary area is located on the most southern 45 km of the Tanzanian coast with the border of Mozambique between 10°34'46"S 40°16'13" E and 10°34'25"S 10°16'02"E and 10°07'29"S 40°28'10"E and 10°09'28"S 40°13'56"E. The area includes Msimbati Channel, Mnazi Bay, Ruvula Peninsula and Ruvuma Estuary as well as the islands of Namponda, Mmongo and Kisiwa Kidogo. This area is home to a huge diversity of marine life. The mangrove forests are in good health and provide excellent reproductive and nursery habitats to many fish and invertebrates. The open sand habitat is extensive and seagrass beds are variable and diverse. There are over 250 species of hard coral, approximately 400 species of fish and 100 species of echinoderms.

The mangroves in the area account for 10% (70 km^2) of all of Tanzania's mangroves with white, cannonball, red, Indian, white-flowered apple, black and looking glass mangroves present. The intertidal and sub tidal seagrass beds are in good condition and they have high diversity. There are nine species of seagrass that have been reported: *Thalassia hemprichi*, *Halodule uninervis*, *H. wrightii*, *Halophila stipulacea*, *H. ovalis*, *Thalassodendron ciliatum*, *Cymodocea rotundata*, *Cymodocea serrulata* and *Syringodium isoetifolium*.

Five species of turtles have been recorded in the Mnazi Bay – Ruvuma Estuary area. The most common are the green and hawksbill turtles but the olive ridley, leatherback and loggerhead turtles have also been recorded. Turtles forage on the seagrass beds but also use the area for nesting. The main nesting areas are the beaches of Litokoto and Kingumi in the Ruvuma Estuary, and the shores of Msimbati and of Msangamkuu. Most nesting is between April and August, though green turtles have nested in February. Marine turtles are protected under the national laws of Tanzania.

Name & location	**Pemba Channel – Tanzania – Ref = 59**
Habitat	Deep open water channel.
Primary features	Large pelagic fish aggregations; coral biodiversity, dolphins.
Primary threats	Overfishing and damage to reefs.
Monitoring potential	Recovery of red-flagged fishes; trends in pelagic fish catches.
Conservation status	Partially protected.
Strategic relevance to SWIOFP	• General biodiversity and ecological reference site including pelagic fish populations. • Protection for critical red-flagged species including groupers and wrasses under fisheries threat. • Coral reef fish nurseries protection.

The Pemba Channel (5°10'1.35"S 39°20'0.47"E) separates the Tanzanian mainland coast from Pemba Island. The northernmost part of the channel faces the coast of Kenya. The area includes the Pemba Channel Conservation Area (PeCCA) which is a joint management initiative with local agencies. The Island of Pemba lies just 50 km off the Tanzanian Coast, in the Indian Ocean, and forms part of the Zanzibar Archipelago. It is thought to have been isolated from the continent by a deep channel for several million years, and is classified as a true oceanic island (Grimsditch *et al.* 2009). Pemba Channel appears to have special oceanographic features that support a unique and abundant assemblage of pelagic fish species (tunas, marlins, kingfishes and large sharks) which provide a basis for a considerable tourist sport fishery. Marine mammals, including dugong occur. The region is well known for its exceptional coral diversity but this is now under threat from overfishing. Previous abundance of red-flagged fish species have been severely reduced as a result of damaged reefs becoming coral dominated systems following fisheries impacts.

FRANCE

A total of three sites were identified within the French Southern Territories.

Name & location	**Europa – France – Ref = 3**
Habitat	Low lying semi-arid scrub; area = 28 km^2; lagoon = 9 km^2.
Primary features	Large green turtle nesting site; nesting seabirds.
Primary threat	Climatic.
Monitoring potential	Turtle nesting; seabird numbers.
Conservation status	Fully protected; restricted access.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact – especially sooty tern nests. • Reference site for long-term monitoring of green turtles as proxy for regional fisheries impacts. • General biodiversity and ecological reference site including fish populations. • MPA status provides key data on unexploited fish populations.

Europa Island (22 21.5'S; 40 21.5'E) is a 28 km² low-lying tropical island in the Mozambique Channel, about a third of the way from southern Madagascar to southern Mozambique. The island has been a possession of France since 1897, but is also claimed by Madagascar. The island, garrisoned by a detachment from Réunion, has a weather station and is visited by scientists. Though uninhabited, it is part of the "Scattered Islands" of the French Southern and Antarctic Lands administrative region.

Europa has 22.2 km of coastline, but no ports or harbours. Its Exclusive Economic Zone (EEZ), contiguous with that of Bassas da India, is 127 300 km². It is surrounded by coral-sand beaches and a fringing reef and encloses a mangrove lagoon of around 9 km². The island is a nature reserve. Its vegetation consists of dry forest, scrub, euphorbia and the remains of a sisal plantation. It is one of the world's largest nesting sites for green sea turtles. It is also home to goats introduced by settlers in the late 18th century.

The island is fringed by coral which supports a diversity of red-flagged reef fishes while the lagoon supports several estuarine species namely thornfishes, goldlines seabreams, flowery flounders and bonefish (Fourmanoir 1952).

The island has been identified as an Important Bird Area (IBA) by BirdLife International because it supports a large and diverse population of breeding seabirds and other waterbirds. It is the only known breeding site outside Aldabra and Madagascar for Malagasy pond herons. Seabirds include the second largest colony in the western Indian Ocean of Great frigatebirds, tropical shearwaters, dimorphic egrets and Caspian terns. The island is home to an endemic subspecies of white-tailed tropicbird (*Phaethon lepturus europae*). Up to 1 million sooty terns nest annually. There are three species of landbirds present, one of which is an endemic subspecies of the Malagasy white-eye.

Name & location	**Glorieuses – France – Ref = 4**
Habitat	Two islands total= 5 km^2; low profile overlying fossilised coral; fringing coral reef with beaches.
Primary features	Green turtles; seabirds (noddies).
Primary threats	Climatic; alien species.
Monitoring potential	Seabirds; invasive rats; turtles.
Conservation status	Fully protected; restricted access.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact – especially nesting noddies. • Reference site for long-term monitoring of green turtles as proxy for regional fisheries impact. • General biodiversity and ecological reference site including fish populations. • Protection for critical red-flagged fishes. • MPA status provides key data on unexploited fish populations.

The Glorieuses Islands are a group of French islands and rocks totalling 5 km^2 at 11°33'S 47°20' in the northern Mozambique Channel, about 160 kilometres northwest of Madagascar. The islands are nature reserves with a meteorological station garrisoned by French troops. Madagascar continues to claim sovereignty over the islands. The Glorieuses have an Exclusive Economic Zone (EEZ) of 48,350 km^2. The archipelago consists of two islands, Grande Glorieuse and Île du Lys.

Grande Glorieuses is roughly circular and measures about 3 km across. It is thickly vegetated, mainly by the remains of a coconut plantation and she-oak trees. Île du Lys is 8 km northeast of Grande Glorieuses, is about 600 m long and consists of sand dunes and scrub with some mangroves. It was formerly quarried for phosphate (guano). The climate is tropical and the terrain is low and flat, varying from sea level to 12 m. Île de Lys is a nesting ground for migratory seabirds. However, a century long fluctuation between rat and roosting noddy populations is a striking feature (van der Elst and Pryce-Jones 1987).

Name & location	**Bassas da India – France – Ref = 5**
Habitat	Coral atoll fully enclosing a 90 km^2 lagoon.
Primary features	Rich assemblage of ichthyofauna notable for red-flagged species.
Primary threats	IUU fisheries; uncontrolled tourism access; climate.
Monitoring potential	Coral diversity; access levels.
Conservation status	Fully protected; restricted access.
Strategic relevance to SWIOFP	• Key reference site for long-term monitoring and protection of red-flagged fishes. • MPA status provides key data on unexploited fish populations.

Bassas da India is an atoll located centrally in the Mozambique Channel at about 21°27'S and 39°42'E. It is one of several isolated and ancient volcanic cones that lie to the north of the submarine Mozambique plateau. The atoll is almost circular in shape, has an enclosed lagoon of about 90 km^2, measures 11.4 km from east to west and 9.9 km from north to south. The lagoon has a maximum depth of 14 m and it is fringed by reef flats of about 300 m at their widest point. This reeftop is dominated by large expanses of bare coral rubble. The reef front is incised by numerous deep gulleys which open out at a depth of about 10 m and the reef then slopes steeply downwards at an angle of about 20 degrees to the sea floor. Corals are diverse and prolific. Notable amongst the coral species in more sheltered shallow locations are the thin birdnest and knob-horn corals. These so-called "weed corals" are fragile but fast growing pioneer species resilient to frequent storm damage. At least 311 fish species have been recorded for Bassas falling into 50 families (van der Elst & Chater, 2009). Bassas can be considered a refuge for several threatened red-flagged groupers and wrasses and justifies sustained protection. Bassas was established as a Reserves Naturelle on 17 July 1971 (Harroy, 1972).

MAURITIUS

The Republic of Mauritius consists of the main island of Mauritius located in the Indian Ocean at 20.17°S and 57.33°E and a number of smaller islands namely Agaléga, the Cargados Carajos, the Chagos Archipelago, Rodrigues and Tromelin. The total land area amounts to 2,040 km^2 whilst the exclusive economic zone covers an area of about 1.9 million km^2 extending from latitude10°S to 20°S and from longitude 55°E to 75°E.The island of Mauritius is 1,865 km^2 in area, volcanic in origin and consists of a central plateau (mean elevation is 350 m) surrounded by mountain ranges and plains. A total of six hotspot sites were identified and two described as most relevant to SWIOFP.

Name & location	**Agalega – Mauritius – Ref = 12**
Habitat	Two flat islands on coral base total area= 24 km^2.
Primary features	Strategic location in remote part of WIO.
Primary threat	Development.
Monitoring potential	Fisheries records including red-flagged species.
Conservation status	Nil.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of green and hawksbill turtles as proxy for regional fisheries impact. • General biodiversity and ecological reference site including fish populations. • Assessment of new sparid fisheries. • Fisheries bycatch of turtles managed.

Agalega comprises two Mascarene Islands lying 1,100 km north of Mauritius at 10°25'S 56°35'E, with a total area of 24 km^2. The islands are flat on a coral base with one small hill on the northern island.

Agalega is inhabited by about 300 people and managed by the Outer Island Development Company (IDOC), a company which develops remote islands. The economy of the archipelago is based primarily on the exploitation of coconut oil and fisheries.

Agalega forms part of the distant bank fisheries including a new and unique fishery for the Frenchman seabream. Considerable hawksbill and green turtle nesting occurs here although protection is minimal and there has been a history of extensive turtle and egg harvesting despite being illegal. (Griffiths & Tatayah 2007).

Name & location	**St Brandon – Mauritius – Ref = 13**
Habitat	Sandy beaches, coral reefs.
Primary features	Turtle nesting.
Primary threat	Fisheries.
Monitoring potential	Turtle nesting; seabird numbers.
Conservation status	Not protected but a turtle nesting reserve has been proposed for Pearl Island.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact. • Reference site for long-term monitoring of turtles as proxy for regional fisheries impact. • General biodiversity and ecological reference site including fish, lobsters and especially shark populations. • Fisheries better managed including new tourist fisheries. • Remoteness status provides key data on unexploited fish populations.

St Brandon (16°30'S, 59°35'E) is a very remote collection of low islets, coral reefs and sandbanks lying 350 km north-north-east of Mauritius. The area covers several thousand square kilometres but the land area is affected massively by tides and therefore averages at approximately 300 ha over18 islets. The islets are high points on a limestone plateau where the water depth seldom exceeds 20 m. The reef covers an area of 19 km^2 and is 38 km long by 5 km wide, cut by three passes. Natural resources collected incidentally include nesting green turtles and the less common hawksbill turtles, crustaceans such as lobsters and octopus and seabirds and their eggs. The area is, however, most important as a fishing ground for seasonal fishers from Mauritius. While studies of the ichthyofauna are scant, the diversity of fishes in such a remote location is a valuable reference point. Bass (1970) documented extensive and diverse shark populations, comprising at least ten pelagic species and a high number of the threatened blackfin reef sharks in the lagoons. Visits other than by fishermen or government personnel are very rare (Birdlife International 2012a). Recently, St Brandon has been promoted as a sport fishing destination in pursuit of exotic species – an issue of concern unless managed. The island has large seabird nesting colonies, especially sooty terns. Shallow water lobsters are also an important feature, especially the pronghorn spiny lobster (Bass 1970).

COMOROS

The Comoros are comprised of four islands: Anjouan, Grand Comoros, Mohéli and Mayotte, the latter a French possession. The islands are of volcanic origin with the main island served by an active volcano. A total of two hotspot sites were identified.

Name & location	**Mohéli – Comoros – Ref = 1**
Habitat	Bays, seagrass, coral and beaches – 290 km^2.
Primary features	Turtles nesting, dugong.
Primary threats	Fisheries; coral destruction; turtle poaching; management capacity.
Monitoring potential	Turtle nests; dugong counts.
Conservation status	Protected as MPA.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of dugong and turtles as proxy for regional fisheries impact. • General biodiversity and ecological reference site. • Mangrove and seagrass fish nurseries protection. • Fisheries bycatch of turtles managed. • MPA status provides key data on unexploited fish populations.

Mohéli is the smallest of the islands at about 290 km^2, located on a volcanic base with a generally low profile. Beaches and coral reefs with bays and seagrass meadows prevail. This was the first marine park in Comoros proclaimed in 2001. Initial progress was excellent but recent low management is posing a threat. Mohéli is an important site for remnant dugong populations which forage on extensive seagrass beds. Green turtles also nest in considerable numbers.

Name & location	**Gombessa Reserve – Comoros – Ref = 2**
Habitat	Deep sloping reef edges off the main island.
Primary features	Coelacanth populations.
Primary threat	Fisheries.
Monitoring potential	Fisheries and capture details.
Conservation status	Management regulations protect coelacanths.
Strategic relevance to SWIOFP	• Protection of critical coelacanths.

The Gombessa Reserve is located on the south west coast of Grand Comoros, the largest island of the Comoros Archipelago. Its purpose is to limit the artisanal capture of coelacanths. The reserve is still in its early stages of development.

SOUTH AFRICA

South Africa has a coastline that abuts both the Indian and Atlantic Oceans. In this report only WIO information is considered. A total of five hotspot sites were identified. Details of four such sites are presented here.

Name & location	**St Croix Island Group – South Africa – Ref = 45**
Habitat	Rocky islands with minimal vegetation.
Primary features	Seabirds (nesting and resident).
Primary threats	New harbour and heavy-metal industry complex development, pollution, shipping activity.
Monitoring potential	Penguin populations.
Conservation status	Fully protected since 1981 (land and shoreline only).
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact – especially penguins and roseate terns. • General biodiversity and ecological reference site. • Future MPA status provides key data on unexploited fish populations.

Situated at 33°47'58'S 25°46'11'E in the Algoa Bay, the St Croix Island Group consists of the larger (0.12 km^2) St Croix Island and the two smaller islands of Jahleel (0.03 km^2) and Brenton (0.03 km^2). These islands are rocky outcrops that support very minimal vegetation (Birdlife International 2012b). There are currently eight seabird species breeding on the islands and these are the only islands off southern Africa where roseate terns regularly breed. The Algoa Bay islands currently have 43% of the global population of African penguin, the majority of which are on St Croix Island. St Croix Island also has a locally significant breeding population of Cape commorant (Birdlife International 2012).

The area has populations of endemic fish species, especially sparid fishes. However, until fisheries are better controlled in the planed Addo MPA expansion monitoring will not be useful. Signifcantly, the SAEON has established long-term monitoring capacity in the region.

The development of a harbour and heavy-industry complex at the Coega river mouth poses a huge threat to the seabirds of the St Croix group through increased pollution and shipping activity (Birdlife International 2012).

Name & location	**Bird Island Group – South Africa – Ref = 46**
Habitat	Rocky islands with sparce vegetation.
Primary features	Seabirds, seals.
Primary threat	Pollution from shipping activities.
Monitoring potential	Bird and seal populations.
Conservation status	Only the land is fully protected.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of piscivorous seabirds as proxy for regional fisheries impact- especially Cape gannets and Antarctic terns. • Reference site for long-term monitoring of Cape fur seals • Possible future MPA status provides key data on unexploited endemic fish populations

The Bird Island Group consists of the larger Bird Island (0.19 km^2), and the much smaller Seal (0.006 km^2) and Stag (0.001 km^2) islands. This island group lies 7 km offshore and 53 km due east of Port Elizabeth at 33°50'26'S 26°17'10'E. The Bird Island Group has sparse coverage of mixed vegetation dominated by the fleshy herbs *Mesembryanthemum* and *Tetragonia* and *Chenopodium* which form localized thickets that provide cover for seabirds (Birdlife International 2012).

Bird Island is one of only six breeding sites in the world for the Cape gannet. The island group is also known to hold large numbers of Antarctic terns, which roost in winter on the island in their thousands. It is estimated that between 10% and 20% of the estimated total Afrotropical non-breeding population roost on these islands. The island is also home to a colony of Cape fur seals. These mammals interact extensively with fisheries and require sustained monitoring.

Name & location	**iSimangaliso Wetland Park – South Africa – Ref = 47**
Habitat	Estuaries, mangroves, sandy beaches, rocky shore, coral reefs, submerged canyons.
Primary features	Turtle nesting, coral reefs, sharks, coelacanths, fish aggregations.
Primary threats	Resource harvesting, possible tourism developments, diver pressure.
Monitoring potential	Turtle nests, user statistics.
Conservation status	Protected as a World Heritage Site since December 1999.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of loggerhead and leatherback turtles as proxy for regional fisheries impact. • General biodiversity and ecological reference site including endemic fish populations and shark aggregations. • Protection of critical canyon habiat for coelacanths. • Estuarine fish and especially shrimp nurseries protection. • River flow links to fisheries. • Reference site for long-term monitoring of dolphins and whale migrations as proxy for regional fisheries impact. • Fisheries bycatch of turtles managed. • MPA status provides key data on unexploited fish populations.

The iSimangaliso Wetland Park extends from the southern border of Mozambique to Cape St Lucia and it incorporates a variety of tropical and subtropical habitats and species. The marine component is rich and diverse with 53 corals, 812 molluscs and 991 reef fish species. Furthermore there are 50 species of amphibians and 109 species of reptiles, including several that are endemic or threatened. It is also the only area in South Africa where the loggerhead and leatherback turtles come ashore to nest. Annual monitoring of turtles is amongst the longest turtle assessments in the world. Thirty-two species of marine mammals, mostly whales and dolphins, have been observed in the area. There is also an abundance of birds with 521 species occurring in total. The park provides an important breeding and refuge area for migratory waterfowl and waders (KZNNCS 1998).

The park received World Heritage Site status in December 1999. Within iSimangaliso Wetland Park are two contiguous marine protected areas that offer further protection to the habitats and inhabitants. These are the Maputaland MPA and the St Lucia MPA. The St Lucia MPA was proclaimed in 1979 and the Maputaland MPA was proclaimed in 1986. They extend from Cape Vidal to the Mozambique border. Both MPAs have areas where no fishing is allowed and areas where limited fishing may occur. These MPAs serve to protect the nesting grounds of loggerhead and leatherback turtles, some of the most southern coral reefs in the world, threatened reef fish species, coelacanths and the canyons in which they live and the spotted ragged-tooth sharks that aggregate in the area. Protection is also provided to some species, such as the whale shark, that aggregate and migrate through these waters (WWFa 2009).

Included in the iSimangaliso Wetland Park is Africa's largest estuary: St. Lucia which is fed by five river systems. St Lucia is a significant nursery area for fishes and shrimps that contribute to a variety of fisheries in the region. Hence, protection of this nursery function is an essential activity for WIO fisheries.

Name & location	**Aliwal & Protea Shoals – South Africa – Ref = 48 & 49**
Habitat	Rocky reefs.
Primary features	Endemic soft corals, shark aggregations.
Primary threats	Pollution, diver damage, fishing.
Monitoring potential	User statistics.
Conservation status	Aliwal Shoal protected since 2004 with areas of no take and some of limited take, Protea Banks has some form of protection in an informal agreement that no reef fishing or chumming will occur in the crown area.
Strategic relevance to SWIOFP	• General biodiversity and ecological reference site for endemic reef fish populations. • Protection of major and diverse elasmobranch aggregations.

Aliwal Shoal is situated about 5 km offshore from the Umkomaas River mouth at 30°15'S to 30°16'S. The shoal is approximately 5 km in length, 1.5 km wide and varies in depth from 5 to 27 meters. The reef is an ancient shoreline that was submerged and fossilized almost 80,000 years ago (WWF 2009b). The Shoal has large colonies of soft corals and sponges (Connell 1985) as well as many species of invertebrates and fish. In particular the Shoal sustains endemic reef fish populations from the sparid family which are important demersal fisheries resources. Foraging turtles are common while spotted ragged-tooth sharks aggregate on the shoal during the winter months. The reef is a very popular diving and fishing site. In 2004, the Aliwal Shoal was declared a marine protected area. This MPA has a sanctuary zone where no extractive activities are allowed and a controlled zone where limited extractive activities may be undertaken.

Protea Banks is a fossilised underwater relic sand dune located at 30°50'12"S 30°28'54'E approximately 7-8 km offshore. The reef is approximately 6 km long, lying in a north to south direction and is around 800 m wide. It varies in depth from 27-60 m (Jackson 2000). Protea Banks is a popular fishing area for recreational and charter fishing as well as for SCUBA diving specifically to see sharks. Protea Banks is a major elasmobranchs aggregation reef for species such as spotted ragged-tooth sharks during the winter months and Zambezi sharks during the summer months. Tiger sharks, scalloped hammerhead sharks, smooth hammerhead sharks and great hammerhead sharks are in the area all year round and occasionally other shark species frequent the reef (Sjursrether 2005). Periodically large aggregations of batoids have been recorded, including cownose rays. There is no formal protection status for the Protea Banks but an informal agreement has been formed between the various users' associations to declare the crown area of the reef as a no-take zone. How effective this agreement is remains unknown (pers comm. Bruce Mann, ORI).

MOZAMBIQUE

The long Mozambique coastline is endowed with a great variety of habitats and corresponding hotspots. A total of 16 were identified of which seven are described in detail.

Name & location	**Bazaruto Archipelago – Mozambique – Ref = 18** **Includes Ponta don Carlos – Ref = 22**
Habitat	Mangroves, seagrass beds, coral reefs.
Primary features	Dugongs, corals.
Primary threats	Habitat destruction through human impacts, fishing, oil pollution.
Monitoring potential	Dugong numbers, fishing statistics.
Conservation status	Limited protection from 1971 which was extended in 2000. Little fisheries control in place.
Strategic relevance to SWIOFP	• General biodiversity and ecological reference site. • Mangrove and seagrass fish nurseries protection. • Reference site for long-term monitoring of loggerhead turtles and dugongs as proxy for regional fisheries impact. • Fisheries bycatch of dugong managed.

The Bazaruto Archipelago is situated between 21°30'S, 35°22'E and 22°10'S, 35°30'E off the San Sebastião Peninsula. There are five islands: Bazaruto, Santa Carolina, Benguerra, Margaruque and Bangué (Everett *et al.* 2008). These islands are comprised of beach rock and sand dunes which makes them relatively fragile and highly susceptible to wind and wave actions. Impacts from the natural processes are further exacerbated by human activities (Ramsay 1995). The islands have extensive intertidal flats which connect the islands at low tide. These flats are rich in seagrass meadows which provide essential nursery habitat for fishes and nutrients for turtles and dugongs.Vegetation on the islands is mostly scrubby but Benguerra Island has small moderately developed woodland. Several freshwater lakes occur on Bazaruto Island. The human population is dense on the islands and most activities involve subsistence fishing. There is a well-developed infrastructure for tourism (Birdlife International 2012c).

In 2008 a survey of the Bazaruto Archipelago estimated that there were 250 dugongs in the area. While this is most likely the largest population of dugongs in the western Indian Ocean they face numerous threats including destruction of their habitat, entanglement in fishing gear and direct harvesting by the local population (Provancha & Stolen 2008). Besides dugongs, other marine mammals are found around the islands including humpback whales, bottlenose dolphins and Indo-Pacific humpback dolphins. Loggerhead turtles are confirmed to be nesting on the beaches of the islands and it is possible that other turtle species also nest there.

The coral reefs vary considerably in nature from sparse coral growth to the true hermatypic reef formations. There are three types of reef present: submerged sandstone reefs, submerged fringing reefs and patch reefs. The hard corals are the most abundant and diverse group of corals (Everett *et al.* 2008). The northern and eastern sides of Bazaruto are washed by the open ocean which brings charismatic species such as manta rays and whale sharks close inshore (Everett *et al.* 2008).

Name & location	**Quirimbas – Mozambique – Ref = 19**
Habitat	Mangroves, seagrass beds, coral reefs.
Primary features	Dugongs, corals.
Primary threats	Habitat destruction through human impacts, fishing, oil pollution.
Monitoring potential	Dugong numbers, fishing statistics.
Conservation status	Limited protection from 1971 which was extended in 2000. Little fisheries control in place.
Strategic relevance to SWIOFP	• General biodiversity and ecological reference site. • Mangrove and seagrass fish nurseries protection. • Reference site for long-term monitoring of loggerhead turtles and dugongs as proxy for regional fisheries impact. • Fisheries bycatch of dugong managed.

The Quirimbas Archipelago, situated at 12°41’10”S, 40°43’00”E in northern Mozambique, consists of 31 islands stretching south from Cabo Delgado for approximately 200 miles. These islands, running along the coast, are partly linked to the coast by sandbars, coral reefs, mangroves and are in water which has a rich marine biodiversity including turtles, dugongs and many species of fish. Due to the South Equatorial Current diverging in the area, the Quirimbas has a high replenishment capacity and possibly is a critically important source for marine larvae (UNESCO 2012). There are over 48 genera of hard corals, 15 species of soft corals, 137 species of macroalgae and approximately 400 species of fishes (WWF Eastern African Marine Ecoregion 2004).

Name & location	**Ponta do Ouro – Mozambique – Ref = 20**
Habitat	Sandy beaches.
Primary features	Turtle nesting.
Primary threats	Recreational activities e.g. fishing & diving; development.
Monitoring potential	Turtle nests, resident dolphins and corals.
Conservation status	Protected as Ponta do Ouro Partial Marine Reserve. Fisheries controls marginal.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of turtle nests and recovery as proxy for regional fisheries impact. • General biodiversity and ecological reference site including corals. • Reference site for long-term monitoring of dolphins.

Ponta do Ouro is situated just north of the border with South Africa at 26°50’39.73”S, 32°53’22.6”E. It is a popular tourist destination, in particular for South Africans for diving and game fishing. While there are corals at Ponta do Ouro they are not diverse or plentiful enough to be considered as a hotspot for the region (pers. comm. Prof M.H. Schleyer, ORI). The beaches do, however, provide an important nesting ground for leatherback and loggerhead turtles (Peace Parks 2012). This location is known as a hotspot for dolphin aggregations associated with diver tourism. Monitoring of resident dolphins has been ongoing (pers com. A. Gullan, Dolphin Encountours) and provides insight into bottlenose and humpback dolphin populations. Some conflict with fisheries exists.

Name & location	**Saint Lazarus Bank – Mozambique – Ref = 21**
Habitat	Exposed seamount, sandy beach, submerged canyons.
Primary features	Endemic fauna, turtles, coelacanths.
Primary threat	Fishing particularly by foreign & local longliners.
Monitoring potential	Pelagic fish aggregations.
Conservation status	No protection.
Strategic relevance to SWIOFP	• General biodiversity and ecological reference site including pelagic fish populations. • Protection of fish aggregations and associated unique habitat. • Site requires study.

Saint Lazarus Bank is a shallow seamount situated at 12°4'S 41°25'E and about 100 km offshore. This shallow seamount, which is about 30 km long and 20 km wide, has exceptional physical and biological characteristics that make it a biodiversity hotspot. The central, table-like platform of the seamount reaches from 6-60 m deep on the margins but rapidly drops to around 2,000 m on all sides. It is known for its aggregations of gamefish, especially from August/September to December when mantis shrimp rise to the surface to mate. This provides an abundance of baitfish which in turn attracts yellowfin tuna, dogtooth tuna, wahoo and barracuda together with of a wide variety of other game fish and reef fish. This fish aggregating site is a target area for fishers, including longline activities. Protection or limiting access may be justified. More study is needed.

Name & location	**Baixo Danae – Mozambique – Ref = 24**
Habitat	Sub-tidal reef.
Primary features	Fish aggregations.
Primary threat	Fishing activities.
Monitoring potential	Fish aggregations.
Conservation status	Technically protected as Ponta do Ouro Partial Marine Reserve but no fisheries controls in place.
Strategic relevance to SWIOFP	• Reference site for fish aggregations.

Baixo Danae is a reef situated at the northern tip of Inhaca Island at 25°52'37.87'S, 33°3'42.35'E. It rises from 40 m to 3 m below the surface. The reef is an important concentration point for pelagic game fish species and it receives high levels of ski boat pressure especially during fishing competitions (Peace Parks 2009). A feature of this site is its historic seasonal spawner aggregation of fish and notably the uncommon spadefish, which were hugely exploited by local fisheries to the point of near local extinction. (Raba-EOTH pers com). Periodic aggregations of the zebra shark have also been noted (ORI unpublished records).

Name & location	**Tofo Beach – Mozambique – Ref = 25** **Paindane (Jangamo) – Mozambique – Ref = 26** **Zavora – Mozambique – Ref = 27** **Manta Reef – Mozambique – Ref = 29**
Habitat	Sub-tidal reef.
Primary features	Manta rays, whale sharks, turtles.
Primary threats	Tourist activities; illegal harvesting of mantas, dugong and turtles.
Monitoring potential	Manta population.
Conservation status	Nil except local NGO efforts.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of manta rays as red-flagged species and as proxy for regional fisheries impact. • Protection for critical manta species and dugong.

Tofo Beach is situated in south eastern Mozambique at 23°52'0.8'S, 35°33'14.47"E. Jangamo is at 24°6'41.06'S, 35°31'58.36'E, Zavora is at 24°30'49.51"S, 35°12'19.64"E and Manta Reef at 23°58'55.09"S, 35°31'22.01"E. These closely related sites are major Mozambican tourist destinations, primarily for fishing and diving. The most striking feature is the aggregation of reef mantas, a unique phenomenon. Dugongs also occur in moderate numbers, partially linked to the bay at Inhambane. Nearby reefs also attract other rays, turtles and whale sharks.

Name & location	**Inhaça Island – Mozambique – Ref = 28** **Barreira Vermelha – Mozambique – Ref = 23**
Habitat	Seagrass beds, coral reefs.
Primary features	Rich biodiversity, dugongs, turtles, corals.
Primary threats	Pollution, fisheries, development.
Monitoring potential	Extensive data from century long research activities.
Conservation status	Recently declared as part of the Ponto do Ouro MPA; previously partly protected by UEM mandate. Fisheries only marginally regulated.
Strategic relevance to SWIOFP	• Key regional general biodiversity and ecological reference site including diverse resources with links to fisheries, especially shrimp fisheries. • Protection for dugong. • Mangrove and seagrass fish nurseries protection. • River flow links to fisheries. • Reference site for long-term monitoring of dugong and turtle nesting as proxy for regional fisheries impact. • Fisheries bycatch of turtles and dugong managed.

Inhaca is an island of about 40 km^2, located at the entrance of Maputo Bay. It is situated approximately at 26°S and 35°E, separated from the mainland Machingulu Peninsula by a narrow channel. On the west is the large estuarine bay while to the east is the open ocean. Inhaca has a wide diversity of ecosystems including mangroves, seagrass, sandy beaches, tidal lagoon and coral reefs. The island has been intensely studied since 1911 (Kalk 1995). It remains a study site for the University Eduardo Mondlana in Maputo. Monitoring data is available on corals, turtles, birds, dugongs and fishes. The entire island represents a key biodiversity reference site in the region. About 5,000 people live on Inhaca, many associated with fisheries. Tourism is an important feature.

INTERNATIONAL WATERS

Name & location	**Walter's Shoal – International waters – Ref = 6**
Habitat	Seamount.
Primary features	Diversity of fish, crustaceans and molluscs.
Primary threats	Fisheries.
Monitoring potential	Periodic surveys for lobster and fish.
Conservation status	None.
Strategic relevance to SWIOFP	• Reference site for long-term monitoring of lobsters and elasmobranchs as proxy for regional fisheries impact. • General biodiversity and ecological reference site including fish populations. • Urgent need of study and possible protection.

Located at 33°12'0.25'S 43°50'0.04' this seamount forms part of the lower mid-ocean Madagascar Ridge. Walter's Shoal is a major aggregating site for fish, sharks, marine mammals and especially migrating humpback whales. The site has populations of exploitable lobsters. Its remoteness has resulted in lack of study and information.

Conclusion

The selection of hotspots in the WIO with relevance to fisheries is a complex and at times subjective process that is dependent on good existing information. Such information is often lacking so, for that reason, it has seldom before been undertaken except for specific biota such as birds, turtles and marine mammals. The 38 hotspot sites described here represent a start at compiling an inventory that over time should inform fisheries management with environmentally sensitive options for development. The rationale for selection has varied and included several aspects of relevance to WIO fisheries, especially in the context of an EAF approach. The 38 hotspots described are fully protected as an MPA in 9 cases, partially protected in 17 and under no protection in 12 cases. This means that more than half the hotspots identified are under some form of protection, albeit inadequate in many cases. Little comment can be made on the level of compliance at this stage but it is nevertheless an encouraging trend to be sustained.

A black mangrove (*Bruguiera gymnorhiza*) takes root. (Photo: Andrew Gifford)

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Annex: Scientific names of species mentioned in the text

Elasmobranchs	
Blackfin reef shark	*Carcharhinus melanopterus*
Manta rays	*Mobulidae*
Whale sharks	*Rhincodon typus*
Green sawfish	*Pristis zijsron*
Narrow sawfish	*Anoxypristis cuspidata*
Whitetip reef shark	*Triaenodon obesus*
Oceanic whitetip shark	*Carcharhinus longimanus*
Mako shark	*Isurus oxyrinchus*
Scalloped hammerhead shark	*Sphyrna lewini*
Tiger shark	*Galeocerdo cuvier*
Spotted ragged-tooth shark	*Carcharius taurus*
Zambezi shark	*Carcharhinus leucas*
Smooth hammerhead shark	*Sphyrna zygaena*
Great hammerhead sharks	*Sphyrna mokarran*
Cownose ray	*Rhinoptera javanica*
Zebra shark	*Stegostoma fasciatum*
Reef manta	*Manta alfredi*
Invertebrates	
Coconut crab	*Birgus latro*
Thin birdnest coral	*Ceriotopera hystrix*
Knob-horn coral	*Stylophera pistillata*
Pronghorn spiny lobster	*Panulirus penicillatus*
Mantis shrimp	*Stomatopoda*
Lobsters	*Jasus spp.*
Mammals	
Paulian's Triple Leaf-nosed Bat	*Paratriaenops pauliani*
Aldabra Flying Fox	*Pteropus aldabrensis*
Spinner dolphin	*Stenella longirostris*
Common bottlenose dolphin	*Tursiops truncatus*
Blainville's beaked whale	*Mesoplodon densirostris*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sperm whale	*Physeter macrocephalus*
Killer whale	*Orcinus orca*
Curvier's beaked whale	*Ziphius cavirostris*
Short-beaked common dolphin	*Delphinus delphis*
Pantropical spotted dolphin	*Stenella attenuatea*
False killer whale	*Pseudorca crassidens*
Risso's dolphin	*Grampus griseus*
Melon-headed whale	*Peponocephala electra*
Humpback whale	*Megaptera novaeangliae*
Dugong	*Dugong dugon*
Indo-Pacific humpback dolphin	*Sousa chinensis*
Indo-pacific Bottlenose Dolphin	*Tursiops aduncus*
Cape fur seal	*Arctocephalus pusillus*

Teleosts	
Anchovies	*Engraulidae*
Barracuda	*Sphyraena spp.*
Billfish	*Istiophoridae*
Bonefish	*Albula vulpes*
Brown-marbled grouper	*Epinephelus fuscoguttatus*
Camouflage grouper	*Epinephelus polyphekadion*
Cobia	*Rachycentron canadum*
Coelacanth	*Latimeria chalumnae*
Dogtooth tuna	*Gymnosarda unicolor*
Eels	*Anguilla spp.*
Flowery flounder	*Bothus mancus*
Frenchman seabass	*Polysteganus baissaci*
Giant trevally	*Caranx ignobilis*
Goatfishes	*Upeneus spp.*
Goldlined seabream	*Rhabdosargus sarba*
Green humphead parrotfish	*Bolbometopon muricatum*
Groupers	*Epinephalus spp.*
Groupers	*Serranidae*
Hairtail	*Trichiurus lepturus*
Halfbeaks	*Hemiramphus spp.*
Humphead wrasse	*Cheilinus undulatus*
Marbled coralgrouper	*Plectropomus punctatus*
Milkfish	*Chanos chanos*
Mullets	*Mugilidae*
Needlefish	*Belonidae*
Queenfish	*Scomeroides spp.*
Rays	*Rajiformes*
Seacatfish	*Arius spp.*
Sharks	*Carcharhinus spp.*
Thornfishes	*Therapon spp.*
Trevallies	*Caranx spp.*
Wahoo	*Acanthocybium solandri*
Wrasses	*Labridae*
Yellowfin tuna	*Thunnus albacares*
Spadefish	*Tripterodon orbis*
Reptiles	
Aldabra tortoise	*Aldabrachelys gigantea*
Green turtle	*Chelonia mydas*
Hawksbill turtle	*Eretmochelys imbricata*
Loggerhead turtle	*Caretta caretta*
Leatherback turtle	*Dermochelys coriacea*

Birds	
Seychelles Brush-Warbler	*Acrocephalus sechellensis*
Brown Noddy	*Anous stolidus*
Lesser Noddy	*Anous tenuirostris tenuirostris*
Grey Heron	*Ardea cinerea*
Wedge-tailed Shearwater	*Ardenna pacifica*
Ruddy Turnstone	*Arenaria interpres*
Western Cattle Egret	*Bubulcus ibis*
Striated Heron	*Butorides striata*
Abbott's sunbird	*Cinnyris abbotti abbotti*
Aldabra drongo	*Dicrurus aldabranus*
Crab Plover	*Dromas ardeola*
Aldabra rail	*Dryolimnas aldabranus*
White throated rail	*Dryolimnas cuvieri*
Aldabra fody	*Foudia aldabrana*
Lesser Frigatebird	*Fregata ariel*
Great Frigatebird	*Fregata minor*
Common White-Tern	*Gygis alba*
Aldabra brush warbler	*Nesillas aldabrana*
Bridled tern	*Onychoprion anaethetus*
Sooty tern	*Onychoprion fuscatus nubilosus*
White-tailed tropicbird	*Phaethon lepturus*
Red-tailed tropicbird	*Phaethon rubicauda*
Tropical Shearwater	*Puffinus lherminieri nicolae*
Roseate Tern	*Sterna dougallii arideensis*
Black-naped tern	*Sterna sumatrana mathewsi*
Masked booby	*Sula dactylatra melanops*
Red-footed booby	*Sula sula rubripes*
Swift tern	*Thalasseus bergii*
Malagasy Pond Heron	*Ardeola idea*
dimorphic egret	*Egretta dimorpha*
Caspian tern	*Hydroprogne caspia*
Malagasy white-eye	*Zosterops maderaspatanus voeltzkowi*
African penguin	*Spheniscus demersus*
Cape commorant	*Phalacrocorax capensis*
Cape gannet	*Morus capensis*
Antarctic tern	*Sterna vittata*

Plants	
White mangrove	*Avicennia marina*
Black mangrove	*Bruyuiera gymnorrhiza*
Indian mangrove	*Ceriops tagal*
Red mangrove	*Rhizophora mucronata*
White-flowered apple mangrove	*Sonneratia alba*
Canonball mangrove	*Xylocarpus granatum*
Cedar mangrove	*Xylocarpus moluccensis*
	Pemphis acidula
	Pembris
Bully trees	*Sideroxylon*
Fig trees	*Ficus*
Climbing milkweeds	*Sarcostemma*
Fan-flowers	*Scaevola*
Soldierbush	*Tournefortia*
Bay cedar	*Suriana*
She-oak trees	*Casuarina*
Cabbage tree	*Pisonia grandis*
Noni	*Morinda citrifolia*
Wooden bat tree	*Ochrosia oppositifolia*
Looking-glass Mangrove	*Heriteria littoralis*
Sickle seagrass	*Thalassia hemprichi*
Narrowleaf seagrass	*Halodule uninervis*
Shoalgrass	*Halodule wrightii*
Broadleaf seagrass	*Halophila stipulacea*
Spoon seagrass	*Halophila ovalis*
Sickle-leaved cymodocea	*Thalassodendron ciliatum*
Cymodocea	*Cymodocea rotundata*
	Cymodocea serrulata
Round-leaf seagrass	*Syringodium isoetifolium*
	Mesembryanthemum
	Tetragonia
	Chenopodium

IN CONCLUSION

Rudy van der Elst[1]

Perusal of this volume leaves little doubt as to the great diversity of fisheries in the Southwest Indian Ocean. It presents a picture of complexity in terms of species, users, scientific assessment and environmental sustainability. This complexity, set in an ocean bordered by numerous developing countries with modest resources, would normally signal a negative perception with fisheries in decline, lack of scientific understanding and absence of management. Yet, this milestone publication reflects numerous positive attributes of the industrial fisheries in the region and, notwithstanding many shortcomings, the region's fisheries present opportunities for development within an ecosystem approach. Each of the fisheries is described and assessed in considerable detail based on a retrospective analysis of available data. Many fisheries management challenges have elicited a response, albeit imperfect in some cases. Indeed, considering the improved regional collaboration, policies and structures in place, the region's fisheries and vulnerable biota could be on the threshold of improved scientific understanding and protection. Each chapter concludes with a section on challenges and recommendations. What follows here is a summary that encapsulates the more positive aspects of the fisheries and the status of vulnerable biota that are impacted.

Shallow-water prawn fisheries are shown to be an important feature in five countries of the region. Historically, these fisheries were subject to considerable fluctuation and depletion. In addition, there have been environmental impacts, user-conflicts and competition with mariculture, resulting in several fisheries' closures. Significantly, in most countries the prawn stocks are now assessed and recent management interventions appear to have stabilised these fisheries, albeit at reduced levels, and they continue to generate much-needed revenue. Although the full ecological impact of trawling remains unstudied and a source of concern, bycatch reduction devices have been evaluated and implemented in several fisheries with promising results. Characteristics of these shallow-water prawn fisheries are similar between all five countries and stocks could well be shared, in response to which genetic studies have been initiated to elucidate the extent or otherwise of connectivity between populations.

Two long-term deep-water trawl fisheries for crustaceans operate in the region – Mozambique and South Africa – targeting a mix of species including pink prawn, langoustine, crab and lobster. A variable number of vessels operate in depths of 300-500m, landing up to 3,000t of crustaceans per year. Both fisheries have shown considerable fluctuations which are difficult to interpret because of technology creep such as changes in vessel power. Nevertheless, these fisheries have now stabilised, and are managed according to national management strategies, in recognition of their value. Genetic studies reveal highly structured populations, suggesting that there is no single shared stock. A shift in management of deep-water prawns or langoustines from local to regional would therefore be premature on the grounds of shared or transboundary stocks. In contrast to the reasonable condition of these stocks, is the high level of discarded bycatch taken by deep-water trawling, including many species of fish, elasmobranchs, cephalopods and crustaceans of low economic value.

Industrial trap fishing for spiny lobsters and deep-sea crabs takes place in depths of 100-450m on an experimental and, in one case, a full commercial basis. The latter targets endemic South Coast lobster off South Africa that yields up to 1,000t per annum. Other trap fisheries for related spiny lobster species have taken place in Mozambique and eastern South Africa, and exploratory trapping for spiny lobsters occurs occasionally on seamounts to the south of Madagascar. These high-value spiny lobster species are often slow-growing and vulnerable to over-exploitation, as evidenced by the sharply declining catch rates in several trap fisheries leading to their temporary suspension. Significantly, stock recoveries of fished-down populations of lobster have occurred after a reduction in fishing effort, so that stock rebuilding through conservative management proved viable. Although traps do take a bycatch, this is often in the form of valuable slipper lobster, deep-sea crab and octopus, which are mostly retained, thereby adding value to the fishery.

Some of the largest fisheries in the region by tonnage revolve around pelagic species, especially those fisheries targeting large pelagic fishes out of Seychelles, where the annual catch of tuna can reach 300,000t. Notwithstanding such large harvests, these pelagic stocks are considered to be in reasonable condition by IOTC, with only albacore and swordfish raising concerns about the future. Medium pelagics fall into two groups, those being monitored by IOTC and those that fall outside the attention of IOTC. The former group includes bullet tuna and king mackerel, which have undergone significant increases in landings and are also considered to be in reasonable condition. The second group, which includes dorado, kingfishes and striped bonito, are not formally monitored and hence their status is poorly understood. Nevertheless, country reports to the Southwest Indian

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Ocean Fisheries Commission (SWIOFC) suggest that populations of these coastal species are largely under- or only moderately exploited. Small pelagics, comprising of a suite of 14 scad, mackerel and herring-like species, are poorly documented even though submissions to SWIOFC suggest that most were less than fully-exploited. Although the status of pelagic fisheries in the region presents a reasonably positive picture, there are a number of species for which the status is unknown, including some that straddle or migrate across country borders, and hence require collaborative action.

Almost 600 fishes can technically be described as demersal, collectively the largest category of species reported in SWIO landings, providing opportunities for diverse fishing sectors including industrial, semi-industrial and small-scale artisanal fisheries. More specifically, these sectors consist of shallow-water trawling (as bycatch), linefishing (including deep-water dropline/longline), and artisanal and recreational linefishing. Some 32 species are identified as priority resources of common concern for the demersal fisheries of the region. Considering the great diversity, it is not surprising that landings are mostly reported in highly aggregated format, thereby complicating individual species assessments. Similarly, the diversity of users and gear complicates calculations of fishing effort and thereby the monitoring of catch rates. The region's demersal fish stocks, especially in nearshore areas, have experienced heavy fishing pressure over the past few decades with catch rates of 13 priority species having declined and four having increased/recovered, partly attributable to management intervention. Demersal fisheries of the region provide the greatest level of access to the widest range of user. However, to maximise on these opportunities presents a significant number of scientific and management challenges.

The status of vulnerable organisms that are impacted by industrial fisheries in the SWIO is reported on in this assessment and in the case of sea turtles presents a mixed picture. Although sea turtles are technically protected throughout the region, including nesting sites, interactions with a few fisheries remains a threat. In particular three fisheries are implicated: prawn trawling, longlining and especially artisanal gillnets. Specific hotspots of concern have been identified, for example, up to 15,000 killed per annum by artisanal fishers at one location in Madagascar. In contrast, turtle mortality in the prawn trawl fisheries has been declining following the progressive introduction of turtle excluding devices (TEDs). Long-term monitoring programmes have proved extremely valuable; such as for green and hawksbill turtles in Seychelles, green turtles from the French Îles Éparses, and loggerhead and leatherback turtles in South Africa. Recognising that for each of the five turtle species, all of the SWIO is considered to be a single management unit, satellite tracking is now implemented as a tool to improve population modelling.

This Retrospective Analysis concludes that marine mammal mortality through offshore fisheries interactions in the SWIO is generally low and certainly lower than many other regions of the world. In contrast to parts of the Pacific where purse-seining caused the decline of several dolphin species, the marine mammal bycatch in SWIO purse seine fisheries is insignificant. While this is true for offshore fisheries, there is greater concern for coastal species affected by human activities and inshore fisheries: *Sousa plumbea, Tursiops aduncus* and especially *Dugong dugon.* While most are taken as incidental bycatch especially in gillnets, opportunistic hunting of dolphins in parts of Madagascar leads to considerable localised mortalities. Depredation, where the bait is removed from longline gear by false killer and short-finned pilot whales, is commonly reported. Mitigation measures to reduce both the bycatch and depredation are being investigated and implemented.

Seabird populations in the SWIO region are diverse and rich with spectacular nesting populations on some islands. Tropical seabirds feed on live prey, in contrast to the more temperate procellariiforms which forage on dead and floating food, making them vulnerable to drifting bait on longline hooks. Accordingly, none of the typical SWIO tropical species is threatened by fisheries impacts, although two Reunion-endemic petrel species are of global conservation concern. Further to the south, however, South Africa reports an estimated annual seabird mortality of 18,000 birds, with particular concern for the African penguin and Cape gannet as threatened coastal species in the SWIO region. The fact that seabirds are conspicuous and breed in large colonies makes them easy to monitor, hence serving as important indicators of biodiversity and productivity.

The SWIO sustains a great diversity of elasmobranchs with 188 species, of which 39 are endemic and 46 carry IUCN "flags of threat". At least 15 species are exploited by longline, purse seine and occasionally pelagic driftnet fisheries; either as target species or as bycatch. These fisheries probably represent the most significant sources of shark mortality in the region. For example, the declared catch of elasmobranchs in the Western Indian Ocean reached 180,500t before declining sharply, while the bycatch of silky sharks through gear entanglement can average 0.5 million individuals annually, apparently increasing with the use of fish aggregating devices. Putting such data into context is near-impossible considering the virtual absence of population assessments and the lack of proper species identification. Not only does this pose a threat to their abundance, but it compromises the potential for sustainable harvesting of a valuable resource. Mitigation measures to minimise elasmobranch bycatch, such as bycatch reduction devices (BRDs) in shrimp trawl fisheries, other technical gear modifications and implementation of better practices on board vessels, have become a priority. A positive step is the development of National Plans of Actions for sharks, underway in several countries of the region.

Of further note is the environmental monitoring of key biodiversity sites as a fisheries independent tool to assessing the overall impact on vulnerable organisms. Chapter13 identifies 59 biodiversity hotspots in the SWIO as significant in evaluating the status of sea turtles, seabirds and certain marine mammal species. Some of these sites also protect threatened fish species, critical life stages such as nursery areas and spawning aggregations. Moreover, through effective monitoring these hotspots can provide insight into the region's response to climate change. To the credit of the SWIOFP countries, 35 of the hotspots identified are already legally under full or partial MPA protection. In several cases key elements of these hotspots have been monitored for many years.

It is often tempting to conclude on a negative note by highlighting all the shortcomings and challenges facing capture fisheries, which in turn may focus future funding and action to remedy these problems. However, each of the individual chapters draws adequate attention to the challenges ahead. In contrast, the overall perception of this publication should evoke a positive disposition. Many of the fisheries are assessed and receiving management intervention, thereby leading to their stabilisation or recovery. The growing awareness and implementation of an ecosystem approach to fisheries management is a notable positive development, as indeed are the greater use of bycatch reduction devices. Whilst the impact of industrial fisheries on vulnerable organisms remains a concern, it is comforting to note that the situation is not perilous and that improved monitoring programmes are underway.

While the FAO continues to report a declining global fisheries catch (FAO-*Sofia 2014), o*ne of the few fisheries regions of the world that contradicts this trend is Region 51: the Western Indian Ocean, where landings peaked at 4.5mt in 2006 and have persisted at well over 4mt since. In the SWIO region the Southwest Indian Ocean Fisheries Commission reported that one quarter of the region's fisheries were being fished at unsustainable levels in 2010, moderately better than the global average of 30%. Whilst this may provide some comfort it leaves no room for complacency, especially as it does not take into consideration the effects of ecosystem overfishing.

The region has highly credible scientific and management structures, a good number of academic institutions with competent staff and facilities as well as a considerable and growing resource of scientific publications and reports. Moreover, SWIOFP has provided an excellent programme of international teamwork to serve as a future model for regional collaboration. The momentum it created should not be lost and instead should be harnessed to develop a new phase of endeavour in the SWIO region. Indeed, this is already happening on several fronts.

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GLOSSARY, ACRONYMS AND ABBREVIATIONS

ACAP	Agreement on the Conservation of Albatrosses and Petrels
ADNAP	Administração Nacional das Pescas (Mozambique)
ADSEI	Association pour le Developpement Socio Economique d'Itsamia: Mohéli
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
AS@S	Atlas of Seabirds at Sea
ASCLME	Agulhas Somali Current Large Marine Ecosystem (project)
ASFS	Aquatic Species Fact Sheets (FAO)
Bsp	Spawner biomass
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CI	Confidence Interval
CPUE	Catch per unit effort
CV	Coefficient of Variation
CW	Carapace width
DAFF	Department of Agriculture Forestry and Fisheries (South Africa)
DFAD	Drifting Fish Aggregation Devices
EAF	Ecosystem Approach to Fisheries Management
EAME	East African Marine Ecosystem program (WWF)
EEZ	Exclusive Economic Zone
ERA	Environmental Risk Assessment
EU	European Union
F	Instantaneous Fishing Mortality
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organization (UN)
FiD	Fisheries department
FIRMS	Fishery Resource Monitoring Systems
FL	Fork Length
GEF	Global Environmental Facility
GIS	Geographic Information System
ICCAT	Inter-governmental Commission for the Conservation of Atlantic Tuna
IIP	Instituto Nacional de Investigaçao Pesquiera (Mozambique)
IMR	Institute of Marine Research (Bergen)
IOSEA	Indian Ocean – South-East Asia Turtle Network (MOU)
IOTC	Indian Ocean Tuna Commission
IRD	Institut de Recherche pour le Développement
ITQ	Individually Transferable Quotas
IUCN	World Conservation Union
IUU	Illegal, unregulated and unreported fishing
IWC	International Whaling Commission
KCDP	Kenya Coastal Development Project
KMFRI	Kenya Marine and Fisheries Research Institute
KZN	KwaZulu-Natal
M	Instantaneous Natural Mortality
Macemp	Marine and Coastal Environment Management Project (Tanzania)
MADE	Mitigating ADverse impacts of open ocean fisheries
PAT	Passive Acoustic Transponder
FAD	Fishing Aggregating Device
MDGs	Millenium Development Goals
MPA	Marine Protected Area

MSY	Maximum Sustainable Yield
MTSG	Marine Turtle Specialist Group (IUCN)
NANSIS	Fisheries Survey Information software
Nei	Not elsewhere included
NORAD	Norwegian Agency for Development Cooperation
NPOA	National Plan Of Action (sharks)
NPOA	National Plan of Action
OMP	Operational Management Procedure
ORI	Oceanographic Research Institute
OT	Eye-fork length
Prawn	Used synonymously with shrimp
RFMO	Regional Fisheries Management Organisation
RMUs	Regional Management Units
SAEON	South African Environmental Observation Network
SAR	National Shark Assessment Report
SBPR	Spawner (Spawning) Biomass Per Recruit
SCAR	Scientific Committee on Antarctic Research
SFA	Seychelles Fishing Authority
Shrimp	Used synonymously with prawn
SIF	Seychelles Island Foundation
SIOFA	Southern Indian Ocean Fisheries Agreement
SL	Standard Length
SOFIA	State of World Fisheries and Aquaculture
SSF	Small-scale fisheries
SWIO	Southwest Indian Ocean
SWIOFC	Southwest Indian Ocean Fisheries Commission
SWIOFP	Southwest Indian Ocean Fisheries Project
TAAF	Terres Australes et Antarctiques Françaises
TAC	Total Allowable Catch
TAE	Total Allowable Effort
TAFIRI	Tanzania Fisheries Research Institute
TED	Turtle Excluder Device
TL	Total Length
TOR	Terms of reference
TRAFFIC	The wildlife trade monitoring network
UNCL	Undeclared (gear)
UNDP	United Nations Development Programme
WIO	Western Indian Ocean
WIOLAB	West Indian Ocean Land-based Activities and Pollution (project)
WIOMSA	Western Indian Ocean Marine Science Association
WIO-MTTF	Western Indian Ocean -Marine Turtle Task Force
WPEB	Working Party on Ecosystems and Bycatch (IOTC)
WW	Whole weight
WWF	World Wide Fund for Nature
WWII	World War II
YPR	Yield Per Recruit
Z	Instantaneous Total Mortality

OFFSHORE FISHERIES OF THE SOUTHWEST INDIAN OCEAN: their status and the impact on vulnerable species brings together in one volume the status of some of the region's largest fisheries with an evaluation of the impact these fisheries impose on vulnerable organisms.

This multi-authored compendium is broadly based on results generated by the Southwest Indian Ocean Fisheries Project (SWIOFP) and deals with offshore fisheries in the EEZ of nine countries in the Southwest Indian Ocean. Included are trawl and trap fisheries for crustaceans, a range of pelagic fisheries, as well as a diversity of demersal fisheries. For each of these sectors several databases, a range of research cruises and a wide spectrum of literature is analysed to reflect historic trends and report on the status of selected key species. Attention is given to the dilemma of bycatch whilst individual chapters are devoted to the status of vulnerable biota namely seabirds, marine mammals, elasmobranchs, sea turtles and threatened teleost fishes.

This volume concludes with an identification of 59 of the region's biodiversity hotspots that justify special protection and can serve as biodiversity reference sites.