STATUS OF THE SOUTH AFRICAN MARINE FISHERY RESOURCES

2023

forestry, fisheries
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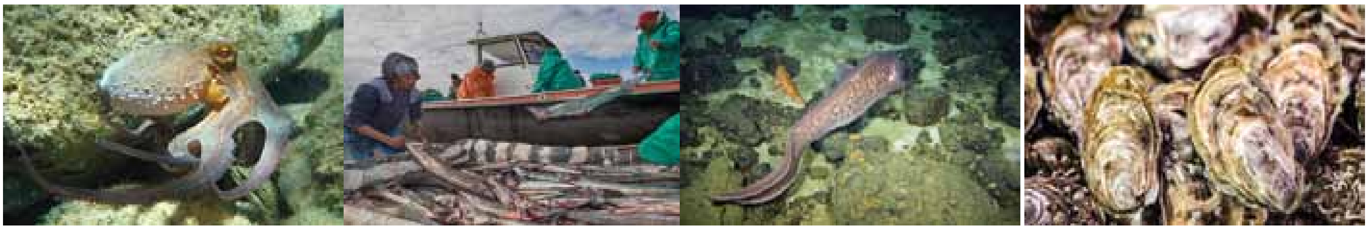
Acronyms and abbreviations

ASPM	Age-structured production model
B_{MSY}	Biomass that would produce MSY
CAL	Catch-at-length
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CL	Carapace length
CoG	Centre of gravity
CPUE	Catch per unit effort
DFFE	Department of Forestry, Fisheries and the Environment
EC	Exceptional circumstances
EEZ	Exclusive economic zone
EFZ	Exclusive fishing zone
FIAS	Fishery-independent abalone survey
FIMS	Fishery-independent monitoring survey
F_{MSY}	Fishing mortality that would produce MSY level
GERMON	Genetic structure and migration of albacore tuna project
GIS	Geographic information system
GLM	General linear model
GLMM	General linear mixed model
GSI	Gonadosomatic index
ICCAT	International Convention for the Conservation of Atlantic Tunas
ICSEAF	International Commission for the South East Atlantic Fisheries
IFREMER DIO	French Research Institute for Exploration of the Sea, Indian Ocean Delegation
IOTC	Indian Ocean Tuna Commission
IUCN	International Union for Conservation of Nature
IUU	Illegal, unreported and unregulated fishing
KZN	KwaZulu-Natal
LMP	Linefish management protocol
MLRA	Marine Living Resources Act
MLS	Minimum legal size
MPA	Marine protected area
MSY	Maximum sustainable yield
NMLS	National marine linefish system
NPOA	National plan of action
NRCS	National Regulator for Compulsory Standards
OMP	Operational management procedure
ORI	Oceanographic Research Institute
PEI-EEZ	Prince Edward Island exclusive economic zone
PMCL	Precautionary management catch limit
PSAT	Pop-up satellite archival tag
PUCL	Precautionary upper catch limit
RFMO	Regional fisheries management organization
RY	Replacement yield
SB	Shell breadth
SPOT	Smart position-only tag
SSB	Spawning stock biomass
SSB_{MSY}	Spawning stock biomass at MSY level
SWIO	Southwest Indian Ocean
SWIOFP	Southwest Indian Ocean Fisheries Programme
TAB	Total allowable bycatch
TAC	Total allowable catch
TAE	Total allowable effort
TRAFFIC	The Wildlife Trade Monitoring Network
TRO	Total reproductive output
TURF	Territorial user Rights in fisheries
USA	United States of America
WWF	World Wide Fund for Nature



Overview

This report presents the most up-to-date information and analyses of the status of marine fishery resources in South Africa at the time of compilation. The number of fish stocks covered has increased steadily from 43 in 2012 to 77 in the current report (Figure I). Among the species included for the first time are a further six sharks (bronze whaler and dusky sharks; Izak catshark, puffadder shyshark, white spotted houndshark and bluntnose spiny dogfish) and nine rays and skates (leg skates, African softnose skate, roughbelly skate, munchin skate, yellowspotted skate, spearnose skate, leopard skate, Rajidae spp. and lesser guitar shark), six linefishes (bronze bream, stone bream, zebra, blacktail, spotted grunter and elf) and one seaweed (*Ulva* spp.). Species included in the 2020 report but excluded from this one include two sharks (great hammerhead and oceanic whitetip).

This overview presents a summary of the status of each marine fishery resource covered in this report. An explanation of the rationale adopted in assessing the status of each resource is provided in the section entitled 'About the report', which follows the overview.

The latest assessments indicate that 66% of the 77 stocks are considered not to be of concern (being of unknown, abundant or optimal status)[1], while 34% of stocks are of concern (being of depleted or heavily depleted status). These figures indicate an improvement over the past eight years, with 46% of stocks considered not to be of concern in 2012, 49% in 2014, 52% in 2016 and 61% in 2020 (Table I). There are some changes to the perception[2] of certain fish stocks since the previous report in 2020. The number of stocks for which the status (18; Figure II) and fishing pressure (9) are unknown has increased. All the 21 stocks that were considered to be in an optimal state in the 2020 report have remained in this state. The number of stocks considered to be abundant (underutilised) has increased from the previous nine in 2020 to 11 in 2023.

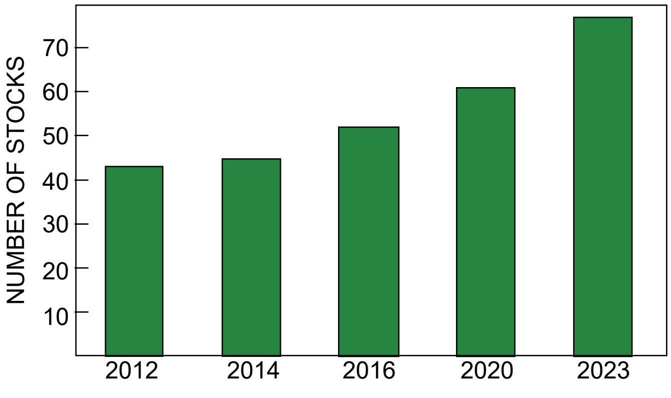


Figure I: The number of fish stocks assessed between 2012 and 2023

Table I: Number and percentage of stocks considered of concern or not

	2012	2014	2016	2020	2023
Stocks not of concern	20 (46%)	22 (49%)	27 (52%)	37 (61%)	51 (66%)
Stocks of concern	23 (54%)	23 (51%)	25 (48%)	24 (39%)	26 (34%)
Number of stocks assessed per year	**43**	**45**	**52**	**61**	**77**

The number of stocks that are considered to be depleted has increased from nine in 2020 to 13 in 2023, this increase arising from the inclusion of dusky shark, zebra and blacktail in this report, an improvement in the status of bigeye tuna (Atl.) from heavily depleted to depleted, and a decline in the status of yellowfin tuna (Ind.) from depleted to heavily depleted. The number of stocks considered to be overexploited (heavily depleted) has increased from 15 in 2020 to 13 in 2023.

Some of South Africa's marine fishery resources are targeted by multiple sectors (e.g. the Cape hakes are targeted by the hake handline and inshore and offshore demersal trawl sectors) and several resources are taken as bycatch by one or more sectors other than that targeting a specific resource. These multiple sources of fishing mortality for each resource, and the estimated annual quantities caught, are indicated in Table II. These data were derived from 2021 catch data provided to the FAO and supplemented by peer-reviewed analyses of observer data which includes discards for hake inshore trawl (Attwood et al. 2011), hake deep-sea trawl (Walmsley et al. 2007) and midwater trawl (Reed et al. 2017). Broad catch categories were used to highlight larger catch and illustrate the multi-species nature of many sectors.

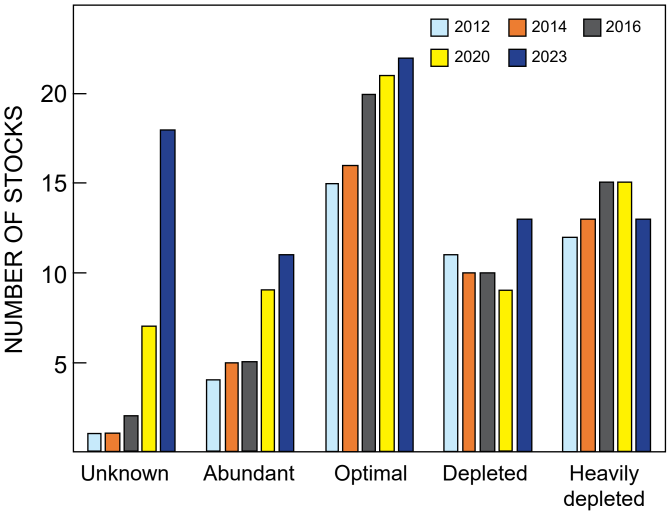


Figure II: Number of fish stocks according to status from 2012 to 2023

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[1] For this summary appraisal, where a particular resource falls across two categories of stock status or pressure, precaution was applied and the resource has thus been assigned to the 'worst case scenario'.

[2] Perceptions of stock status may change with improvements in the information available for that stock. Thus either deteriorations or improvements in the perception of status may not necessarily be indicative of actual changes in the stock status.

Table II: Matrix indicating the estimated quantities of a variety of South African exploited marine fisheries resources by sector, with colour coding used to indicate small (blue) through moderate (green and yellow) to high (orange and red) quantities (tonnes in 2021)

Sector → **Resource ↓**	**Abalone**	**Hake inshore trawl**	**Hake deep-sea trawl**	**Hake longline**	**Midwater trawl**	**Traditional linefish**	**Beach-seine**	**Gillnet**	**Small-scale***
Abalone	>10								>100
Agulhas sole		>100	0.1						
Cape hakes		>1 000	>100 000	>1 000	>100			0.1	>10
Cape horse mackerel		>1 000	>1 000		>10 000		>1	>1	>10
Kingklip		>100	>1 000	>100		0,1			0,1
Linefish (not specified)		>1 000	>1	>100	>10	>100	>100	>1 000	>1 000
Carpenter		>100	>100	>1	>1	>100			>100
Geelbek		>10			>1	>10	0.1	>1	>100
Hottentot seabream		>1				>100	0.1	>10	>100
Santer		>1				>10			>10
Silver kob		>100	>1			>100	>10	>10	>100
Slinger						>10			>10
Snoek		>10	>1 000	>10	>10	>1 000	0.1	0.1	>100
Yellowtail						>100	>100		>100
Monkfish		>10	>1 000	>100					
Netfish (not specified)		>100			>1		>100	>1 000	>100
Harders							>1 000	>1 000	>100
Patagonian toothfish									
Sharks (not specified)		>1 000	>1	>10	>10	>100	>10	>100	>100
Blue shark									
Mako shark									
Smoothhound sharks		>10				>10	>10	>100	>100
Soupfin shark		>10				>10		>100	0.1
Small pelagic fish									>100
Anchovy									
Round herring					>100		>1		>10
Sardine		0.1			>10		>100	>10	>100
South Coast rock lobster		0.1							
Squid		>100	>1		>10		>1		>100
Trawl-caught crustaceans							0.1	>10	>10
Tunas and swordfish					>1				
West Coast rock lobster		0,1						0,1	>100

*Beach-seine, gillnet, hake handline

Table II: (continued)

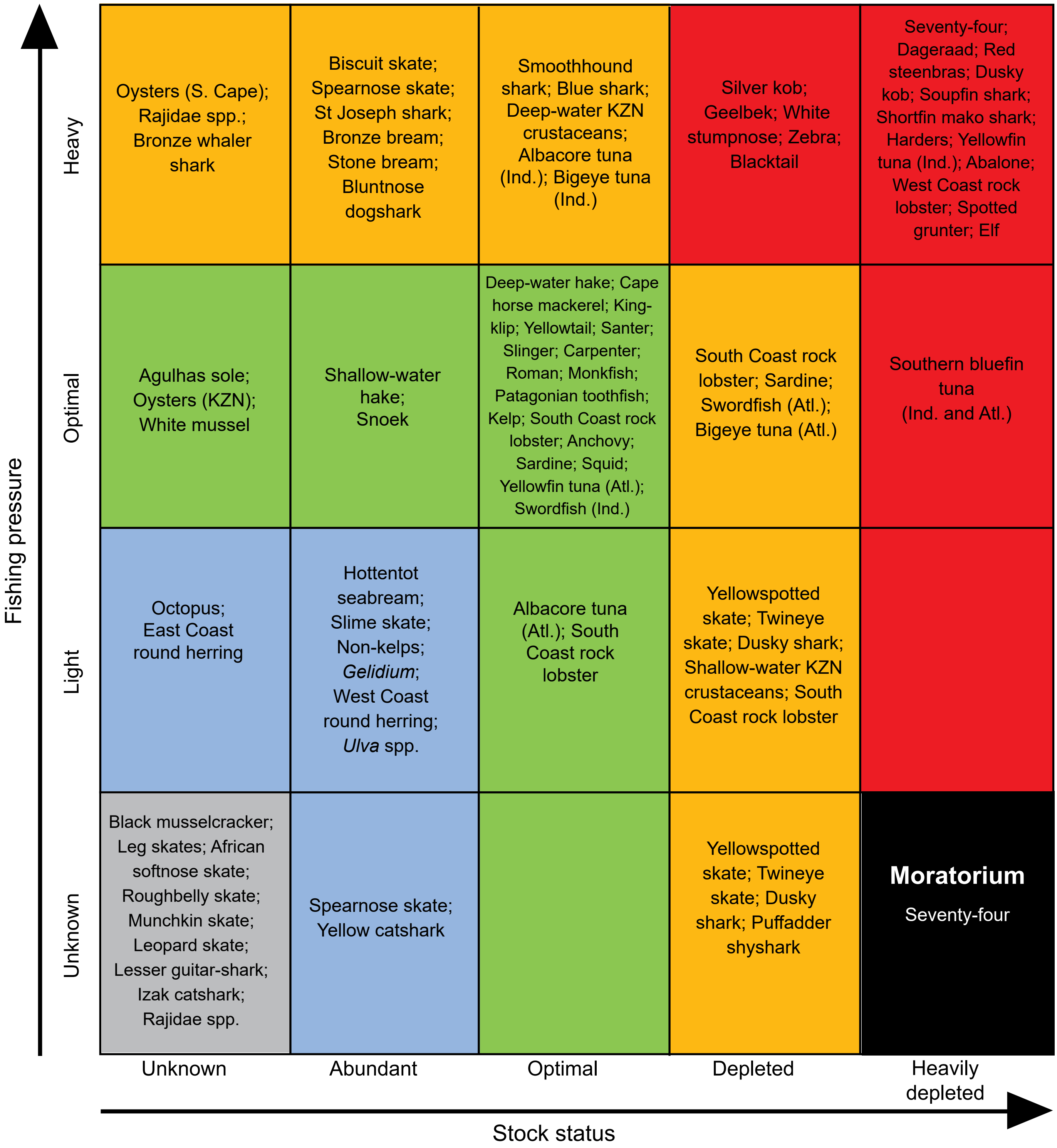
Sector → **Resource ↓**	**Patagonian toothfish longline**	**KZN crustacean trawl**	**Demersal shark longline**	**Small pelagic purse-seine**	**South Coast rock lobster**	**Squid jig**	**Large pelagics longline**	**Tuna pole-line**	**West Coast rock lobster**
Abalone									
Agulhas sole									
Cape hakes		>10							
Cape horse mackerel				>1 000					
Kingklip					0.1				
Linefish (not specified)		>100			0.1			>1	
Carpenter									
Geelbek									
Hottentot seabream									
Santer									
Silver kob									
Slinger									
Snoek								>100	
Yellowtail				>10				>1	
Monkfish									
Netfish (not specified)									
Harders									
Patagonian toothfish	>100								
Sharks (not specified)		>10	>10				>10		>10
Blue shark							>100		
Mako shark							>100		
Smoothhound sharks			>10						
Soupfin shark			>10						
Small pelagic fish									
Anchovy				>100 000					
Round herring				>10 000					
Sardine				>10 000					
South Coast rock lobster					>100				0.1
Squid						>1 000		0.1	
Trawl-caught crustaceans		>100							
Tunas and swordfish							>1 000	>1 000	
West Coast rock lobster									>100

The following is a brief summary for each resource:

- **Abalone:** The status of the abalone resource continues to decline in response to extremely high levels of illegal harvesting, over-allocation of total allowable catches (TACs), and ecological changes.
- **Agulhas sole:** Uncertainty remains regarding the true status of the Agulhas sole stock. The assessment conducted in 2021 suggested that replacement yield (RY) and maximum sustainable yield (MSY) were lower than those estimated in the 2020 assessment, resulting in a decrease in the Agulhas sole TAC for 2022.
- **Cape hakes:** The 2021 assessment for Cape hakes provided similar results to the 2020 update and indicated a continued steady increase in the spawning biomass of shallow-water hake but a decrease in that of deep-water hake. Spawning biomasses of both species are estimated to lie well above those that yield MSY.
- **Cape horse mackerel:** The most recent assessments for Cape horse mackerel indicate that the estimates of current spawning biomass are well above those that yield MSY.
- **Kingklip:** Recent research suggests that there are genetically separate stocks on the West and South coasts, but with some degree of gene flow between the two components. The 2021 assessment suggested that the South Coast component of the resource is increasing in abundance at about 1.7% per annum, whereas the West Coast component is increasing at about 2.9% per annum. The precautionary upper catch limit (PUCL) for this resource increased slightly in 2022.
- **Linefish:** Stocks of hottentot seabream, snoek, carpenter, santer, slinger, Roman and yellowtail are considered to be in good condition and are not overfished. Silver kob, geelbeck and white stumpnose are considered depleted and continue to be overfished. Collapsed resources, such as seventy-four, red steenbras, dageraad and dusky kob, require stronger intervention in order to rebuild stocks.
- **Monkfish:** The 2021 assessment indicated a slight increase in the abundance of the West Coast component of this stock whilst the South Coast component of the resource has remained stable.
- **Netfish:** Harders, the main target of the beach-seine and gillnet fisheries, remain in a heavily depleted state with the most recent assessment estimating spawner biomass to be 24% of pristine. This depletion is a result of overfishing, illegal harvesting and adverse environmental conditions that have reduced juvenile harder recruitment into estuaries.
- **Oysters:** The oyster resource along the KwaZulu-Natal coast is considered to be optimally exploited, although uncertainty remains around the actual stock status. Similar uncertainty also remains regarding the status of oysters in the Southern Cape, with their level of exploitation considered to be heavy. This, together with illegal harvesting from subtidal “mother beds” that seed the intertidal oyster reefs, remains a cause for concern.
- **Patagonian toothfish:** The 2022 update of the reference case (RC) assessment model for Patagonian toothfish suggested a slight improvement in status and the resource remains above the estimated biomass that yields MSY. A new operational management plan (OMP) that utilises trends in CPUE and tag-recapture data was adopted in 2020 and has been used subsequently to recommend annual TACs.
- **Seaweeds:** Kelp resources are considered stable and healthy and are generally optimally exploited, although some areas offer the opportunity for greater harvesting. Other seaweed resources, with the exception of the gracilarioids, are abundant and generally also offer opportunities for increased harvesting.
- **Sharks**: Almost one third of the 22 chondrichthyan species that are caught in appreciable quantities in South Africa’s marine fisheries are listed as Endangered or Critically Endangered, and mitigation against fisheries threats to these species is a priority action of the recently developed second South African National Plan of Action for sharks (NPOA-Sharks II). Recent assessments indicate that slime-, spearnose-, and biscuit skates and St Joseph are abundant; smoothhound- and blue sharks are at optimal status; yellowspotted- and twineye skates as well as dusky shark are depleted; and soupfin- and shortfin mako sharks are considered heavily depleted. The stock statuses of several skate and some shark species is unknown.
- **Small invertebrates and new fisheries:** The stock status of white mussel, octopus and East Coast round herring remain unknown. Potential new fisheries currently under investigation include octopus and East Coast round herring (in KwaZulu-Natal) and fishing pressure is considered to be light for both.
- **Small pelagic fishes:** Small pelagic fishes are characterised by inherent and high levels of natural variability. Recent genomic results have confirmed the existence of two sardine stocks off South Africa, one associated with the cool-temperate West Coast and the other with the warm-temperate South Coast, that show some degree of gene flow between them. The 2022 pelagic biomass survey indicated some recovery in sardine but the population remains below the long term average and that resource is considered as being between a depleted and an optimal status. Anchovy are considered at optimal status and West Coast round herring are considered abundant.
- **South Coast rock lobster:** Although assessments have suggested recent growth in the South Coast rock lobster resource it is still considered to be in an optimal to depleted state and fishing pressure is being maintained at light to optimal levels. The objective of the OMP for this resource is to increase its spawning biomass in the long term whilst restricting interannual fluctuations in TACs.
- **Squid:** The most recent assessment indicates that the squid resource’s status is at an optimal level, and fishing effort is also optimal.
- **KwaZulu-crustaceans:** Heavy fishing pressure on deep-water crustaceans has reduced the status of these stocks to ‘depleted’. Shallow-water prawns are also considered to be depleted, largely due to the closure of the mouth of the St Lucia Estuary blocking their recruitment to the Thukela Bank.
- **Tunas and swordfish:** Stock assessments and country allocations for tunas and swordfish are the responsibility of the relevant regional fisheries management organisations

(RFMOs). The statuses of swordfish (Atlantic Ocean), and bigeye- (Atlantic Ocean), southern bluefin- (Indian and Atlantic Oceans), and yellowfin tunas (Indian Ocean) remain of concern.

- **West Coast rock lobster:** The West Coast rock lobster resource remains heavily depleted, with the 2022 assessment indicating that the depletion is appreciably more than estimated in previous assessments with the current male >75 mm carapace length biomass now estimated to be 1.4% of pristine levels compared to 1.8% in 2020. Fishing pressure remains heavy and there is continued concern regarding the levels of illegal harvesting of the resource.
- **Small-scale / Subsistence:** Assessments of seven of the most important linefish species targeted along the Eastern Cape coast by the Small-Scale / Subsistence fisheries sector (but not by any other commercial sectors) indicated that three of them (dusky kob, shad / elf and spotted grunter) are heavily depleted, two are depleted (blacktail and zebra), and two are abundant (bronze- and stone bream).



Fishing pressure

	Unknown	Abundant	Optimal	Depleted	Heavily depleted
Heavy	Oysters (S. Cape); Rajidae spp.; Bronze whaler shark	Biscuit skate; Spearnose skate; St Joseph shark; Bronze bream; Stone bream; Bluntnose dogshark	Smoothhound shark; Blue shark; Deep-water KZN crustaceans; Albacore tuna (Ind.); Bigeye tuna (Ind.)	Silver kob; Geelbek; White stumpnose; Zebra; Blacktail	Seventy-four; Dageraad; Red steenbras; Dusky kob; Soupfin shark; Shortfin mako shark; Harders; Yellowfin tuna (Ind.); Abalone; West Coast rock lobster; Spotted grunter; Elf
Optimal	Agulhas sole; Oysters (KZN); White mussel	Shallow-water hake; Snoek	Deep-water hake; Cape horse mackerel; Kingklip; Yellowtail; Santer; Slinger; Carpenter; Roman; Monkfish; Patagonian toothfish; Kelp; South Coast rock lobster; Anchovy; Sardine; Squid; Yellowfin tuna (Atl.); Swordfish (Ind.)	South Coast rock lobster; Sardine; Swordfish (Atl.); Bigeye tuna (Atl.)	Southern bluefin tuna (Ind. and Atl.)
Light	Octopus; East Coast round herring	Hottentot seabream; Slime skate; Non-kelps; *Gelidium*; West Coast round herring; *Ulva* spp.	Albacore tuna (Atl.); South Coast rock lobster	Yellowspotted skate; Twineye skate; Dusky shark; Shallow-water KZN crustaceans; South Coast rock lobster	
Unknown	Black musselcracker; Leg skates; African softnose skate; Roughbelly skate; Munchkin skate; Leopard skate; Lesser guitar-shark; Izak catshark; Rajidae spp.	Spearnose skate; Yellow catshark		Yellowspotted skate; Twineye skate; Dusky shark; Puffadder shyshark	**Moratorium** Seventy-four

Stock status

About the report

The purpose of this report is to make available information related to the status of South Africa's exploited marine fishery resources. The output largely reflects the work of the Fisheries Research and Development Chief Directorate and its partners up to and including 2021.

A quick-overview at the beginning of each section provides an indication of stock status and fishing pressure, colour-coded for ease of reference. The first line indicates the present status of the resource in relation to a reference point or level, most often the status of the resource before it was commercially exploited. The present status is the result of different pressures, such as fishing and environmental fluctuations, and past management practices. The second measure indicates the present level of fishing pressure exerted on that resource. Historical overfishing may have reduced some stocks to depleted or heavily depleted levels and rebuilding these stocks to optimal levels that are ecologically and commercially sustainable requires reduced fishing pressure. Such rebuilding can take several years or even decades as the rate of recovery is dependent on the level of decrease in fishing pressure, the biology of the species and fluctuations in the environment. Additionally, short-lived species (e.g. anchovy and squid) typically show substantial interannual fluctuations in population size; these could lead to the status of that resource being considered depleted in one year to optimal in the next. Five categories are defined for stock status, ranging from 'Abundant' though to 'Heavily depleted', and including an 'Unknown' category for which there are insufficient or conflicting data to enable a status estimate. Fishing pressure is defined within four categories, from 'Light' though 'Optimal' to 'Heavy', and again including an 'Unknown' category for data-poor species.

Each stock assessment method has specific outputs and various methods can be applied depending on the type, and quality, of data available. In general, stock assessment outputs are described relative to two predefined reference points: Target and Limit. Target reference points describe the optimal stock state while Limit reference points define the undesirable low biomass threshold that, if exceeded, would require urgent management intervention. Examples of Target reference points are maximum sustainable yield (MSY), or 40% pre-exploitation (pristine) biomass. Biomass can refer to that part of the population susceptible to capture (exploitable biomass, EB), or a particular part of the population such as mature fish only (spawner biomass, SB), or female fish. Limit reference points are generally formulated as a percentage of pre-exploitation biomass (i.e. biomass < 25% pristine biomass). A comprehensive stock assessment typically requires several streams of data i.e. a time-series of catch, fishing effort and biological information, including sizes of the fish caught. This information is generally only available for industrial fisheries. Stock status for smaller, artisanal fisheries can still be derived from changes in relative abundance or size composition.

The following tables describe the definitions used to categorise stock status in this report:

Stock status

Category	Abundant	Optimal	Depleted	Heavily depleted	Unknown
Definition	$B > B_{Target}$	$B = B_{Target}$	$B < B_{Target}$	$B << B_{Limit}$	$B = ?$

where B is the present biomass level (or population size), B_{Target} is considered the optimal biomass level, and B_{Limit} is the lower biomass level threshold.

Fishing pressure

Category	Light	Optimal	Heavy	Unknown
Definition	$F < F_{Target}$	$F = F_{Target}$	$F > F_{Target}$	$F = ?$

where F is the present fishing pressure and F_{Target} is that fishing pressure level at which the optimal biomass level is obtained.

For some, but not all, multiple-species fisheries, both the status and pressure measures are given per species. In some cases the stock status and/or fishing pressure may vary around South Africa's coastline and / or in different sectors, which is indicated using multiple categories. Furthermore, available information may not unambiguously indicate the appropriate category for a resource, and this is also indicated by using multiple categories.

Abalone

Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
Fishing pressure	Unknown	Light	Optimal	Heavy	

Introduction

Abalone *Haliotis midae*, locally called 'perlemoen', is a large marine snail that is a highly prized seafood delicacy. Abalone are slow growing, reaching sexual maturity at around seven years of age, and take approximately 8–9 years to reach the minimum legal size of 11.4 cm shell breadth (SB). They reach a maximum size of 18 cm SB and are believed to live to an age of greater than 30 years. They occur in shallow waters of less than 20 m depth, but the highest densities occur in waters of less than 5 m depth.

Abalone are widely distributed around the South African coastline, from St Helena Bay on the West Coast to just north of Port St Johns on the East Coast. Historically, the resource was most abundant in the region between Cape Columbine and Quoin Point and supported a commercial fishery for about 65 years. Along the East Coast, the resource was considered to be discontinuous and sparsely distributed and as a result no commercial fishery for abalone was implemented there. However, experimental and subsistence permits were allocated along the East Coast at various times in the past. The recreational sector also caught abalone for many years, but due to illegal fishing and the decline in the resource, this component of the fishery was suspended in 2003/2004.

Once a lucrative commercial fishery, earning up to approximately R100 million annually at the turn of the Century, rampant illegal harvesting and continued declines in the abundance of the resource resulted in a total closure of the

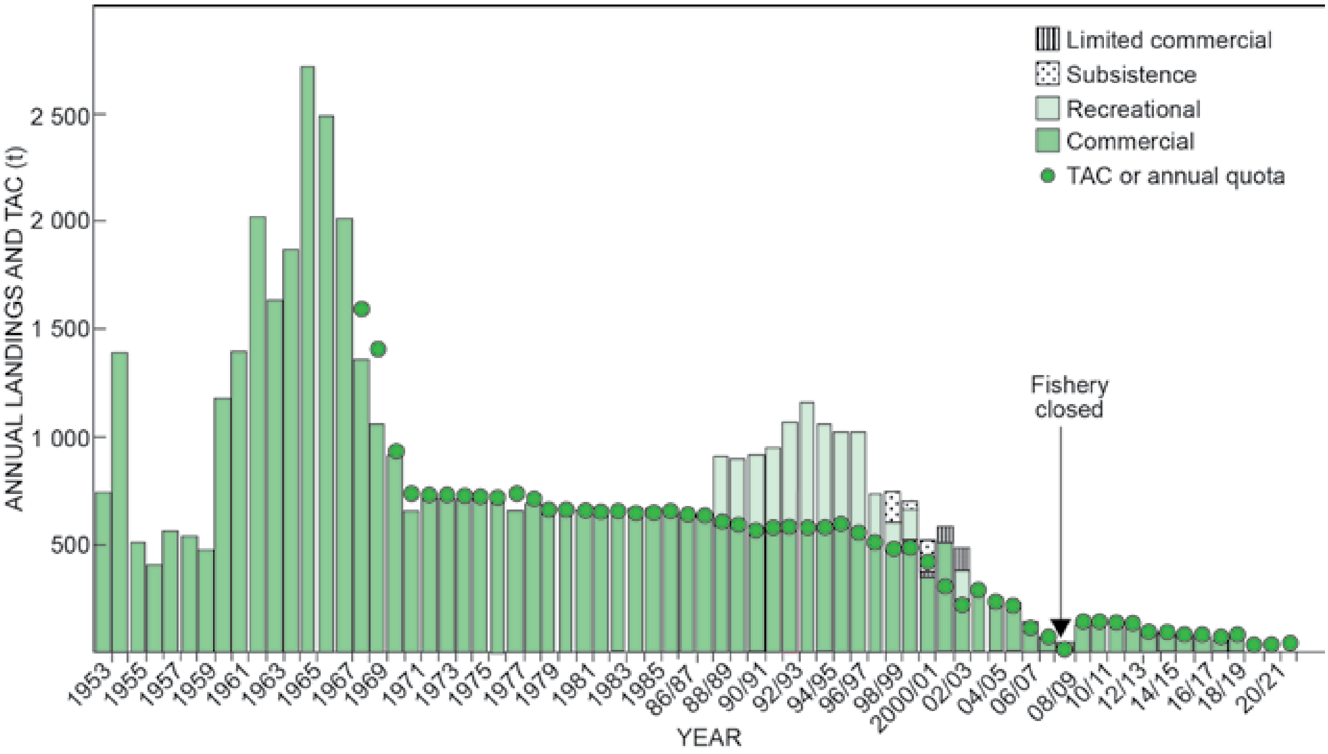


Figure 1: TAC and recorded (legal) annual landings for the abalone fishery from 1953 to 2021/22. Landings for the recreational sector are only available since 1988/1989. Note that the substantial illegal catches are not shown

Figure 2: Abalone fishing Zones A to G, including sub-zones, and distribution of abalone, *H. midae* (inset). The experimental fisheries (2010/11–2013/14) on the western and eastern sides of False Bay and in the Eastern Cape are also shown. These areas within False Bay, included in the commercial fishery recommendations for 2017/18, are referred to as Sub-zone E3 and Sub-zone D3 The yellow marked areas indicate Experimental areas

fishery in February 2008. The resource has also been heavily impacted by an ecosystem shift that was brought about by the migration of West Coast rock lobster into two of the main, most productive, abalone fishing areas. The commercial abalone fishery subsequently reopened in July 2010.

History and management

The commercial (diver) fishery for abalone started in the late-1940s. During the early phase, the fishery was dominated by five large abalone processing plants. Initially, catches were unregulated, and reached a peak of close to 3 000 t in 1965 (Figure 1). By 1970 catches had declined rapidly, although the fishery remained stable with a total annual catch of around 600–700 t until the mid-1990s, after which there were continuous declines in commercial catches.

The early-1990s saw the booming of the recreational fishery, and a significant increase in illegal fishing activities. Continued high levels of illegal fishing and declines in the resource led to closure of the recreational fishery in 2003/2004. Transformation of the fishery in post-apartheid years sought to increase participation in the fishery, particularly by people who had been previously marginalised. Subsistence Rights were introduced in 1998/1999 and were replaced by two-year medium-term Rights. In 2003/2004, 10-year long-term Rights were allocated, broadening participation in the fishery to some 300 Right Holders. At this time, the previous management zones were replaced with Territorial Use Rights in Fisheries (TURFs), aimed at developing a sense of ownership of the resource by the new Right Holders and, in so doing, introducing co-management of the resource and improving compliance with regards to illegal fishing activities.

Illegal fishing, however, remained high despite the introduction of TURFs and increased compliance effort, including strengthening of the compliance fleet, introduction of stricter penalties for offenders, and controls on international trade.

Although illegal fishing of abalone occurs in all areas, its concentration has shifted from one area to another over the years in response to resource abundance and law enforcement presence. Illegal fishing is not selective with regards to the size

Table 1: The availability of data for TAC assessments since 2017. Y indicates data were available, N indicates data were not available. FIAS = fishery-independent ablone survey

Data inputs		Zones A-D	Zones E-G	Aggregated
FIAS	Abundance	N	N	
	Size composition	N	N	
Commercial	CPUE	Nominal only	Nominal only	
	Size composition	N	N	
Poaching	Compliance	N	N	
	TRAFFIC			Y

of abalone taken, and around two-thirds of confiscated abalone are below the minimum legal size of 11.4 cm SB.

Therefore, most of the illegally caught abalone are taken before having had the opportunity to reproduce.

The continued high levels of illegal fishing and declines in the resource led to the introduction of diving prohibitions in selected areas and the closure of the commercial fishery in February 2008. The fishery was subsequently reopened in July 2010, conditional on a 15% per annum reduction in poaching. The required reduction in illegal harvesting has, however, not been achieved. The management objectives for the sustainable utilisation and recovery of the abalone resource have been to prevent the abalone spawning biomass in each zone from dropping below 20% of its estimated pre-fished biomass (a "limit reference point"), and to see it recover to 40% of that level (a "target reference point") within 15 years of the re-opening of the commercial fishery in 2009/10, i.e. by the 2024/25 season. The 20% and 40% values are in line with international norms, and the 40% target reference point approximates the level at which the greatest catches can be sustained. In order to achieve this, illegal harvesting (poaching) must be substantially reduced.

Research and monitoring

The data inputs usually used in the assessment of the abalone resource are derived from the commercial fishery catch-per-unit-effort (CPUE and size composition), from fishery independent abalone surveys (FIAS; abundance and size composition), and from poaching information (numbers and size composition of poached abalone confiscated by Compliance officers). International trade data on imports of *Haliotus midae* by key importing countries provided by WWF's wildlife trade monitoring network, TRAFFIC, (a non-governmental conservation organization) also inform on the trends in illegal harvesting of this species.

A summary of the data available since 2017 is presented in Table 1. Due to capacity and administrative issues no FIAS were completed since 2020 and FIAS abundance and size composition information was therefore not available for the TAC assessments. In 2017, an allocation of 3 t was recommended for the newly established Sub-zone D3, however; this allocation was only accepted in 2018 and implemented in 2019. In addition, while nominal commercial CPUE data for Zones A to D and E to G (Figure 2) were recorded, the CPUE standardisations could not be performed, nor was the corresponding size composition information able to be determined. Prior to 2018, trends in illegal catch were assessed using DFFE Compliance data on confiscations and inspections ('policing') effort and international trade data on imports of *Haliotis midae* into key importing countries provided by TRAFFIC. While the aggregated poaching information (TRAFFIC) is available from 2018, the Compliance data on confiscations and policing effort are not.

Resource assessment

In 2016 the main historic fishing areas, namely Zones A, B, C and D (Figure 2), were assessed by means of a spatially explicit annual surplus production model (ASPM), which was fitted to commercial CPUE and FIAS data as abundance indices, as well as to catch-at-age information inferred from catch-at-length data. The model also estimated the reduction in recruitment of juvenile abalone in Zones C and D due to ecosystem changes and illegal catches.

An updated model-based assessment was not undertaken in 2017 due to administrative issues.

In 2016 an assessment of the fishery was made. In 2017, together with data on trends in illegal catch (poaching), FIAS and commercial CPUE that had become available since as well as the 2016 assessment, were used to determine if any change to the TAC recommendation was required. Since the full 2016 assessment, due to administrative issues, no new assessments were done. Therefore, for the 2021/2022 TAC recommendation, there was no justification in moving away from the projections made in 2016

Current status

Trends in illegal catch (poaching)

The analysis of international trade data indicates a significant increase in levels of illegal catch (Figure 3) in 2018 (47% increase from 2017 levels). However, over the last three years of the reporting period (2019-2021) this number has decreased again to between 8 and 10 million animals poached.

Commercial catch-per-unit-effort (CPUE)

Zones A and B (Figure 4)

There was a 0 TAC for Zones A and B for the 2019/20 season until 2021/22. An inspection of the nominal CPUE data shows no marked changes in the CPUE in Zone A from 2009/10 to 2017/18 but a sharp reduction in 2018/19 that was also seen in Zone B. The apparent slight increase in the nominal CPUE in Zone B between 2015/16 and 2017/18 must be weighed against the consideration that these are nominal and not standardised CPUE data, and concerns have been raised about the accuracy of CPUE data-reporting in Zones A and B in recent

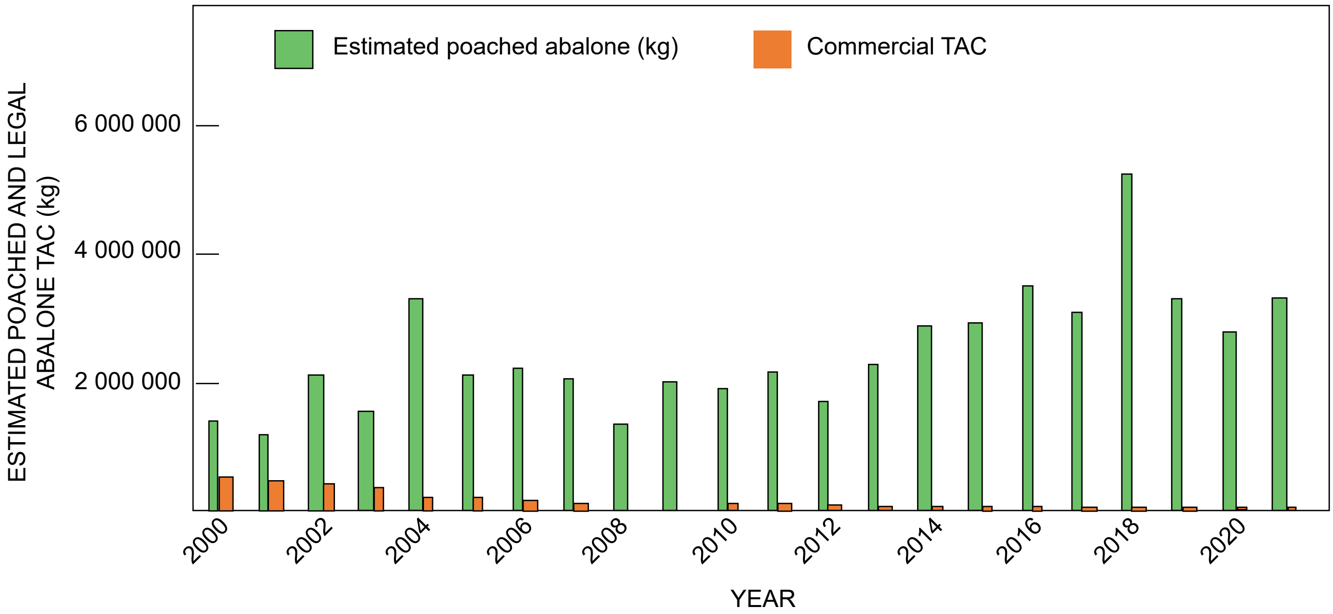


Figure 3: Estimated weight of poached abalone based on international trade data for the calendar years 2000–2019 (adapted from: Burgener (2019). An estimation of the international trade in illegally harvested *Haliotis midae*, 2000–2019. FISHERIES/2019/AUG/SWG- AB/05), and recorded legal abalone catch (weight) for the calendar years 2000–2021

years. One of these is that abalone commercial fishing vessels have been observed around the Dyer Island closed area, so that the recent CPUE values for Zones A and B may have been artificially inflated by catches off Dyer Island.

Zones C-D

Spawning biomass projections in 2016 showed continuing declines in resource abundance in Zones C and D at recent estimated levels of illegal take. The resource has been severely reduced by the lobster-urchin effect on recruitment of abalone (see below), in addition to the effects of illegal fishing. Populations in these two Zones were also estimated to be below the 20% limit reference point set out in the management objectives. No new data have become available to suggest a change in the previously estimated status of the resource in these Zones.

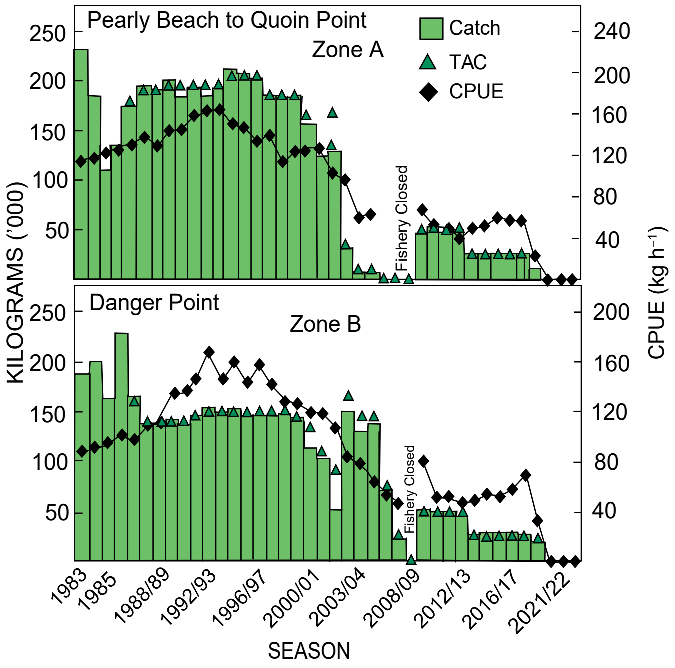


Figure 4: Catch and nominal (unstandardised) CPUE, with annual TACs indicated for Zones A and B for the period 1983–2021/22. There was a 0 TAC for Zones A and B for the 2019/20 season until 2021/22. Note that the fishery was closed during the 2008/09 season

Zones E to G (Figure 5)

There were no marked changes in the nominal CPUE data for Zones F and G. A sharp decline in CPUE was, however, noted in Zone E.

Ecosystem interactions

Since the early 1990s, ecological changes have severely disrupted normal abalone recruitment patterns in two of the major fishing zones, i.e. Zones C and D. These involved the large-scale incursion of West Coast rock lobsters into Zones C and D. The lobsters have now altered the ecosystem by consuming large numbers of sea urchins as well as other invertebrate species, including juvenile abalone. Sea urchins perform the important function of providing protection for juvenile abalone. A recent study found that, in Zone D, there have been substantial increases in rock lobsters, seaweeds and sessile species and a substantial decline in grazers (of which abalone are a component). The current ecosystem state in Zone C is similar to that in Zone D.

The ecosystem state in Zones A and B is currently different to Zones C and D, with very few lobsters present, a lower biomass of seaweeds and sessile species, more encrusting corallines, and urchins and grazers still present in relatively high abundance.

The combined effect of poaching and ecological changes has resulted in severe declines in the abalone resource in Zones C and D. The Betty's Bay Marine Protected Area (MPA), situated within Zone D, was also affected, which has meant the loss of the main conservation area for abalone. As a result, Dyer Island has been closed to commercial fishing since the

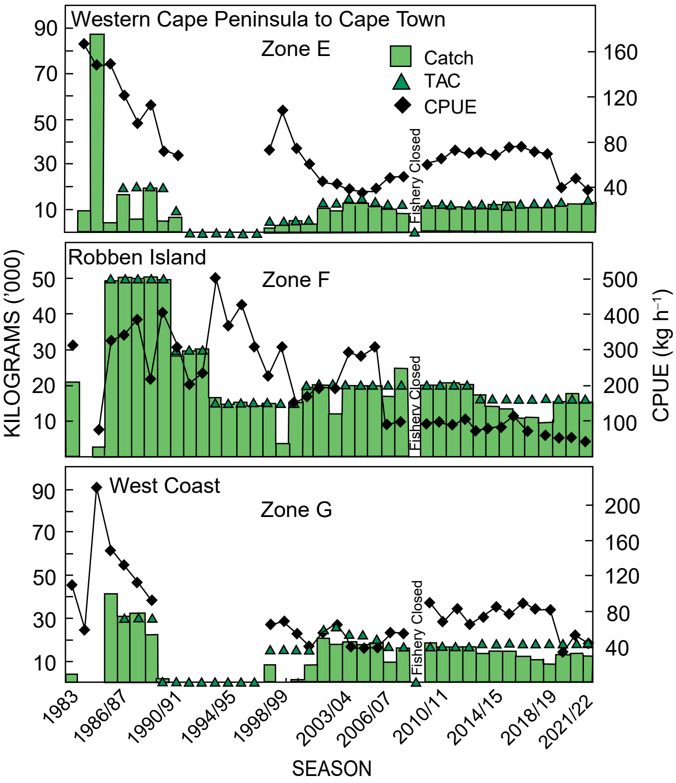


Figure 5: Catch and nominal (unstandardised) CPUE, with annual TACs indicated for Zones E, F and G for the period 1983 to 2021/22. Note that the fishery was closed for the 2008/09 season

2003/2004 season to function as a refuge area for abalone. FIAS surveys undertaken at Betty's Bay MPA in 2012 indicated that the mean density of abalone dropped to 1% of the level recorded in the 1990s. This confirms that Betty's Bay no longer functions as a closed area (reserve) for abalone, indicating that Dyer Island should continue as a closed area.

Climate change implications

Calcifying organisms such as abalone are particularly susceptible to changes in seawater carbonate chemistry that will occur from ocean acidification, and abalone will likely also be negatively impacted by ocean warming. Experimental work conducted at an abalone farm near Hermanus has demonstrated that South African abalone held for 12 months under ocean acidification (a decrease in pH of 0.4 from ambient) and warming (an increase of 1.5 °C from ambient) conditions showed decreased haemolymph (the invertebrate equivalent of blood) pH and increased haemolymph pCO_2 levels that resulted in reduced growth and condition factor, much-reduced shell strength, and an alteration in spawning patterns. These results are cause for serious concern for wild abalone targeted by the fishery, but also for the rapidly growing South African abalone farming industry, which presently accounts for >75% of the country's aquaculture revenue.

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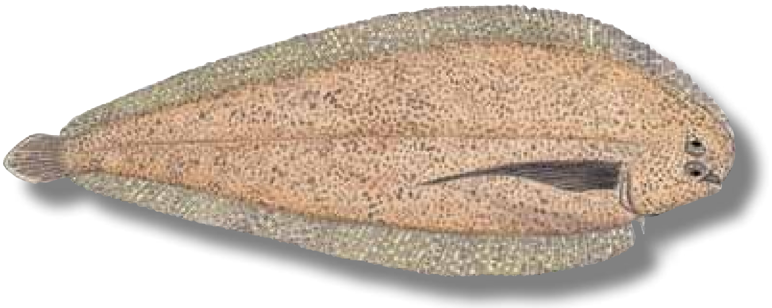
Useful statistics

Total allowable catches (TACs) and catches for the abalone fishery.

Season	TAC (t)	Total commercial catch (t)	Total recreational catch (t)
1993/94	615	613	549
1994/95	615	616	446
1995/96	615	614	423
1996/97	550	537	429
1997/98	523	523	221
1998/99	515	482	127
1999/00	500	490	174
2000/01	433	368	95
2001/02	314	403	110
2002/03	226	296	102
2003/04	282	258	0
2004/05	237	204	0
2005/06	223	212	0
2006/07	125	110	0
2007/08	75	74	0
2008/09	0	0	0
2009/10	150	150	0
2010/11	150	152	0
2011/12	150	145	0
2012/13	150	*	0
2013/14	96	95	0
2014/15	96	95	0
2015/16	96	98	0
2016/17	96	89	0
2017/18	96	87	0
2018/19	96	53	0
2019/20	50.5	50.5	0
2020/21	50.5	50.5	0
2021/22	50.5	50.5	0

Agulhas sole



Stock status	**Unknown**	**Abundant**	**Optimal**	**Depleted**	**Heavily depleted**
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	

Introduction

Agulhas or East Coast sole *Austroglossus pectoralis* belong to a group of fish referred to as flatfish because they have adapted to lying on their side on the seabed by evolving a laterally compressed body shape with both eyes migrating to the upper side of the head during larval development. Well-developed fins encircle the body. They are bottom-dwelling, preferring sand or silt substrates, and feed on small crustaceans, molluscs, worms and brittle stars. They occur mainly in the area between Cape Agulhas and Port Alfred (Figure 6) between depths of 10 to 120 m, although they have occasionally also been caught in deeper water during research surveys. The average size landed by commercial vessels is between 32.0 cm and 33.6 cm.

The Agulhas sole resource is a small but commercially important component of the mixed-species inshore trawl fish-

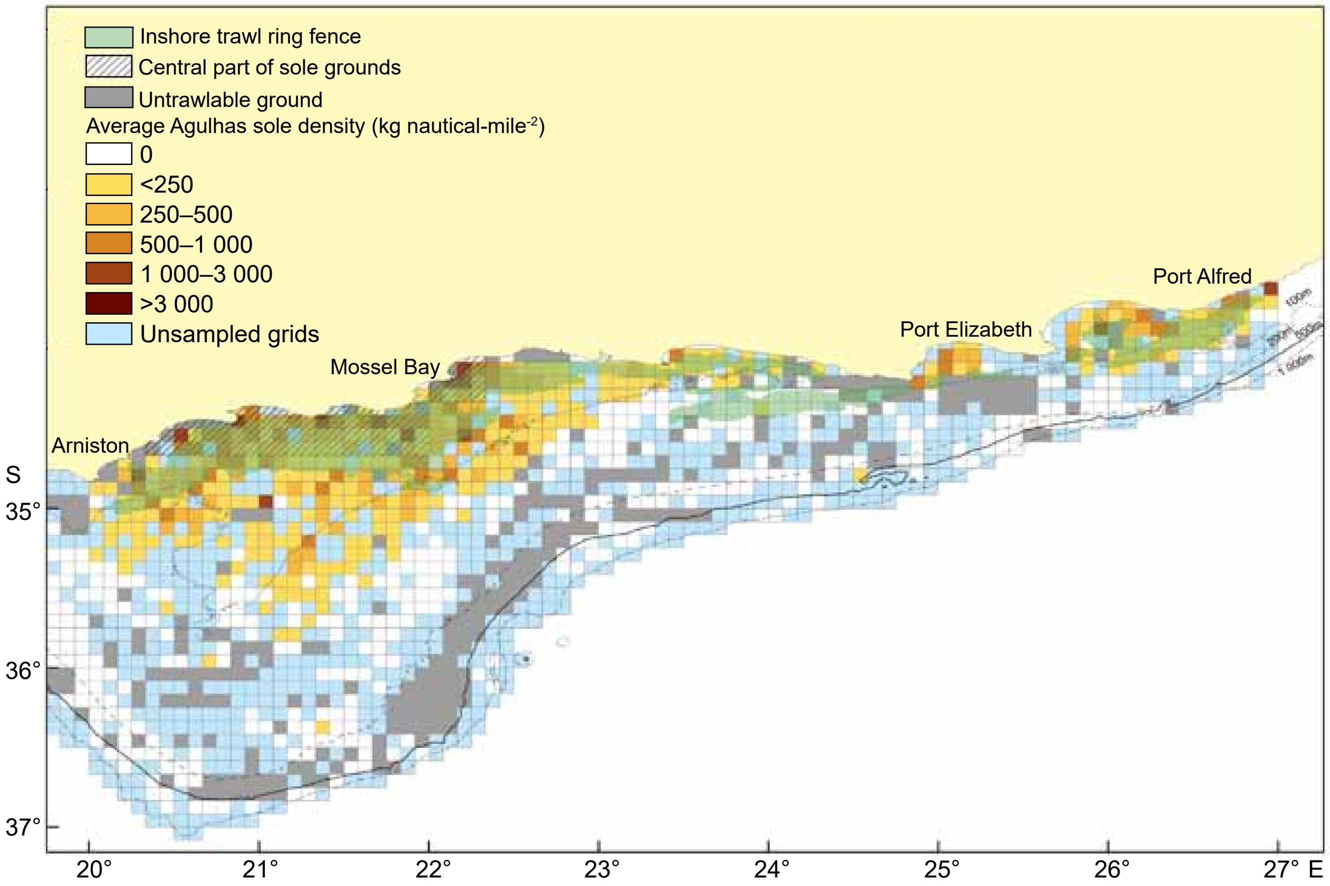


Figure 6: Distribution of Agulhas sole *Austroglossus pectoralis* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block. The area considered to be the central part of the sole grounds is indicated

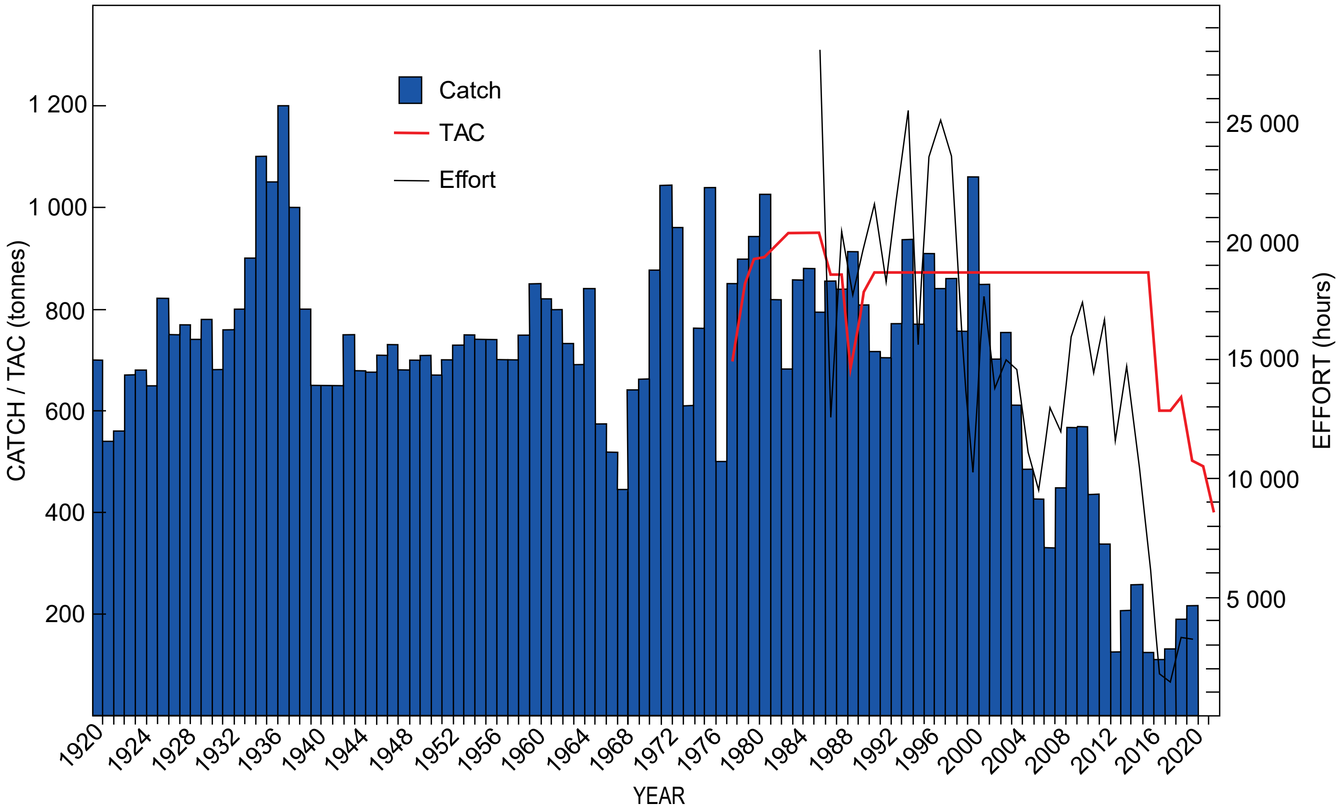


Figure 7: Annual catches (landings), TACs (both in tonnes) and an estimate of annual total sole-directed fishing effort on the Agulhas sole grounds (hours) in the Agulhas sole fishery 1920–2020

ery on the South Coast. The inshore trawl fleet comprised 14 active vessels in 2020, of which four primarily target the sole resource but also rely on hake bycatch, while the remainder of the fleet targets primarily hake. The 2022 annual total allowable catch (TAC) of 400 t is estimated to be worth approximately R22 million.

History and management

The Agulhas sole resource has been exploited since the 1890s, and was one of the first fish stocks to be managed in South Africa. Exploitation of Agulhas sole was the economic base for the early fishery on the Cape South Coast and was the driving force for the development of the coastal fishing fleet. In the early years fishing was directed largely at Agulhas sole, but the fishery gradually shifted to targeting a number of additional species, including hake and various linefish species, by the late 1970s. The first formal attempt at managing the Agulhas sole fishery was made in 1935, with the introduction of a 75 mm minimum mesh size for bottom trawl nets. The inshore trawl fishery was formally defined as a management unit (i.e. the Hake and Sole Inshore Trawl sector) separate from the Hake Deepsea Trawl sector in 1978. An annual TAC of 700 t was first introduced in 1978, and individual quotas were introduced in 1982. The TAC remained fairly stable thereafter, varying between 700 t and 950 t between 1982 and 1992, and was subsequently maintained at 872 t until 2016 (Figure 7). Management of the fishery has, since 1978, restricted its operations to the South Coast between the 20° E line of longitude and the line drawn due south from the mouth of the Great Kei River, and since the start of 2015, to the area defined as the “Hake Trawl Ring Fence” (see the section on Cape hakes).

Landings of Agulhas sole have declined substantially subsequent to 2000, with a slight increase in 2008–2010, but still well below the TAC (Figure 7). At that time, the decline was attributed mainly to a reduction in the overall effort deployed by the fishery (Figure 7), rather than a decline in the abundance of the resource. The effort reduction was primarily the result of an appreciable decrease in the number of active inshore vessels in the fishery over time (50 in 1979, decreasing to 32 in 2000, and 14 in 2015). The reasons for this are complex, but can be largely attributable to companies not replacing old/damaged vessels due to the limited availability (and substantial costs) of suitable replacement vessels, compounded by uncertainty regarding future long-term Rights allocations. Market/economic forces also resulted in changes in fishing strategies, with some Right Holders moving either all or part of their hake quotas to the hake deepsea trawl sector (with a consequent reduction in sole catch), or directing limited resources (vessels and sea days, and hence effort) to filling hake quotas rather than attempting to fill sole quotas.

In spite of this marked reduction in fishing effort, an appreciable decline in the commercial catch-per-unit-effort (CPUE, the index that has been used to monitor Agulhas sole abundance) became apparent subsequent to 2009, with CPUE reaching unusually low levels over the period 2012 to 2016 (Figure 8)). While this decline could reflect a decrease in resource abundance, the possibility that it could rather reflect a decline in catchability (i.e. in the availability of sole to the fishery) could not be discounted. Confronted with this uncertainty regarding

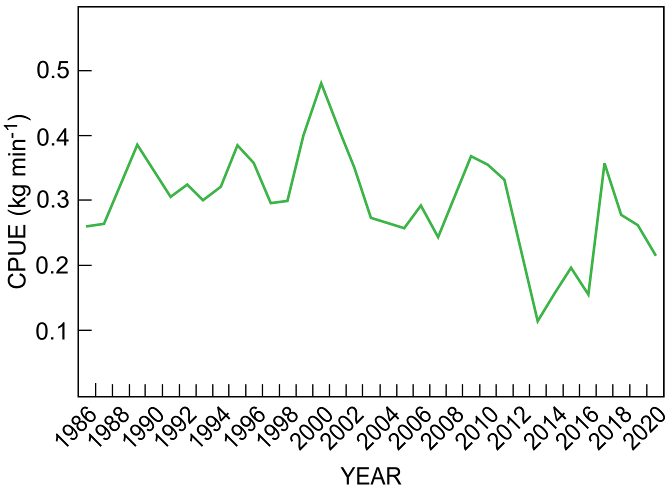


Figure 8: The commercial catch per unit effort (CPUE) index of abundance for Agulhas sole. A nominal index (kg min^{-1}) is calculated from cumulative annual catch and effort data for the period 1986–2020

resource dynamics, a series of assessments using a dynamic Schaefer production model approach that incorporated these two hypotheses were developed in 2014 and used to project forwards in time under various management strategies. Following an evaluation of the results of these analyses, a spatial effort limitation strategy was adopted in 2015 as the primary regulatory measure, while maintaining the TAC at 872 t. This "trade-off" approach was intended to limit fishing mortality (thereby providing scope for resource recovery in the event that the reduced abundance hypothesis was correct), but also to allow scope for an increase in catches if the decline reflected the catchability hypothesis and catch rates returned to "normal" in the short- to medium-term. Considering that about 95% of the total annual catch of Agulhas sole is typically taken from the central part of the sole grounds (see Figure 6), the effort restriction was applied to sole-directed fishing operations within this area only.

This management approach was maintained for the 2016 fishing season. Following an updated assessment during 2016, the TAC was reduced to 600 t for the 2017 fishing season, and the TAE set at 15 243 fishing hours (the change in units was implemented for operational reasons). These limits were retained for the 2018 fishing season following an assessment update during 2017. The assessment conducted in 2018 indicated a slightly more optimistic status of the resource, and the effort limit imposed on the fishery in 2019 was consequently adjusted upwards by 10% to 16 767 fishing hours, with an associated slight increase in the TAC to 627 tonnes.

The assessment conducted during 2019 was confronted with circumstances where the standardised commercial CPUE index of abundance had increased from the 2012–2016 "low" period to levels in 2017 and 2018 that were more comparable to those observed prior to 2010. As a result, the 2019 assessment differed from those conducted in the immediately previous years in several respects:

- Fishery-independent demersal survey estimates of abundance encompassing the period 1986 to 2019 were included in the model fitting.
- A relatively crude nominal CPUE index encompassing the period 1986 to 2018 was used, rather than the standardised CPUE index (which could be computed for the period 2000 to 2018 only because the drag-level data prior to 2000 that are required for this purpose are unavailable).
- In view of the extent of increase in the CPUE that had been observed after the 2012 to 2016 "low" period, it was agreed that the decrease in abundance hypothesis was no longer defensible (as it is very unlikely that abundance could have almost doubled in such a short period). The 2019 assessment consequently considered only the reduction in catchability hypothesis to account for the 2012–2016 low CPUE.
- An observation of some concern, however, was that despite the marked decline in effort (and hence catches) that had been apparent in the fishery since the turn of the century (Figure 7), the resource did not appear to have responded with a corresponding increase in abundance. The 2019 assessment therefore allowed for the possibility of a period of reduced resource productivity from 2000 onwards.

The results of the assessment suggested that while the resource was estimated to be above MSY level, given the uninformative nature of the data, coupled with only two years of higher CPUE values, a precautionary approach would be appropriate. The scientific advice for the 2020 fishing season was consequently to reduce the TAC to 502 tonnes and retain the effort limitation strategy imposed on the sole-directed component of the fishery. The same analytical approach was adopted during 2020, the results of which suggested a slightly lower post-2000 resource productivity than had been estimated previously, leading to a recommendation for a slightly reduced TAC (to 491 tonnes) and retention of the effort limitation strategy.

Research and monitoring

Fishery-independent estimates of Agulhas sole abundance (Figure 9) are derived from demersal research surveys conducted on the South Coast using the swept-area method (see section on Cape hakes). These surveys are designed to estimate the abundance of hakes, although other demersal species (including Agulhas sole) are included in the data collection. The area encompassed by these surveys generally extends to the 500 m isobath (and to the 1 000 m isobath since 2011), with only a few sampling locations falling within the area of Agulhas sole distribution. Consequently, the sole population is not comprehensively sampled and the resulting sole abundance indices should therefore be interpreted with caution. While four intensive Agulhas sole-directed surveys have been conducted (2006–2008) to improve temporal and spatial coverage of the population, budgetary constraints have precluded continuing these surveys, limiting the usefulness of the data that were collected.

Fishery-dependent data (landings, size-composition of the catch, drag-level catch and effort data) are routinely collected.

Current status

The assessment conducted in 2021 incorporated catch and CPUE dataseries extending to the end of 2020 and autumn South Coast demersal survey data extending to 2021. The

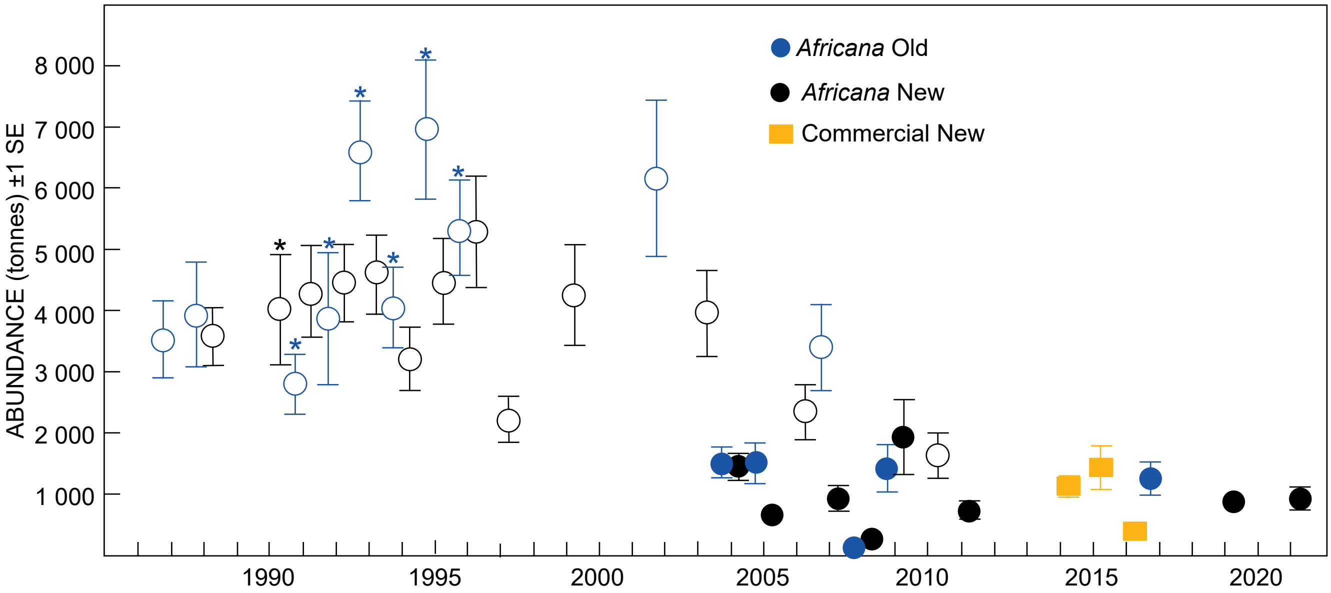


Figure 9: Agulhas sole abundance estimates (tonnes) derived from fishery-independent swept area demersal surveys. Estimates are illustrated for the various vessel-gear combinations. Autumn South Coast surveys are indicated with black symbols, while spring South Coast surveys are indicated with blue symbols. Surveys that only extended to the 200 m isobath have been included in the figure (indicated with an asterisk) because Agulhas sole are largely distributed at depths that are shallower than 200 m. Note that estimates across the vessel-gear combinations cannot be directly compared due to differences in catchability. *Africana* = research vessel RS *Africana*, 'Commercial' = commercial fishing vessel

analysis used the same approach as those conducted in 2019 and 2020, where a suite of models that considered various levels of pre- and post-2000 intrinsic population growth rates were run with the extent of the catchability reduction over the period 2012–2016 being estimated by the models. The best fits to the data were obtained using models where the post-2000 intrinsic population growth rate was somewhat lower than in the 2020 assessment, resulting in the "best" estimates of replacement yield (RY) and maximum sustainable yield (MSY) being lower than those determined in the 2020 assessment. In view of the relatively uninformative nature of the data (manifested in small differences in the "goodness of fit" between the various models) and the continued uncertainty regarding resource dynamics (especially the apparent regime shift to lower productivity across the turn of the century), the TAC for the 2022 season was reduced to 400 tonnes. It was also noted that three successive years of data updates provided little or no support for the increased mortality hypothesis. There was consequently no justification for retaining the effort limitation strategy imposed on sole-directed fishing on the sole grounds to account for the possibility that this hypothesis was correct.

Ecosystem interactions

Measures aimed at reducing the ecosystem impacts of the hake-directed demersal trawl fisheries are contained in Sections B and C of the current permit conditions (see section on Cape hakes), and these measures are also applied to the Agulhas sole-directed component of the hake inshore trawl fishery.

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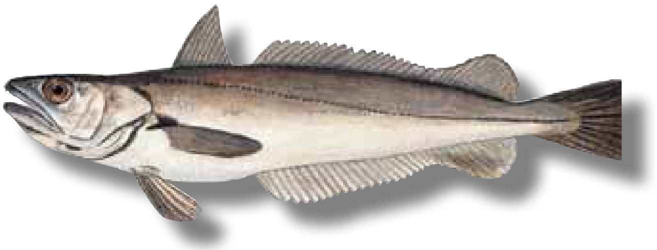
Useful statistics

Total catch (tonnes) of Agulhas sole per calendar year and the annual TACs (tonnes) for the period 1920–2022.

Year	Catch	TAC
1920	700	
1921	540	
1922	560	
1923	670	
1924	680	
1925	650	
1926	820	
1927	750	
1928	770	
1929	740	
1930	780	
1931	680	
1932	760	
1933	800	
1934	900	
1935	1 100	
1936	1 050	
1937	1 200	
1938	1 000	
1939	800	
1940	650	
1941	650	
1942	650	
1943	750	
1944	680	
1945	675	
1946	710	
1947	730	
1948	680	
1949	700	
1950	710	
1951	670	
1952	700	
1953	730	
1954	750	
1955	740	
1956	740	
1957	700	
1958	700	
1959	750	
1960	850	
1961	820	
1962	800	
1963	732	
1964	690	
1965	841	
1966	575	
1967	520	
1968	445	
1969	642	
1970	663	
1972	1 044	
1973	961	
1974	611	
1975	763	
1976	1 040	
1977	500	
1978	850	700
1979	899	850
1980	943	900
1981	1 026	900
1982	817	930
1983	682	950
1984	857	950
1985	880	950
1986	796	950
1987	855	868
1988	839	868
1989	913	686
1990	808	834
1991	716	872
1992	704	872
1993	772	872
1994	938	872
1995	769	872
1996	909	872
1997	840	872
1998	859	872
1999	757	872
2000	1 060	872
2001	850	872
2002	702	872
2003	754	872
2004	612	872
2005	485	872
2006	428	872
2007	331	872
2008	448	872
2009	568	872
2010	570	872
2011	442	872
2012	338	872
2013	127	872
2014	208	872
2015	258	872
2016	125	872
2017	113	600
2018	132	600
2019	190	627
2020	218	502
2021	143	491
2022		400

Cape hakes



Stock status	**Unknown**	**Abundant** Shallow-water hake	**Optimal** Deep-water hake	**Depleted**	**Heavily depleted**
Fishing pressure	**Unknown**	**Light**	**Optimal** Shallow-water hake Deep-water hake	**Heavy**	

Introduction

The South African hake resource comprises two species: shallow-water Cape hake *Merluccius capensis* and deep-water Cape hake *M. paradoxus*. The Cape hakes are distributed on the continental shelf and upper slope around the coast of southern Africa. *Merluccius paradoxus* are distributed from northern Namibia to southern Mozambique, whereas *M. capensis* are distributed from southern Angola to northern KwaZulu-Natal. As the names suggest, the distributions of the two hake species differ with depth, although there is a substantial overlap in their depth ranges. *Merluccius capensis* are distributed over a depth range of 30 to 500 m with most of the population occurring between 100 and 300 m (Figure 10a). In contrast, *M. paradoxus* are distributed over a depth range of 110 m to deeper than 1 000 m with most of the population occurring in depths of between 200 and 800 m (Figure 10b). The sizes of both species increase with depth and large *M. capensis* consequently co-exist with and feed extensively on smaller *M. paradoxus*. It is difficult to distinguish between the two hake species, so they are generally processed and marketed as a single commodity.

Cape hakes are targeted by four fishery sectors: hake deep-sea trawl, hake inshore trawl, hake longline and hake handline. The deep-sea trawl sector lands the most hake of the four sectors (Figure 10b). Approximately 80% of the total annual hake catch in the last decade has been *M. paradoxus*. Hakes are also caught as incidental bycatch in the horse-mackerel-directed midwater trawl and demersal shark longline fisheries, and to a lesser extent in the linefish sector. The inshore trawl and hake handline sectors operate only on the South Coast, whereas the deep-sea trawl and longline fleets operate on both the West and South coasts. On the West Coast, the continental shelf is fairly narrow so most trawling is in deep water on the shelf edge and upper slope, and as much as 90% of the hake caught are *M. paradoxus*. In contrast, most trawling on the South Coast is on the wide continental shelf, the Agulhas Bank, and as much as 70% of hake catches on this coast are *M. capensis*. The hake fishery is the most valuable of South Africa's marine fisheries, providing the basis for some 30 000 jobs and an annual landed value in excess of R5.2 billion.

History and management

The demersal fishery off southern Africa started with the arrival of the purpose-built research vessel, *Pieter Faure*, in 1897 and the first commercial trawler, *Undine*, in 1899 off the Cape. In the early years of the fishery, Agulhas and West Coast sole (*Austroglossus pectoralis* and *A. microlepis,* respectively) were the primary target species, with hake being caught as an incidental bycatch. Directed fishing of Cape hakes began towards the end of the First World War, with catches averaging about 1 000 t per annum until 1931. The fishery then began escalating during and after World War II, with catches increasing steadily to around 170 000 t by the early 1960s. The incursion of foreign fleets in 1962 led to a dramatic increase in fishing effort and catches in South African waters eventually peaked in 1972 at over 295 000 t (Figure 11a). By this time, effort had extended farther offshore and also into Namibian waters, with over 1.1 million t being caught in the Southeast Atlantic in 1972.

In 1972, following concerns over the combination of increasing catches and decreasing catch rates, the International Commission for the South-East Atlantic Fisheries (ICSEAF) was established in an attempt to control what had become an international fishery. Various management measures such as a minimum mesh size, international inspections and quota allocations to member countries were implemented through ICSEAF. However, catch rates continued to decline, and in November 1977 the declaration of a 200 nautical mile Exclusive Fishing Zone (EFZ) by South Africa marked the onset of direct management of the South African hake resource by the South African government. Apart from a few vessels operating under bilateral agreements and being subject to South African regulations, foreign vessels were excluded from South African waters.

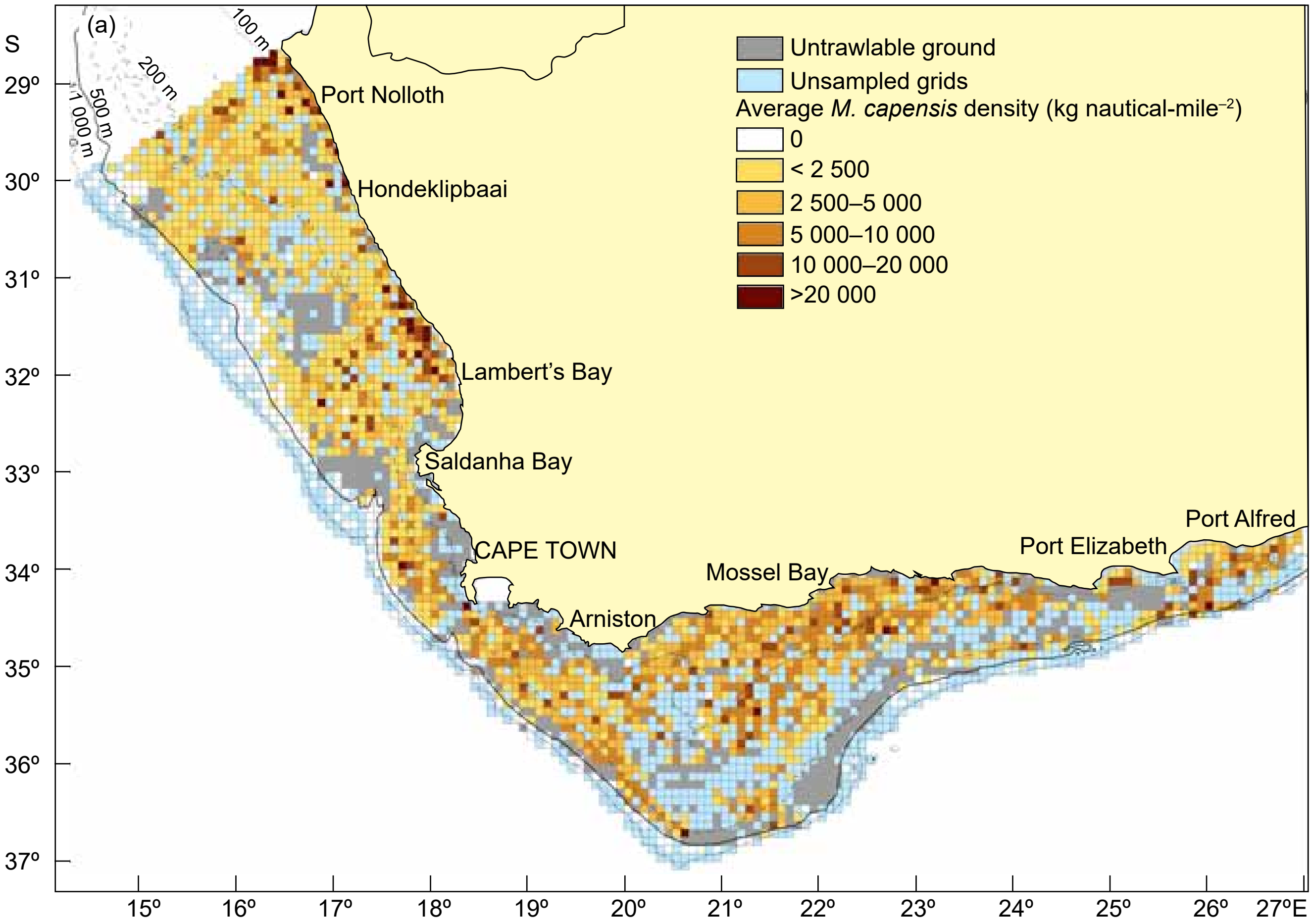


Figure 10 (a): Distribution of shallow-water hake *Merluccius capensis* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

After the declaration of the EFZ, South Africa implemented a relatively conservative management strategy to rebuild the hake stocks to B_{MSY}, the biomass level that would provide the maximum sustainable yield (MSY). Total allowable catch (TAC) restrictions were imposed on the fishery, aimed at keeping catches below levels deemed necessary for stock rebuilding. The TACs were recommended on the basis of assessments of the resource using first steady-state models, then dynamic production models, and finally age-structured production models. An operational management procedure (OMP) approach was adopted in 1990 to provide a comprehensive basis for management of the hake resources. The hake OMP is essentially a set of rules that specifies exactly how the TAC is calculated using stock-specific monitoring data (both commercial and fishery-independent indices of abundance). Implicit in the OMP approach is a 4-year schedule of OMP revisions to account for possible revised datasets and improved understanding of resource and fishery dynamics. Assessments are routinely updated every year to check that resource indicators remain within the bounds considered likely at the time that the OMP was adopted.

As a result of the substantial overlap in distribution and the difficulty of distinguishing between the two hake species, species-specific catch and effort data are not available from the commercial fishery, and the two species were initially assessed and managed as a single resource. However, the development of the longline fishery during the 1990s led to shifts in the relative exploitation rates of the two species, rendering species-combined assessments of the resource inappropriate. Algorithms to apportion the commercial hake catch between the two species were developed using research survey data, enabling the development of species-disaggregated assessment models. The first such algorithm was developed during 2005 and was used in the development of the revised OMP implemented in 2006. Subsequent revisions of the species-splitting algorithms using updated datasets have coincided with the routine OMP revision conducted every 4 years. The most recent (2018) revision of the hake species-splitting algorithm used scientific observer records of catch composition as well as research survey data.

The management strategies implemented since the EFZ was declared showed positive results initially, with both catch rates and research survey abundance estimates (and hence TACs and annual catches) increasing gradually through the 1980s and 1990s (Figure 12). In the early 2000s, however, the hake fishery again experienced a decline in catch rates. Results of the species-disaggregated assessments developed in 2005 revealed that the decline was primarily attributable to a reduction in the *M. paradoxus* resource to well below B_{MSY}. Although the *M. capensis* resource had also declined, the es-

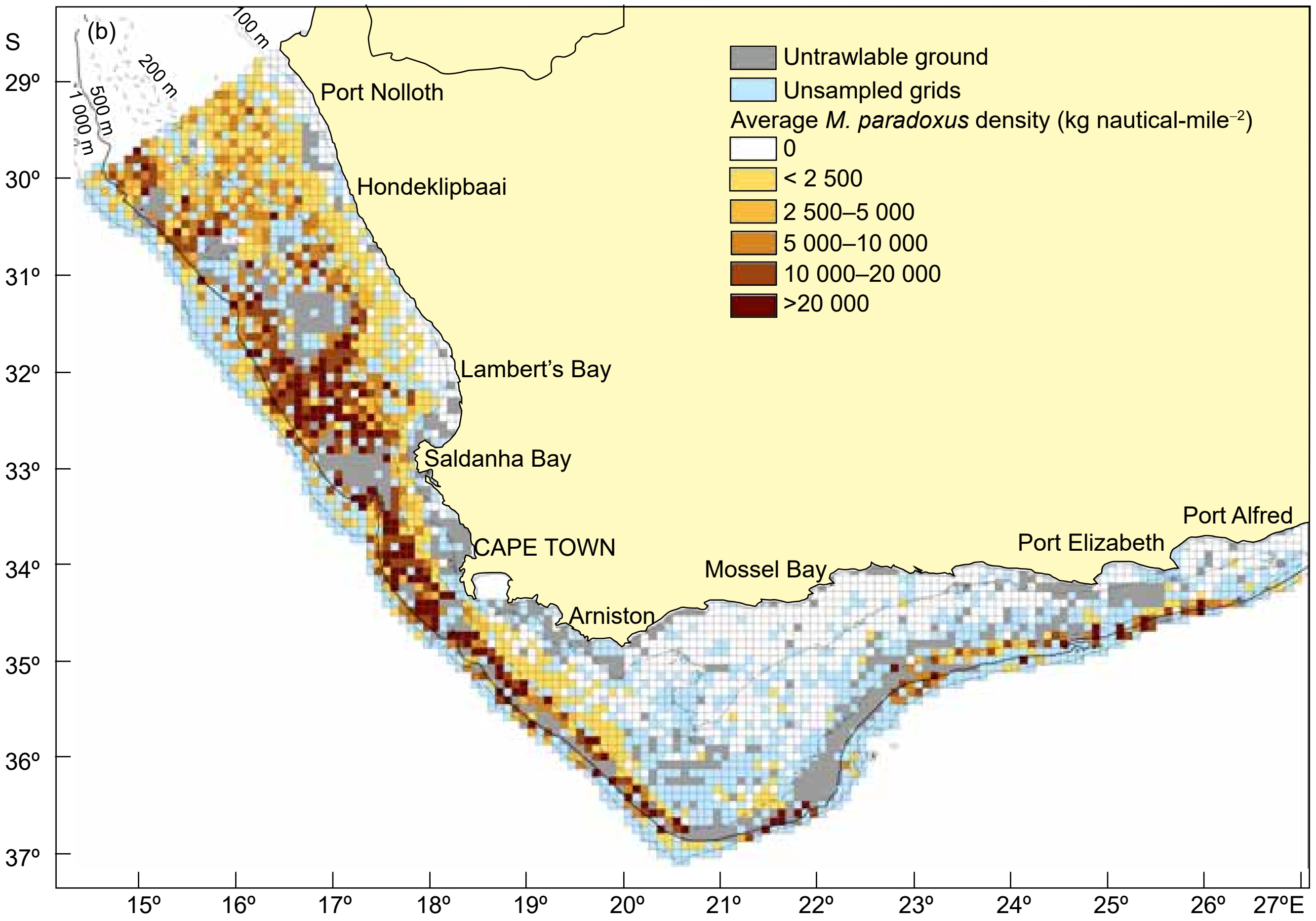


Figure 10 (b): Distribution of deep-water hake *Merluccius paradoxus* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

timated biomass was still above B_{MSY}. The decline was likely a response to several years of below-average recruitment for both species in the late 1990s and early 2000s. The reasons for the poor recruitment are unknown.

The OMP developed in 2006 was based on a species-disaggregated assessment available for the first time, and amidst industry concerns about financial viability given the downturns in catch rates. This OMP provided TAC recommendations for the period 2007–2010 that aimed to allow recovery of the *M. paradoxus* resource to 20% of its pre-exploitation level over a 20-year period, while restricting year-to-year fluctuations in the TAC to a maximum of 10% to provide stability for the industry. Implementation of this OMP led to substantial reductions in the TAC from 2007 until 2009 (Figure 11), but TACs subsequently increased as the resource responded positively to the recovery plan, with survey indices of abundance, and to some extent commercial catch rates, turning around to show increasing trends (Figures 12 & 13). In accordance with the agreed OMP revision schedule, revised OMPs were developed in 2010 (OMP-2010), 2014 (OMP-2014) and 2018 (OMP-2018) to provide TAC recommendations for the years 2011–2014, 2015–2018 and 2019–2022, respectively. OMP-2010 was aimed at continuing the *M. paradoxus* rebuilding strategy inherent in OMP-2006, with the objective of returning the *M. paradoxus* resource to B_{MSY} by 2023. OMP-2014 was developed in circumstances where, although the *M. paradoxus* resource was estimated to have improved to above B_{MSY} during 2012–2013 (indicating that the rebuilding strategy inherent in OMP-2010 had been successful), the stock had experienced below-average recruitment over 2009–2013, likely to result in a short-term reduction in spawning biomass. OMP-2014 was consequently aimed at reversing this downward trend and returning *M. paradoxus* to B_{MSY} by 2023.

The comprehensive assessments that were conducted in preparation for the 2018 OMP review yielded somewhat different perceptions of resource status to those of preceding years, particularly in the case of *M. paradoxus*. Previous perceptions of the status of the hake resources suggested that while the *M. capensis* resource had been well above B_{MSY} since the early 1980s, the *M. paradoxus* resource had declined to below B_{MSY} for most of the 2000s, recovering to only slightly above MSY from 2011 onwards. The assessments conducted during 2018, however, generally suggested that while the status of *M. capensis* was slightly more positive than estimated previously, the *M. paradoxus* resource was appreciably above B_{MSY} from 2010 onwards. More recent RC assessments have conformed to this perception (Table 2, Figure 14). While this improvement could be partially attributed to the rebuilding strategy inherent in OMP-2010 and OMP-2014, the improvements to the assessment methodology and input data that were implemented in early 2018 had a large influence. Given these results, a slightly more aggressive management strategy aimed at increasing

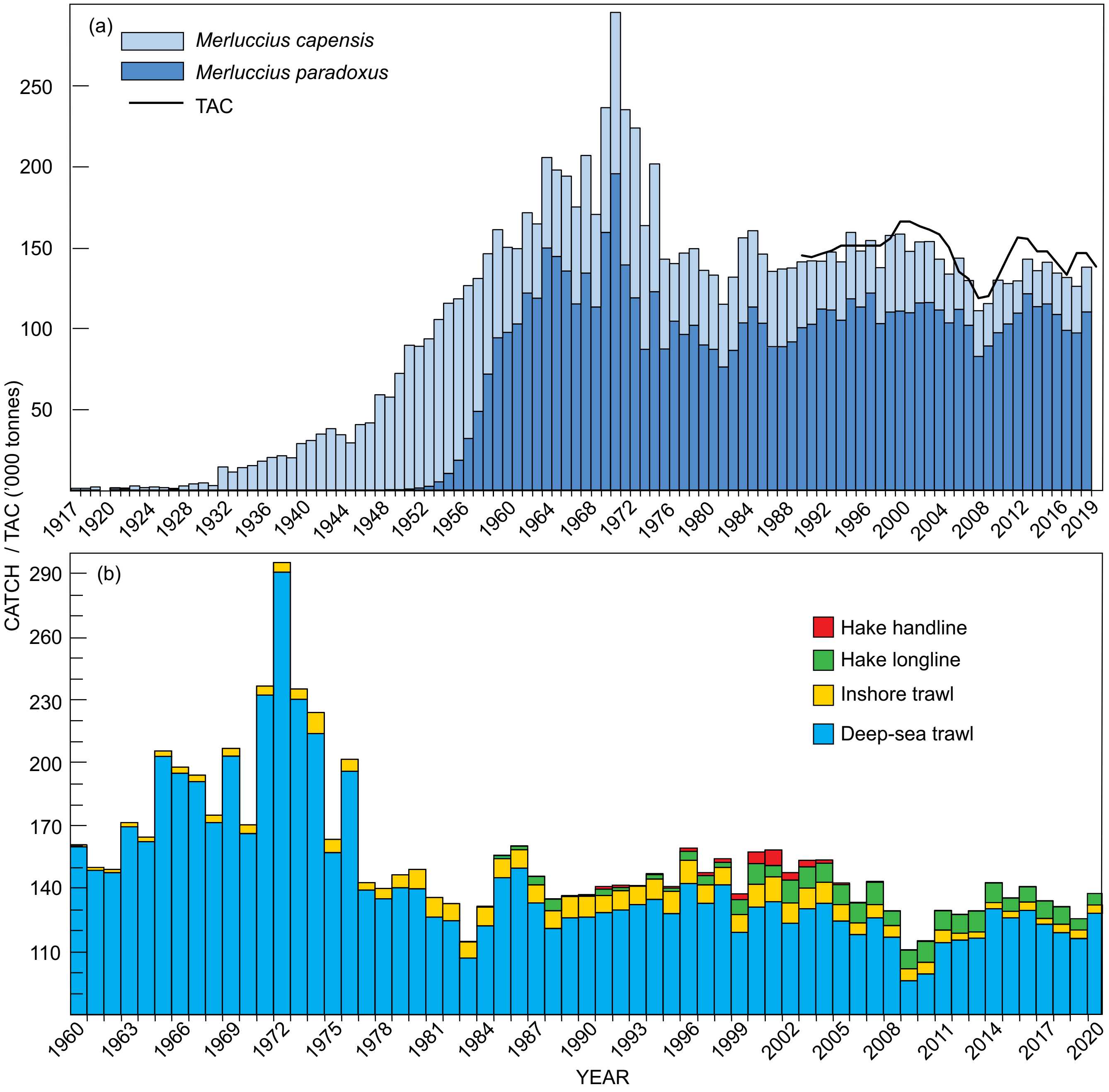


Figure 11: (a) Total catches ('000 tonnes) of Cape hakes split by species over the period 1917–2020 and the TAC set each year since the implementation of the OMP approach in 1991. Prior to 1978, where the data required to split the catch by species are not available, the split is calculated using an algorithm that assumes 1958 as the centre year for the shift from a primarily *M. capensis* to a primarily *M. paradoxus* deep-sea trawl catch. (b) Catches of Cape hakes per fishing sector for the period 1960–2020. Prior to 1960, all catches are attributed to the deep-sea trawl sector. Note that the vertical axis commences at 80 000 tonnes to better clarify the contributions by each sector

the exploitation of the resource was considered during the 2018 review of the hake OMP.

The management procedure that was adopted as OMP-2018 following an evaluation of the performance of various management strategies has the following general specifications:

a) The TAC for 2019 and 2020 is set at 146 431 tonnes per annum.
b) For 2021 and 2022, the TAC for each year is calculated as the sum of the intended species-disaggregated TACs.
c) The intended TAC for each species is calculated as a function of the difference between a measure of the immediate past level in the abundance indices (survey and CPUE) and a pre-specified target level.
d) A 160 000-t upper "hard cap" (i.e. the TAC over the period 2019–2022 may not exceed 160 000 t per annum).
e) The TAC may not be increased by more than 10%, or decreased by more than 5% from one year to the next.

f) A “safeguard” meta-rule that over-rides the percentage TAC decrease constraint in the event of large declines in resource abundance. This allows the TAC to be decreased by more than 5% from one year to the next, depending on the level of the *M. paradoxus* resource relative to pre-specified thresholds.
g) An additional pre-specified *M. capensis* threshold below which action would be needed to reduce the catch of this species without reducing the catch of *M. paradoxus* unnecessarily.
h) “Exceptional Circumstances” provisions that regulate the procedures to be followed in the event that future monitoring data fall outside of the range simulated in the development of the OMP.

OMP-2018 has been used to set the hake TACs for the 2019–2022 fishing seasons. The OMP will be reviewed during 2022 as per the routine 4-year schedule of the hake OMP revision cycle.

An important consideration in the development of the recent hake OMPs has been the certification of the South African hake trawl fishery (both the deep-sea and inshore trawl sectors) by the Marine Stewardship Council (MSC). The fishery first obtained this prestigious eco-label in 2006, and was successfully re-certified in 2010, 2015 and again in 2021. MSC certification has provided substantial socio-economic benefits to the fishery through enabling access to international markets that are increasingly demanding that seafood products are MSC-certified. Recent economic studies conducted by the Bureau of Economic Research and independent consultants have indicated that withdrawal of MSC certification of the South African hake trawl fishery would decrease the net present value of the fishery by about 35% over a 5-year period, and result in a potential loss of up to 13 600 jobs. In fulfilling their mandate of ensuring responsible and sustainable fishing practices through granting the use of the MSC eco-label to a fishery, the MSC have stringent standards in terms of assessments and subsequent management of exploited fish resources. The development of the recent iterations of hake OMPs had to conform to these standards to ensure that certification of the hake trawl fishery will not be jeopardised. In particular, the importance of returning the *M. paradoxus* resource to its median B_{MSY} level by 2023 and maintain it fluctuating around that level had to be considered during the development of OMP-2010 and OMP-2014.

Uncertainty remains as to the extent to which the *M. paradoxus* resource is shared between South Africa and Namibia. At present, the two fisheries are managed independently. Efforts are being directed at developing a joint SA–Namibia assessment of the *M. paradoxus* resource to evaluate the need for possible joint management, but limited information on the possible movement of various life-stages between the two fisheries remains an obstacle to effective modelling of resource dynamics.

Research and monitoring

Fishery-independent hake abundance indices (Figure 12) are determined from research trawl surveys conducted on the West Coast (WC) in summer and the South Coast (SC) in autumn each year since 1985. Additional winter WC and spring SC surveys have been conducted in some years, but budgetary and operational constraints have prevented these surveys from being routinely conducted. Prior to 2011, surveys typically encompassed the area between the coastline and 500-m isobath. Since 2011, the surveys have been extended to the 1 000-m isobath. For each survey, 120 trawl stations are selected using a pseudo-random stratified survey design. The survey area is subdivided by latitude (WC) or longitude (SC) and depth into several strata, and the number of stations selected within each stratum is proportional to the area of the stratum. Areas of rough ground that cannot be sampled using demersal trawls are excluded from the station selection process, and it is assumed that fish densities in these areas are the same as those in adjacent areas. Trawling is conducted only during the day to minimise bias arising from the daily vertical migration of hake, which are known to move off the sea floor and into the water column at night to feed. All organisms in the catch, including benthic invertebrate macrofauna, are identified to species level where possible, in some cases also separated by sex, and the catch weight of each species is then recorded. The size composition of the catch of each species is measured and more-detailed biological analyses are conducted on sub-samples of commercially important species. Such biological analyses include individual fish length and weight measurements, macroscopic estimation of maturity stage, gonad and liver weight measurements and samples, evaluation of stomach contents and extraction of otoliths for age determination. Data and samples collected during the surveys are also being used in research projects aimed at elucidating questions regarding the trophodynamics, stock structure and migration patterns of hake, kingklip and monkfish, as well as the potential impacts of climate change and variability on demersal fish populations. The analyses of hake stomach contents have provided useful data towards estimating natural mortality of hake using intra- and interspecific predation models.

Abundance indices are calculated from the survey data using the swept-area method, which, in part, relies on fishing methods and gear remaining unchanged between surveys. In 2003, it was considered necessary to change the trawl gear configuration on the FRS *Africana* because net-monitoring sensors showed that the gear was being over-spread (i.e. the wings of the net were being pulled too far apart, which reduced the vertical opening and frequently lifted the foot rope off the sea bed). In selecting a new gear configuration, particular emphasis was placed on minimising the possible effect of herding on the abundance indices. This change is currently taken into account in the assessment model by the application of conversion factors estimated from experiments. Another recent (2011) change to the survey design is the extension of the survey area into deeper water (1 000 m) to encompass the full extent of the *M. paradoxus* resource. However, abundance estimates for input to assessments and the hake OMP are still calculated for the historical survey area (<500 m) for consistency purposes. Once abundance time-series of sufficient duration are available for the extended survey area it will be possible to incorporate these data into the assessments and OMP. Operational problems with the departmental research vessel (FRS *Africana*) prevented this vessel conducting demersal surveys between March 2012 and September 2016. In the absence of the FRS *Africana*, the research surveys were conducted on board commercial vessels (the MV *Andromeda* and the MV *Compass Challenger*), although no autumn SC surveys were

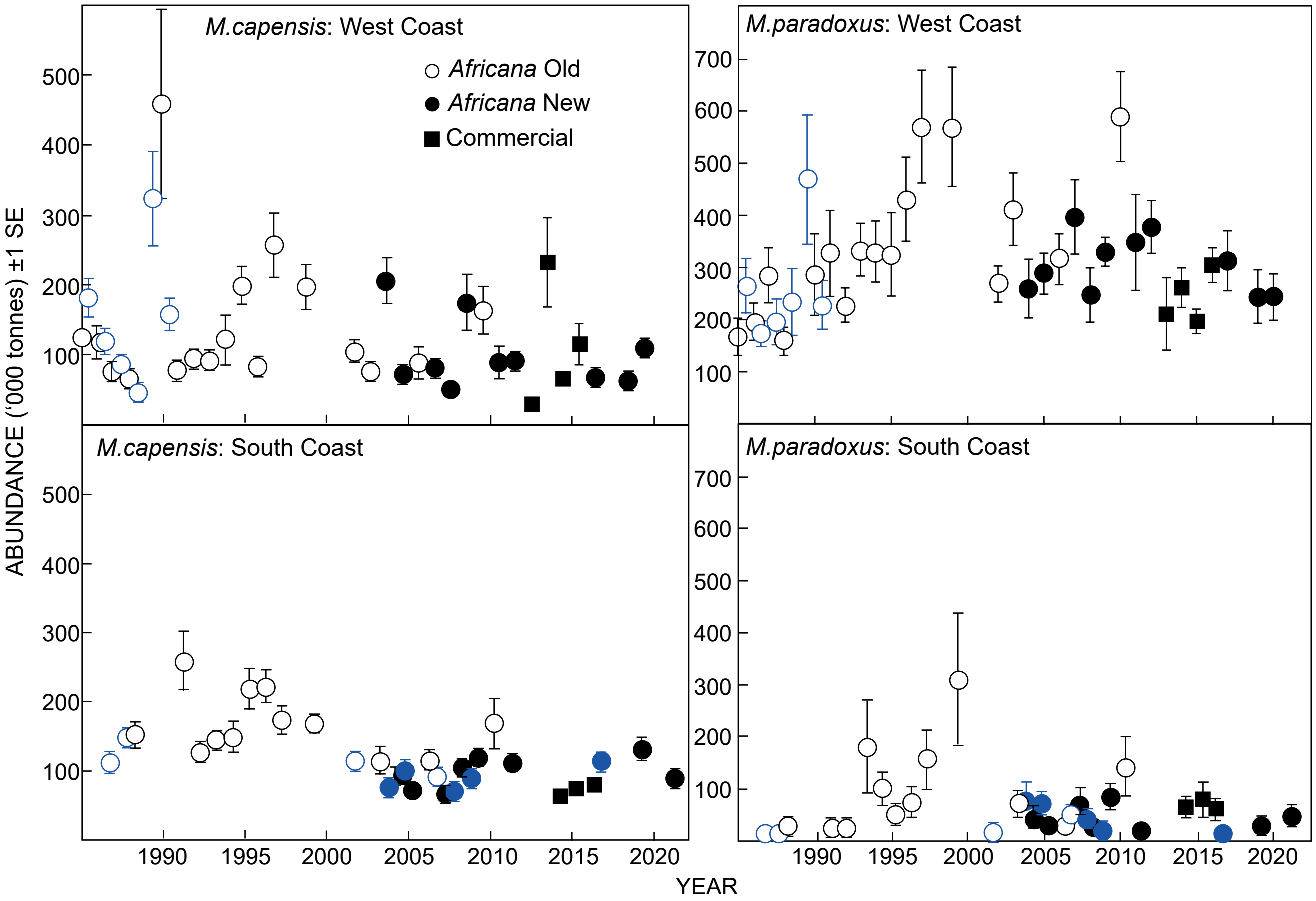


Figure 12: Hake abundance estimates ('000 t ± 1 SE) derived from fishery-independent swept-area demersal surveys. Estimates are illustrated by species and coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West Coast) and spring (South Coast) surveys are indicated with blue symbols. Note that only results from surveys that encompassed the area between the coast and the 500-m isobath are shown and that estimates across the vessel-gear combinations cannot be directly compared due to differences in catchability. *Africana* = research vessel RS *Africana*, Commercial = commercial fishing vessel

conducted in 2012 and 2013. Ongoing technical problems with the FRS *Africana* have also prevented the completion of the autumn 2017 (SC), summer 2018 (WC), autumn 2018 (SC), autumn 2020 (SC), summer 2021 (WC) and autumn 2022 (SC) surveys, while the summer 2022 WC survey was conducted aboard MV *Compass Challenger*.

Species-specific catch-per-unit-effort (CPUE) time-series derived from commercial catch and effort data are standardised using general linear modelling (GLM) techniques to account for differences in factors such as depth, area, and vessel power. These time-series (Figure 13) are then used in the assessment to provide additional estimates of resource abundance and trends.

Assessments of the hake resources in recent years have typically followed a 2-year cycle. An in-depth assessment that fits a suite of age structured production models (ASPMs) to updated datasets is conducted every two years, timed to coincide with the 4-year schedule of OMP revision. The suite of operating models that is considered, referred to as the reference set (RS), is designed to encompass major sources of uncertainty, and includes the reference case (RC) model that is considered to provide the most plausible measures of stock status and dynamics. A routine update of the RC model is conducted every year to ensure that the resources have not deviated from what was predicted during OMP testing.

Preliminary analyses aimed at investigating the implications of the potential sharing of the *M. paradoxus* resource between South Africa and Namibia have been conducted. Variants of the SA RC Operating Model that took account of Namibian catches in a manner that corresponds to the extreme scenario of demographic panmixia of *M. paradoxus* between the SA and Namibian regions were run. A key finding was that allowing for the possibility that there is sharing of the *M. paradoxus* resource between South Africa and Namibia results in an estimated status for that species that is better than that indicated by the assessment of SA hake in isolation. Pending further research into the possibility and implications of a shared *M. paradoxus* resource, evaluations of the performance of the SA hake OMP and its Exceptional Circumstances (EC) provisions have demonstrated that the OMP is sufficiently robust to avoid adverse consequences (in resource conservation terms) which could result from a shared-resource scenario.

Current status

The most recent update of the hake RC assessment was conducted in 2021. The results were similar to those from the previous (2020) RC update and suggest a continued steady

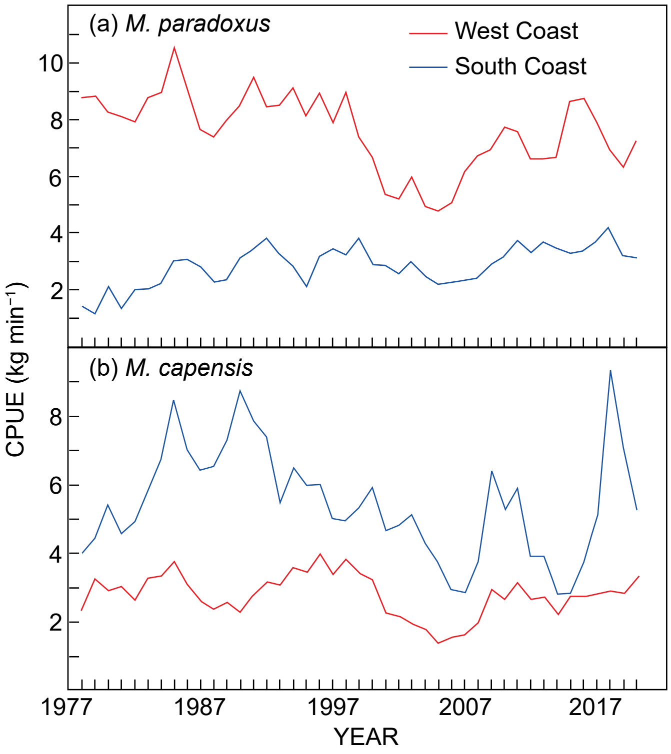


Figure 13: Coast and species-specific standardised indices of abundance (CPUE) for the deep-sea trawl sector. The CPUE indices are calculated using a GLM after application of the revised species-splitting algorithm to updated catch and effort data

increase in spawning biomass for *M. capensis* (increasing from 0.70 relative to K^{sp} in 2020 to 0.74 in 2021 – see Table 2 and Figure 14), but a recent decrease for *M. paradoxus* (from 0.29 relative to K^{sp} in 2020 to 0.27 in 2021). This downward reduction is consistent with the decline in the *M. paradoxus* West Coast offshore trawl commercial catch rates observed over the 2016–2019 period (see Figure 13). Both species are, however, estimated to lie well above B_{MSY} (B^{sp} relative to B_{MSY} is estimated at 1.67 for *M. paradoxus* and 2.67 for *M. capensis*).

Ecosystem interactions

South Africa has committed to implementing an “ecosystem approach to fisheries management” (EAF). This approach extends fisheries management beyond the traditional single-species approach to the entire marine ecosystem. In 2006, the permit conditions for all sectors in the hake fishery contained a specific “ecosystem impacts of fishing” section for the first time and reflected the first concrete step towards the implementation of an EAF in South Africa. These clauses in the permit conditions (and subsequent additions and improvements) are aimed at:

- Minimising seabird mortalities through the deployment of tori lines, management of offal discharge and regulating the nature of the grease on the trawl warps (substantial numbers of seabird mortalities have been attributed to the “sticky warps” phenomenon)
- Reducing damage to the seabed through restrictions on trawl gear and restriction of fishing operations by the demersal trawl fleet (both deep-sea and inshore) to the “trawl ring fence” area (see below)
- Reducing bycatch through per-trip catch limits for kingklip, monkfish and kob as well as annual bycatch limits for kingklip and monkfish
- Reducing bycatch through the “move-on” rule for kob, kingklip and snoek (if bycatch of these species is above a specified threshold, then the vessel may not redeploy fishing gear in that locality, but must move at least five miles away)
- Prevention of overharvesting of kingklip through a time-area closure on the Southeast Coast near Port Elizabeth where the species aggregates to spawn, rendering it susceptible to excessive catches.

Explicit in the permit conditions are also restrictions on fishing in specified fishery management areas (FMAs) and proclaimed marine protected areas (MPAs).

A procedure to limit fishing capacity in the hake trawl sectors (through matching the fishing capacity that is available to a Right Holder to their hake allocation) has been developed jointly with Industry and has been implemented (and reviewed) each year since 2008. This management tool has been effective in limiting the capacity in the trawl fishery, in terms of the number of active vessels as well as the number of days spent fishing, to what is required to catch the TAC.

Considerable effort is being directed at developing a management strategy for the Inshore Trawl sector that aims at minimising bycatch of potentially vulnerable chondrichthyan and linefish species. A co-management plan for this purpose has been developed through consultation between the South East Coast Inshore Fishing Association (SECIFA), the World Wide Fund For Nature (WWF) and academics at the University of

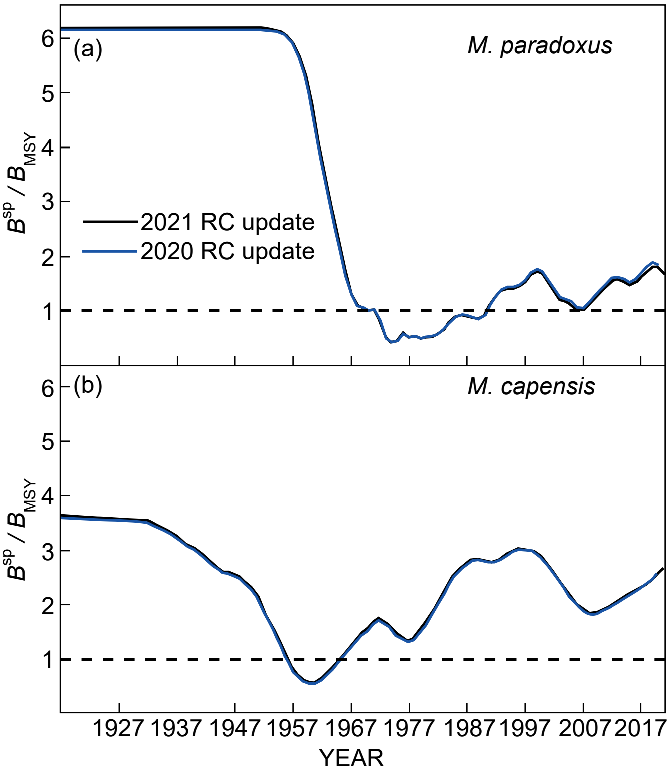


Figure 14: Trajectories of female spawning biomass (B^{sp}) relative to maximum sustainable yield biomass (B_{MSY}) estimated by the 2017, 2018 and 2019 reference case operating models

Table 2: Key outputs of the 2020 and 2021 updates of the reference case (RC) operating model (note that estimates of spawning biomass are in terms of female spawning biomass)

	M. paradoxus		*M. capensis*	
	2020 RC	2021 RC	2020 RC	2021 RC
K^{sp}	337	338	341	346
B^{sp}_{MSY}	55	55	95	96
B^{sp}_{2020}	101	98	244	243
B^{sp}_{2020}/K^{sp}	0.30	0.29	0.72	0.70
$B^{sp}_{2020}/B^{sp}_{MSY}$	1.84	1.80	2.57	2.54
B^{sp}_{2021}	–	91	–	255
B^{sp}_{2021}/K^{sp}	–	0.27	–	0.74
$B^{sp}_{2021}/B^{sp}_{MSY}$	–	1.67	–	2.67
MSY	139	139	81	79

K^{sp}	Pre-exploitation biomass (‘000 t)
B^{sp}_{MSY}	Spawning biomass yielding MSY (‘000 t)
B^{sp}_{2020}	Spawning biomass in 2020 (‘000 t)
MSY	Maximum sustainable yield (‘000 t)

Cape Town (UCT) and is currently being tested using a suite of experimental catch thresholds for 10 species. In parallel with this initiative, research efforts are being directed at formally assessing the status of several key hake trawl bycatch species (additional to kingklip, horse mackerel and monkfish, which are already assessed and managed). Key species have been identified, and work is progressing on collating available data and identifying and conducting the most appropriate assessment approaches.

To promote the continued certification of the South African hake trawl fishery by the MSC, the hake trawl industry implemented the “trawl ring fence” initiative in 2008 as a precautionary measure to address the issue of impacts of demersal trawling on marine benthic habitats. This voluntary initiative was a commitment by the industry to prevent the expansion of trawling into new areas until such time as an improved understanding of the impacts of bottom trawling on the sea floor has been reached. This measure was formalised in 2015 through incorporation into the permit conditions for the two trawl sectors and will ensure that impacts on benthic habitats will not extend beyond currently fished areas. Research into the impacts of trawling on benthic habitats is being conducted through the “benthic trawl experiment”, a collaborative initiative between DFFE, the South African Environmental Observation Network (SAEON), the South African National Biodiversity Institute (SANBI), UCT and the South African Deep Sea Trawling Industry Association (SADSTIA). The experiment involves a closure of specifiedlocations in the Childs Bank area off the West Coast to trawling, while immediately adjacent sites remain open to fishing. A series of five annual surveys of the “trawled” and “untrawled” sites were conducted over the period 2014 to 2018. The surveys encompassed monitoring of sediments and benthic infauna through use of cores and grab samples, as well as benthic epifauna using an underwater camera system. Analyses of the data collected during this research are in progress.

Further reading

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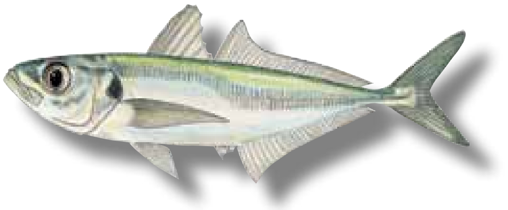
Useful statistics

Annual total allowable catch (TAC) limits and catches (tonnes) of the two species of hake by the hake-directed fisheries on the West (WC) and South (SC) coasts.

Year	TAC	*M. paradoxus*					*M. capensis*								TOTAL (both species)
		Deep-sea		Longline		TOTAL	Deep-sea		Inshore		Longline		Handline	TOTAL	
		WC	SC	WC	SC		WC	SC	SC	WC	WC	SC	SC		
1917		0					1 000							1 000	1 000
1918		0					1 100							1 100	1 100
1919		0					1 900							1 900	1 900
1920															
1921		0					1 300							1 300	1 300
1922		0					1 000							1 000	1 000
1923		0					2 500							2 500	2 500
1924		0					1 500							1 500	1 500
1925		0					1 900							1 900	1 900
1926		0					1 400							1 400	1 400
1927		0					0 800							0 800	0 800
1928		0					2 600							2 600	2 600
1929		0					3 800							3 800	3 800
1930		0					4 400							4 400	4 400
1931		0					2 800							2 800	2 800
1932		0					14 300							14 300	14 300
1933		0					11 100							11 100	11 100
1934		0					13 800							13 800	13 800
1935		0					15 000							15 000	15 000
1936		0					17 700							17 700	17 700
1937		0					20 200							20 200	20 200
1938		0					21 100							21 100	21 100
1939		0					20 000							20 000	20 000
1940		0					28 600							28 600	28 600
1941		0					30 600							30 600	30 600
1942		1				1	34 499							34 499	34 500
1943		1				1	37 899							37 899	37 900
1944		2				2	34 098							34 098	34 100
1945		4				4	29 196							29 196	29 200
1946		10				10	40 390							40 390	40 400
1947		20				20	41 380							41 380	41 400
1948		56				56	57 744							57 744	57.800
1949		106				106	57 294							57 294	57 400
1950		257				257	71 743							71 743	72 000
1951		620				620	88 880							88 880	89 500
1952		1 188				1 188	87 612							87 612	88 800
1953		2 395				2 395	91 105							91 105	93 500
1954		5 092				5 092	100 308							100 308	105 400
1955		10 229				10 229	105 171							105 171	115 400
1956		18 335				18 335	99 865							99 865	118 200
1957		31 885				31 885	94 515							94 515	126 400
1958		48 593				48 593	82 107							82 107	130 700
1959		71 733				71 733	74 267							74 267	146 000
1960		94 095				94 095	68 805		1 000					68 805	160 900
1961		97 390				97 390	51 310		1 308					52 618	150 008
1962		102 622				102 622	44 978		1 615					46 593	149 215
1963		121 695				121 695	47 805		1 923					49 728	171 423
1964		118 512				118 512	43 788		2 231					46 019	164 531
1965		149 541				149 541	53 459		2 538					55 997	205 538

Year	TAC	*M. paradoxus*					*M. capensis*							TOTAL (both species)
		Deep-sea		Longline		TOTAL	Deep-sea		Inshore	Longline		Handline	TOTAL	
		WC	SC	WC	SC		WC	SC	SC	WC	SC	SC		
1966		144 301				144 301	50 699		2 846				53 545	197 846
1967		131 066	4 260			135 326	45 634	9 926	3 154				58 714	194 040
1968		106 642	8 391			115 034	36 958	19 517	3 462				59 936	174 970
1969		122 685	11 412			134 097	42 415	26 518	3 769				72 703	206 799
1970		105 925	7 140			113 064	36 575	16 583	4 077				57 236	170 300
1971		150 177	9 065			159 242	51 823	21 050	4 385				77 258	236 500
1972		181 368	14 057			195 425	62 565	32 639	4 692				99 896	295 321
1973		117 318	21 782			139 100	40 464	50 574	5 000				96 088	235 138
1974		91 458	27 351			118 809	31 542	63 502	10 056				105 100	223 909
1975		66 637	20 310			86 947	22 980	47 153	6 372				76 505	163 452
1976		106 996	15 634			122 630	36 898	36 296	5 740				78 934	201 564
1977		76 089	11 131			87 219	26 239	25 841	3 500				55 581	142 800
1978		101 042	3 220			104 263	26 470	4 365	4 931				35 766	140 029
1979		94 331	1 924			96 255	39 192	4 995	6 093				50 280	146 535
1980		99 654	2 206			101 861	33 873	4 254	9 121				47 248	149 109
1981		88 883	910			89 793	32 048	4 575	9 400				46 023	135 816
1982		83 618	3 353			86 971	29 732	8 005	8 089				45 825	132 796
1983		71 238	4 723	126		76 088	23 195	7 792	7 672	104			38 763	114 851
1984		82 358	3 796	200	5	86 359	28 897	7 139	9 035	166	11		45 248	131 607
1985		94 428	8 059	638	91	103 216	30 642	11 957	9 203	529	201	65	52 597	155 813
1986		103 756	8 580	753	94	113 183	30 049	7 385	8 724	625	208	84	47 075	160 258
1987		93 517	7 459	1 952	110	103 038	24 008	8 225	8 607	1 619	243	96	42 798	145 836
1988		79 913	5 876	2 833	103	88 725	26 669	8 640	8 417	2 350	228	71	46 375	135 100
1989		82 230	6 182	158	10	88 581	25 029	12 730	10 038	132	22	137	48 087	136 668
1990		81 996	9 341	211		91 548	21 640	13 451	10 012	175		348	45 626	137 174
1991	145 000	87 093	12 448		932	100 474	19 357	9 626	8 206		2.068	1 270	40 526	141 000
1992	144 000	84 768	17 297		466	102 531	18 519	9 165	9 252		1.034	1 099	39 069	141 600
1993	146 000	102 125	9 880			112 005	15 940	4 380	8 870			278	29 468	141 473
1994	148 000	103 541	6 726	882	194	111 342	20 327	4 326	9 569	732	432	449	35 835	147 177
1995	151 000	100 268	4 004	523	202	104 997	20 629	3 146	10 630	434	448	756	36 043	141 040
1996	151 000	107 381	8 966	1 308	568	118 223	21 794	4 323	11 062	1 086	1 260	1 515	41 040	159 263
1997	151 000	100 654	10 509	1 410	582	113 155	16 500	5 327	8 834	1 170	1 290	1 404	34 525	147 680
1998	151 000	111 154	9 742	505	457	121 858	16 499	4 411	8 283	419	1 014	1 738	32 364	154 222
1999	151 000	88 581	11 420	1 532	1 288	102 822	15 179	3 926	8 595	1 272	2 856	2 749	34 577	137 399
2000	155 500	96 587	7 700	2 706	3 105	110 098	21 114	5 830	10 906	2 000	1 977	5 500	47 327	157 426
2001	166 000	101 247	7 850	1 417	84	110 598	16 349	8 306	11 836	2 394	1 527	7 300	47 713	158 311
2002	166 000	91 207	12 443	4 469	1 585	109 704	13 724	6 141	9 581	2 391	2 546	3 500	37 883	147 587
2003	163 000	93 711	17 397	3 305	1 252	115 665	11 665	7 636	9 883	2 526	3 078	3 000	37 788	153 453
2004	161 000	85 722	26 065	2 855	1 196	115 838	12 510	8 704	10 004	2 297	2 731	1 600	37 846	153 684
2005	158 000	85 869	21 778	3 091	472	111 210	9 398	7 468	7 881	2 773	3.270	700	31 490	142 700
2006	150 000	81 513	18 050	3 241	485	103 289	11 984	6 578	5 524	2 520	3 227	400	30 233	133 522
2007	135 000	92 724	13 488	2 512	3 021	111 745	16 145	3 757	6 350	2 522	2 522	400	31 696	143 441
2008	130 532	85 538	13 191	2 255	809	101 792	13 838	4 316	5 496	1 937	1 893	231	27 711	129 503
2009	118 578	68 202	10 895	2 410	1 069	82 576	12 296	4 806	5 639	2 828	2 520	265	28 354	110 930
2010	119 831	69 709	15 457	2 394	1 527	89 087	10 186	4 055	5 472	3 086	3 024	275	26 098	115 185
2011	131 780	76 576	17 904	2 522	140	97 142	15 673	4 086	6 013	3 521	3 047	186	35 525	129 667
2012	144 671	81 411	16 542	4 358	306	102 616	12 928	4 584	3 223	2 570	1 737	8	25 050	127 666
2013	156 075	74 341	28 859	6 056	60	109 316	8 761	4 475	2 920	2 606	1 308	0	20 071	129 387
2014	155 280	73 252	41 156	6 879	8	121 295	9 671	6 286	2 965	2 123	315	1	21 361	142 656
2015	147 500	77 521	31 745	4 001	18	113 286	12 727	4 085	3 077	2 325	53	1	22 217	135 503
2016	147 500	93 173	18 968	2 806	1	114 948	14 744	2 810	3 973	4 360	2	1	25 889	140 837
2017	140 125	72 326	30 961	5 288	25	108 600	15 273	4 466	2 812	2 807	126	4	25 488	134 088
2018	133 119	64 252	29 218	5 156	89	98 715	12 689	12 863	3 983	2 615	481	24	32 655	131 370
2019	146 431	70 608	22 201	3 177	20	96 006	14 193	9 454	4 148	2 160	178	9	30 142	126 148
2020	146 431	97 093	10 061	3 220	26	110 400	18 115	3 500	4 536	1 293	177	4	27 625	138 025
2021	139 109													

Cape horse mackerel



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	

Introduction

Cape horse mackerel *Trachurus capensis* are semi-pelagic shoaling fish that occur on the continental shelf off southern Africa from southern Angola to the Wild Coast. Off South Africa, adult horse mackerel are currently more abundant off the South Coast than the West Coast (Figure 15). They are replaced by the very similar Cunene horse mackerel *T. trecae* and African horse mackerel *T. delagoa* to the north and east, respectively. Horse mackerel as a group are characterised by a distinct dark spot on the gill cover and a row of enlarged scutes (spiny scales) along the "S"-shaped lateral line. It is difficult, however, to distinguish between the three species that occur off southern Africa. Cape horse mackerel generally reach 40–50 cm in

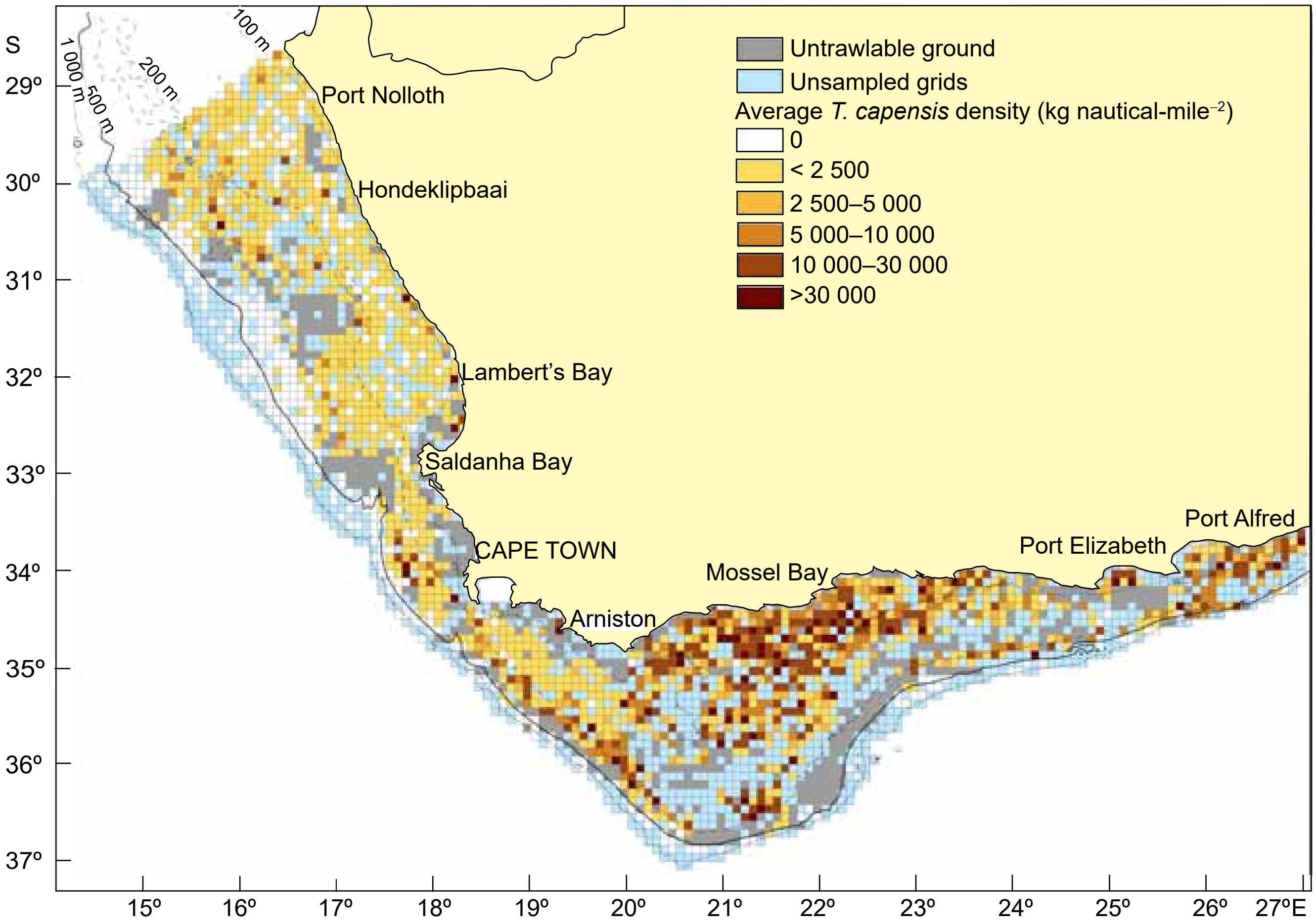


Figure 15: Distribution of Cape horse mackerel *Trachurus capensis* in South African waters, as derived from fishery-independent demersal research surveys. Data are shown as the average density (kg nautical-mile^{-2}) per grid block over surveys conducted from 1986 to 2023

length and become sexually mature at about three years of age when they are roughly 20 cm long. They feed primarily on small crustaceans such as copepods and euphausiids, which they ingest using their protrusible mouths and filter with their modified gill rakers.

Historically, large surface schools of adult Cape horse mackerel occurred on the West Coast and supported a purse-seine fishery that made substantial catches, particularly during the early 1950s (Figure 16). These large schools have since disappeared from the South African West Coast but still occur off Namibia, where horse mackerel catches dominate marine fishery landings. Purse-seine catches of Cape horse mackerel on the West Coast of South Africa currently comprise mainly juvenile fish that shoal together with, and are caught as incidental bycatch during directed fishing for, small pelagic species such as sardine and anchovy.

Adult Cape horse mackerel are currently caught as incidental bycatch by the hake-directed demersal trawl fleet and as a targeted catch by the midwater trawl fleet, mainly on the South Coast. At present, the midwater trawl fleet comprises a single, large midwater trawler (the FV *Desert Diamond*, which lands about 70% of horse mackerel trawl catches) and a number of smaller hake trawlers carrying both hake and horse mackerel Rights (the so-called "dual rights vessels") that allow them to opportunistically target horse mackerel with midwater gear additional to their normal hake fishing operations using demersal trawl gear. Horse mackerel yield a low-value product and are a source of cheap protein.

History and management

Purse-seine catches of adult Cape horse mackerel on the West Coast peaked at 118 000 t in the early 1950s (Figure 16) and declined to negligible levels by the late 1960s. In the 1990s, purse-seine catches of Cape horse mackerel (now comprising largely juvenile fish taken as bycatch in anchovy-directed fishing) again showed an increasing trend, reaching 26 000 t in 1998. This increase raised concerns as to the likely effects of large catches of juvenile Cape horse mackerel on the trawl fishery for adults. Analyses exploring this potential impact indicated a pronounced yield-per-recruit effect, leading to the introduction of an annual 5 000 t precautionary upper catch limit (PUCL) for horse mackerel in the purse-seine fishery in 2000. Subsequent to this measure being implemented, the average annual horse mackerel catch by the purse-seine fleet has been 3 400 t. The 5 000 t annual PUCL was changed to a "PUCL_3" system in 2013 to enable flexibility in horse mackerel bycatch management within the small pelagic purse-seine sector. This system, which effectively uses a three-year "running average" catch limit approach, was developed to enable continued fishing for anchovy by the purse-seine fleet during periods of unusually high juvenile horse mackerel abundance (as was the case during 2011).

In the 1950s and 1960s, trawl (midwater and demersal) catches of horse mackerel on the South Coast were incidental to directed hake and sole fishing and amounted to less than 1 000 t per annum. Japanese vessels using midwater trawl gear then began targeting the resource in the mid-1960s and catches rapidly escalated, peaking at over 116 000 t in 1977. Following the declaration of the South African Exclusive Fishing Zone (EFZ) in 1977, foreign participation in the fishery was controlled and catches stabilised at between 27 000 t and 58 000 t per annum. When foreign fleets were finally phased out in 1992, annual catches (now by South African vessels only) declined to about 10 000 t in 1995. Whereas demersal trawl catches have subsequently remained low, the re-establishment of a midwater trawl fishery for Cape horse mackerel in 1997 resulted in an increase in the annual catch (Figure16), which has fluctuated between 8 000 t and 31 000 t since the 2000 fishing season.

Annual total allowable catch (TAC) restrictions for the trawl fishery (both demersal and midwater components) were set for

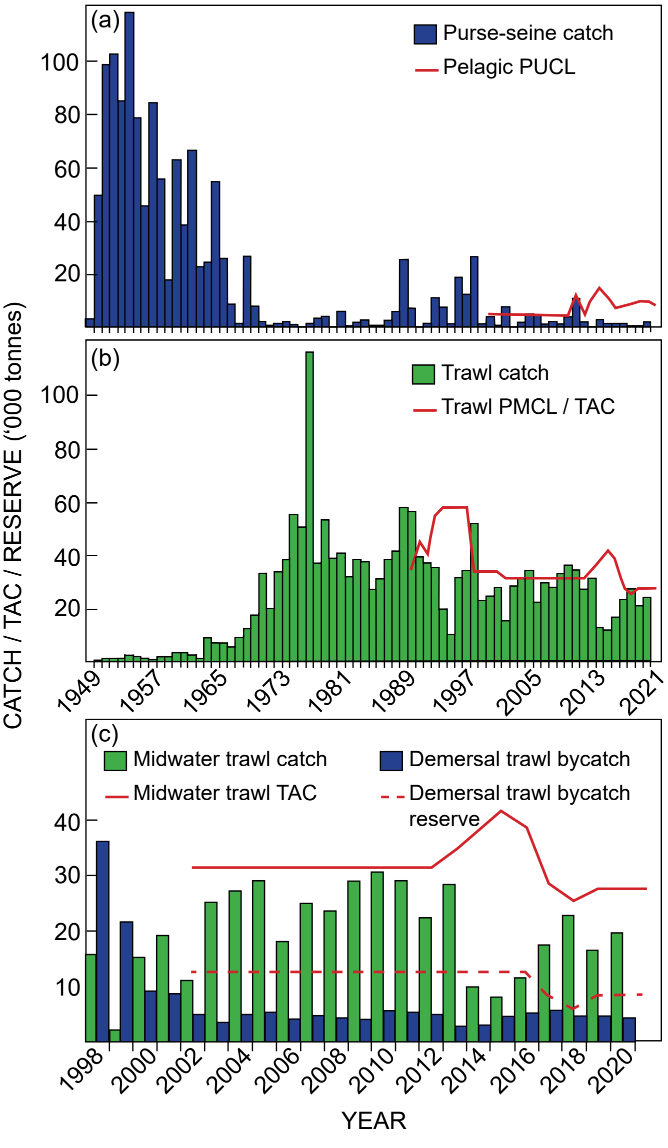


Figure 16: Catches and catch limits of Cape horse mackerel *Trachurus capensis*. (a) Pelagic purse seine catches 1949–2020 and the precautionary upper catch limit (PUCL) 2000–2021. (b) Trawl (demersal and midwater combined) catches 1949–2020 and the precautionary maximum catch limit / TAC 1990–2021. Catches cannot be reliably separated be sector (demersal versus midwater) or fleet (local versus foreign) prior to 1998. (c) Trawl catches 1998–2020 (all by SA vessels) split into the demersal and midwater trawl components. The midwater trawl TAC (solid line) and demersal trawl bycatch reserve (dashed line) are also shown for the period 2002–2021

1990 (35 000 t) and 1991 (45 000 t) using assessments of the resource based on catch-per-unit-effort (CPUE) data derived from the Japanese fleet, combined with survey biomass and egg abundance indices. With the phasing out of the foreign fleets in 1992, the Japanese CPUE time-series was terminated and this modelling approach was no longer appropriate. A precautionary maximum catch limit (PMCL) of 40 000 t was set for 1992. Thereafter, a yield-per-recruit modelling approach was adopted on which to base PMCLs until 1999, when an age-structured production model (ASPM) of the resource was developed. Biomass projections using the model indicated that a PMCL of 34 000 t for the trawl fishery combined with the 5 000 t PUCL for the purse-seine fishery would be appropriate, and these catch restrictions were imposed for the 2000 fishing season. The trawl PMCL was increased to 44 000 t for 2002, and was maintained at that level until 2012. Between 2002 and 2012, the trawl PMCL was separated into a 12 500 t reserve to account for incidental bycatch of horse mackerel in the hake demersal trawl fishery, and a 31 500 t allocation for the directed midwater trawl sector.

In 2012, an operational management procedure (OMP; see the section on Cape hakes) was implemented for the directed midwater trawl fishery to improve utilisation of the resource (to allow increased catches during periods of high horse mackerel abundance) without undue increase in the risk of unintended reduction of resource abundance. The horse mackerel OMP incorporated a harvest control rule that adjusted the annual TAC each year (either upwards or downwards) depending on the level of current resource abundance indices relative to averages over a fixed past period. Note that this approach applied only to the directed midwater trawl fishery; the 12 500 t demersal trawl bycatch reserve, which had been in place since 2002, was maintained. Implementation of the midwater harvest control rule resulted in 10% per annum increases in the midwater TAC over the period 2013–2015.

The 2015 assessment of the horse mackerel resource was conducted in circumstances where the only reliable index of horse mackerel abundance (the commercial CPUE for the FV *Desert Diamond*) was at a level in 2014 that was appreciably lower than the bounds projected by the horse mackerel OMP, having declined from a relatively high level the previous year (Figure 17). In these Exceptional Circumstances, it was recognised that the horse mackerel OMP was no longer an appropriate means of providing scientific advice for the management of the resource. Initial analyses demonstrated that the available data were insufficient to inform on whether the low CPUE reflected a decline in catchability or an increase in natural mortality. Further analyses encompassing a suite of possible management responses that included both TAC reductions and effort limitations were conducted. Following consideration of these analyses, it was agreed that the most appropriate precautionary approach for managing the horse mackerel resource would be to set the midwater component of the 2016 TAC at the level indicated by the OMP (38 658 tonnes) and to additionally implement an effort limitation scheme that would restrict the midwater trawl effort in 2016 to a level comparable to the annual average realised over the 2010 to 2013 period. These measures would avoid the necessity for a substantial reduction in the TAC, and would allow for the possibility of large midwater catches in the event that the 2014 CPUE reflected a downward fluctuation in catchability, rather than an increased natural mortality event.

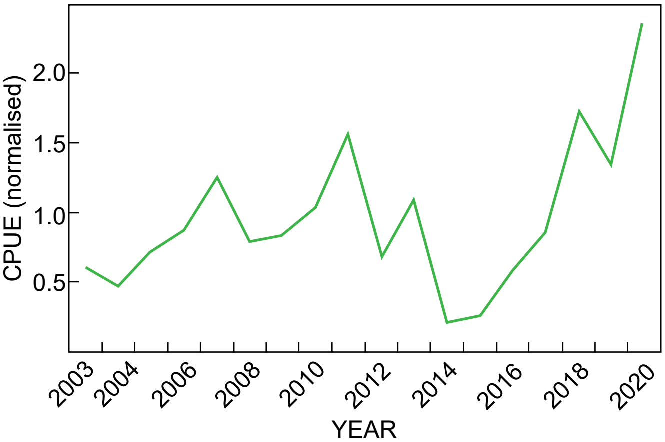


Figure 17: Annual standardised CPUE estimates for the midwater trawler FV *Desert Diamond* over the period 2003–2020. Note that the series of estimates have been normalised to the mean, and that due to the absence of scientific observers on the vessel in 2015 (and consequently lack of drag-level data required for the CPUE standardisation), the value for 2015 is an estimate derived from a comparison of standardised and crude nominal (catch per trip) CPUE estimates

The low CPUE circumstances persisted until 2017, and assessments conducted in 2016 and 2017 consequently followed the same approach as described above, resulting in recommendations for maintaining the effort limitation scheme as well as for sequential reductions in both the midwater TAC and demersal trawl bycatch reserve for the 2017 and 2018 fishing seasons.

Although the CPUE in 2017 had increased from the low levels observed in the previous year, the assessment conducted in 2018 followed the same approach as previously, and yielded results that were slightly more optimistic. Further analyses indicated that the slightly reduced rate of resource recovery under a relaxed effort restriction strategy in the event that the “increased mortality” hypothesis is correct was an acceptable trade-off for the somewhat larger future catch that is likely under this management strategy. The midwater trawl effort limit for the 2019 fishing season was consequently increased by about 18% with a corresponding increase in the midwater trawl horse mackerel TAC to 27 670 tonnes (the catch expected in 2019 under the “reduced catchability” hypothesis).

The 2019 assessment of the horse mackerel resource was conducted in circumstances in which the commercial CPUE index of abundance had increased to a level in 2018 that was the highest on record. This observation suggested that the “large mortality event” hypothesis employed in previous assessments was less likely (it is unlikely that recovery from a large increased mortality event would have occurred in such a short period of time), and subsequent analyses indicated that this hypothesis should not be considered in further analyses. Results generated by the 2019 base case operating model suggested that the Cape horse mackerel resource was at about 66% of pre-exploitation biomass, and more than double the level that produces MSY. Projections of future resource status using the 2019 suite of assessment models under various management options indicated that there was no compelling

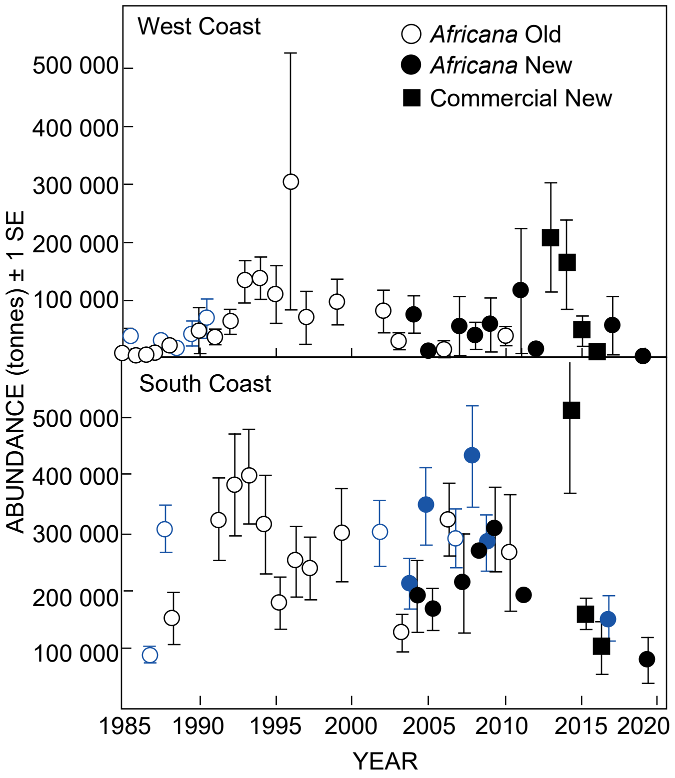


Figure 18: Cape horse mackerel *Trachurus capensis* abundance estimates (tonnes) derived from fishery-independent swept-area demersal surveys. Estimates are illustrated by coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West Coast) and spring (South Coast) surveys are indicated with blue symbols. Note that surveys that only extended to the 200 m isobath have been excluded from the figures, and that estimates across the vessel-gear combinations cannot be directly compared due to differences in catchability. *Africana* = research vessel RS *Africana*, 'Commercial' = commercial fishing vessel

reason to alter the management measures imposed for the previous fishing season, and all catch and effort limits that were set for 2019 were maintained for the 2020 fishing season. A slight decrease in the commercial CPUE index was observed in 2019, but the assessments conducted in 2020 yielded results that were very similar to those obtained in the previous year, and the catch and effort limits imposed for the 2020 fishing season were consequently maintained for 2021.

Research and monitoring

The assessment and management of the horse mackerel resource is currently limited by uncertainties regarding resource abundance. Fishery-independent indices of abundance that are used in the assessment are derived from the demersal hake-directed surveys conducted on the West and South coasts (Figure 18). However, because horse mackerel can occur at any depth within the water column, an unknown proportion of the biomass is distributed above the headline of the demersal trawl gear used for the surveys and is therefore not sampled. It is also likely that the proportion of the biomass that is available to demersal trawl gear varies between surveys. Trends in the time-series of survey abundance indices could consequently be influenced by changes in availability as well as by changes in abundance.

Unfortunately, acoustic methods are also unable to provide unbiased biomass estimates as it is not possible to detect horse mackerel acoustically when they are close to the seabed. A dedicated horse mackerel survey employing both demersal trawl and hydro-acoustic techniques in combination was conducted in 2016 in an attempt to quantify the level of error inherent in the estimates of horse mackerel abundance derived from the hake-directed surveys. Analysis of the hydroacoustic data collected during the survey indicated that a negligible proportion of horse mackerel biomass was distributed above the headline of the demersal trawl gear during sampling, suggesting that the demersal surveys do in fact provide a useful index of horse mackerel abundance.

A second source of information concerning resource abundance has recently been developed from commercial midwater trawl catch and effort data. CPUE data are standardised using generalised linear modelling techniques to account for factors such as depth, location, time of day, lunar phase and wind speed.

Current status

Concerns regarding the reliability of the *Desert Diamond* CPUE index of abundance over time had arisen following the expanded area of operations of the vessel (which is now permitted to fish on the West Coast) and with the recent use of a bycatch mitigation device (BMD) in almost all trawling operations of the vessel. To address these concerns, the 2021 horse mackerel assessments included the incorporation of a "device" factor into the CPUE standardisation and an additional model variant that fitted to the summer West Coast demersal survey abundance index. The 2020 commercial CPUE had increased to the highest level on record, again indicating that the "increased mortality" hypothesis used to explain the low 2014–2016 CPUE in previous assessments remained less likely than the "reduced catchability" hypothesis and, as for the 2019 and 2020 assessments, the "increased mortality" hypothesis was consequently not considered further. The 2021 assessments consequently used the same base case (BC) model as had the 2019 and 2020 assessments and additionally considered a suite of additional variants of the BC to address concerns regarding, among others, the differences between the two primary indices of abundance (*Desert Diamond* CPUE and autumn demersal surveys) over recent years, the extended area of operations of the *Desert Diamond* and sensitivities to alternative assumptions of natural mortality and survey catchability. The results (Table 3) indicated that the resource is in a very healthy state, with the BC model estimating the 2021 spawning biomass to be at about 69% of pre-exploitation biomass (spawning biomass yielding MSY was estimated to be at about 24% of pre-exploitation biomass). Projections of future resource status under future catches ranging from 20 000 to 30 000 tonnes per annum show a reduction in spawning bio-

Table 3: Results for the new base case model ("2021 BC") compared to the previous base case ("2020 BC"), four alternatives of the 2021 base case model ("Alt1"–"Alt4") and the three sensitivity tests ("Sen1"–"Sen3"). The negative log likelihood ("–lnL") is a measure of how well the models fit the data, with a smaller value reflecting a better fit. Note that the units of biomass values are thousands of tonnes

		2020 BC	Alt1 2021 BC	Alt2 Alternate DR CPUE	Alt3 Fit WC summer survey	Alt4 Exclude SC autumn survey	Sen1 Exclude DD CPUE	Sen2 M_a = 0.5	Sen3 q_{aut} = 0.5	q_{aut} = 0.1.0
–lnL	Negative log likelihood	–266.948	–271.242	–273.758	–253.181	–268.183	–236.079	–270.149	–271.602	–265.586
K^{sp}	Pre-exploitation spawning biomass	773	773	773	756	750	768	440	997	755
B^{sp}_{MSY}	Spawning biomass yielding MSY	189	189	188	185	183	187	106	243	185
B^{sp}_{MSY} / K^{sp}	Spawning biomass yielding MSY relative to pre-exploitation spawning biomass	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.25
B^{sp}_{2019}	Spawning biomass in 2019	488	483	478	427	474	470	352	775	467
B^{sp}_{2020}	Spawning biomass in 2020	-	520	520	443	527	481	389	824	473
B^{sp}_{2021}	Spawning biomass in 2021	-	533	535	453	544	488	385	836	477
MSY	Maximum sustainable yield	56	56	56	55	55	55	65	71	55
B^{sp}_{2019} / K^{sp}	Depletion in 2019	0.632	0.624	0.619	0.564	0.631	0.611	0.799	0.778	0.619
B^{sp}_{2020} / K^{sp}	Depletion in 2020	-	0.671	0.672	0.586	0.703	0.626	0.883	0.826	0.627
B^{sp}_{2021} / K^{sp}	Depletion in 2021	-	0.690	0.692	0.600	0.726	0.634	0.874	0.838	0.632

mass over the next 10 years, but that this is not a concern since the stock would remain at levels well above B_{MSY}. In view of these results, the directed midwater TAC for 2022 was maintained at 27 670 tonnes. Considering that the updated datasets provide very little support for the "increased mortality" hypothesis, the effort limitation imposed during recent years to account for the possibility that this hypothesis is correct was discarded for the 2022 fishing season.

Ecosystem interactions

The midwater trawl fleet currently comprises a few relatively small demersal hake trawlers that are permitted to carry midwater gear in addition to the standard demersal trawl gear (the so-called dual hake-horse mackerel vessels), and a single large, dedicated midwater trawler. The vessels using dual hake and horse mackerel permits must also comply with restrictions applied to the demersal hake trawl fishery aimed at minimising other ecosystem impacts such as damage to benthic habitats and bycatch of non-target species (see the section on Cape hakes).

All vessels catching horse mackerel (those conducting horse mackerel directed midwater trawling as well as demersal hake trawlers catching horse mackerel as incidental bycatch) are required by permit condition to deploy bird-scaring ("tori") lines and refrain from discharging offal while trawling in order to minimize seabird mortalities.

The dedicated midwater trawler uses a large midwater net that catches a number of non-target species, including marine mammals, sunfish and various large pelagic shark species. These incidental catches have raised a number of conservation concerns. Recent research has been directed at evaluating the extent of these catches, as well as their potential impacts on the populations concerned. Preliminary results suggest that, on average, annual catches of the bycatch species are relatively low, suggesting no immediate cause for concern. There have been cases, however, of isolated short-term events of large catches of certain species. Further research is being directed at evaluating whether or not such cases reflect more-serious impacts than the long-term averages would suggest. In the interim, a number of management measures aimed at reducing incidental bycatch of these large non-target species have been implemented. These measures include a suite of catch limits and move-on rules.

Research has also been directed at developing an effective bycatch mitigation device to mitigate catches of the larger bycatch species. Collaborative efforts with the fishing industry have tested various configurations of such a device, with a final version now being deployed during almost all trawling operations conducted by the vessel. Efforts are being directed at evaluating the performance of the device.

Further reading

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Useful statistics

Catches and catch limits of Cape horse mackerel *Trachurus capensis* in South African waters. Note that trawl catches cannot be reliably separated by sector (demersal versus midwater) or fleet (local versus foreign) prior to 1998. Dem = demersal; Mid = midwater; Pel = pelagic; Dem Res = demersal trawl bycatch reserve.

	Catch (t)	
Year	Purse-seine	Trawl (Dem+Mid)
1949	3 360	
1950	49 900	445
1951	98 900	1 105
1952	102 600	1 226
1953	85 200	1 456
1954	118 100	2 550
1955	78 800	1 926
1956	45 800	1 334
1957	84 600	959
1958	56 400	2 073
1959	17 700	2 075
1960	62 900	3 712
1961	38 900	3 627
1962	66 700	3 079
1963	23 300	1 401
1964	24 400	9 522
1965	55 000	7 017
1966	26 300	7 596
1967	8 800	6 189
1968	1 400	9 116
1969	26 800	12 252
1970	7 900	17 872
1971	2 200	33 329
1972	1 300	20 560
1973	1 600	33 900
1974	2 500	38 391
1975	1 600	55 459
1976	400	50 981
1977	1 900	116 400
1978	3 600	37 288
1979	4 300	53 583
1980	400	39 139
1981	6 100	41 217
1982	1 100	32 176
1983	2 100	38 332
1984	2 800	37 969
1985	700	27 278

	Catch (t)				Catch limits (t)			
Year	Purse-seine	Dem	Mid	Trawl (Dem+Mid)	Pel PUCL	Mid TAC	Dem Res	Trawl PMCL
1986	500			31 378				
1987	2 834			38 571				
1988	6 403			41 482				
1989	25 872			58 206				
1990	7 645			56 721				35 000
1991	582			39 759				45 000
1992	2 057			37 208				40 000
1993	11 651			35 998				55 000
1994	8 207			20 030				58 000
1995	1 986			10 790				58 000
1996	18 920			31 846				58 000
1997	12 654			31 671				58 000
1998	26 680	36 279	15 770	52 049				34 000
1999	2 057	21 580	2 161	23 741				34 000
2000	4 503	9 229	15 408	24 637	5 000			34 000
2001	915	8 814	19 198	28 011	5 000			34 000
2002	8 148	4 863	11 098	15 961	5 000	31 500	12 500	44 000
2003	1 012	3 562	25 306	28 869	5 000	31 500	12 500	44 000
2004	2 048	4 933	27 153	32 086	5 000	31 500	12 500	44 000
2005	5 627	5 280	28 998	34 278	5 000	31 500	12 500	44 000
2006	4 824	4 133	18 057	22 190	5 000	31 500	12 500	44 000
2007	1 903	4 812	25 028	29 840	5 000	31 500	12 500	44 000
2008	2 280	4 449	23 772	28 221	5 000	31 500	12 500	44 000
2009	2 087	4 129	29 019	33 147	5 000	31 500	12 500	44 000
2010	4 353	5 596	30 791	36 387	5 000	31 500	12 500	44 000
2011	10 990	5 228	29 048	34 277	12 000	31 500	12 500	44 000
2012	2 199	4 941	22 579	27 520	5 000	31 500	12.500	44 000
2013	596	2 695	28 417	31 112	12 469	34 650	12 500	47 150
2014	2 760	3 087	10 053	13 140	15 194	38 115	12 500	50 165
2015	2 040	4 747	7 976	12 723	12 233	41 927	12 500	54 427
2016	1 588	5 230	11 613	16 843	7 268	38 658	12 500	51 158
2017	1 466	5 703	17 545	23 234	8 372	28 200	8 004	36 204
2018	967	4 626	22 775	27 400	8 947	25 500	5 977	31 477
2019	1 082	4 720	16 498	21 218	9 567	27 670	8 455	36 125
2020	2 174	4 301	19 710	24 011	9 989	27 670	8 455	27 670
2021					8 762	27 670	8 455	27 670

Kingklip

Stock status	**Unknown**	**Abundant**	**[✓ Optimal]**	**Depleted**	**Heavily depleted**
Fishing pressure	**Unknown**	**Light**	**[✓ Optimal]**	**Heavy**	

Introduction

Kingklip *Genypterus capensis* (Figure 19) belongs to the cusk-eel family (Ophidiidae) and is a demersal fish that is endemic to southern Africa. Its distribution ranges from Walvis Bay in Namibia to KwaZulu-Natal in South Africa (although there are indications that the distribution extends even further eastwards). Kingklip are found at depths between 50 m and 800 m (Figure 20), generally in rocky areas on the continental shelf and shelf edge. Juveniles feed on benthic fish, crustaceans and squid, whereas the diet of the adults consists almost entirely of demersal fish. Kingklip move further offshore (and deeper) as they get older, with juveniles largely restricted to depths shallower than 200 m. They are relatively slow-growing and long-lived (about 25 years), and grow to lengths of up to 1.6 m. Although female kingklip grow faster than males, male fish generally reach maturity at a younger age than do females. Also, males appear to mature later on the West Coast than on the South Coast.

Figure 19: Kingklip *Genypterus capensis*. Photograph courtesy of SAEON

Length at 50% maturity for male fish on the West Coast is approximately 65.5 cm (~5 years) and on the South Coast about 62 cm (~4 years). The length at 50% maturity for females is 81 cm (~6.5 years) and 72.5 cm (~5.6 years) on the West and South coasts, respectively. Spawning takes place on both the West and South coasts, generally from autumn to spring, with peak spawning between June and September. Kingklip form large aggregations to spawn and the largest known such aggregation is on the Southeast Coast near Port Elizabeth. Although the kingklip resource is relatively small in comparison to other exploited South African fish populations, it is an important bycatch species due to its high market value and it is of appreciable economic importance to several South African fisheries. Kingklip is currently mostly caught as incidental bycatch by the hake trawl and hake longline sectors.

History and management

Annual catches of kingklip (all taken as incidental bycatch by the hake trawl fleet prior to 1983) fluctuated between 400 t and 700 t in the 1930s and 1940s (Figure 21), and then increased steadily to a peak of 5 800 t in 1973, with most catch being taken on the West Coast. Catches then fluctuated between about 3 000 and 5 000 t until the start of the kingklip-directed longline fishery in 1983. The substantially increased catches made by the longline sector over the period 1983–1989 (peaking at over 8 000 t in 1986) clearly impacted the resource and catches in both longline and trawl sectors decreased until the directed longline fishery was closed in 1990. An almost immediate increase in catches by the hake trawl sectors followed, reaching a peak of 4 759 t in 2002. This peak coincided with increased levels of kingklip bycatch in the hake-directed longline fishery that had been established in 1994. Bycatch of kingklip in both the hake trawl and longline fisheries then showed a decline, prompting the introduction of an annual precautionary upper catch limit (PUCL) in 2005 (Figure 21) that has subsequently been retained as the primary regulatory measure for the resource. This PUCL is a "global" catch limit that applies to the hake-directed sectors (trawl and longline) in which kingklip is caught as bycatch. Efforts to ensure that the PUCL is not exceeded have followed a co-management approach, with the

Department interacting closely with the relevant fishing associations.

The results of the first assessment of kingklip conducted in 1992 indicated that the resource was severely depleted. A subsequent assessment undertaken in 2002 used a deterministic age-structured production model (ASPM) and indicated limited recovery (10%) of the resource since the previous assessment. Projections indicated that catches of 3 000 t per annum would keep the stock relatively stable, and this was the basis for the 3 000 t PUCL introduced in 2005. The PUCL was increased to 3 500 t for 2006, and was subsequently maintained at this level until 2014 (Figure 21). An updated assessment was conducted in 2008 using catch and survey abundance data that had since become available. The assessment indicated that estimates of resource status were very sensitive to assumptions with respect to stock structure. If the kingklip on the South African coast is regarded as a single stock, then the resource was estimated to be fully exploited. However, if stocks on the West and South coasts are assumed to be separate, then the West Coast stock was estimated to be healthy whereas the South Coast stock was estimated to be over-exploited. The 2008 updated assessment suggested further analyses were required before an alteration to the PUCL could be considered. Additionally, a seasonal (September–November) closed area on the shelf edge near Port Elizabeth was implemented in 2008 as a management tool to assist the recovery of the stock by protecting a spawning aggregation.

The kingklip PUCL was increased to 5 264 t for the 2014 season based on the results of a simple replacement yield (RY) assessment of the resource conducted during 2013, and this level was maintained for the 2015 and 2016 fishing seasons. An updated RY assessment was conducted in 2016, during which difficulties in properly estimating survey catchability resulted in some uncertainty regarding reliable estimates of replacement yield. Confronted with this uncertainty, a relatively conservative approach was adopted and the PUCL was reduced to 4 450 t for the 2017 fishing season. An ASPM assessment was conducted in early 2017, but problems were encountered in obtaining satisfactory fits to the available data, again leading to unreliable results. The PUCL was consequently maintained at 4 450 t for the 2018 and 2019 fishing seasons. Efforts to find and digitise the historical data required for a reliable ASPM assessment had not advanced to the point where such an assessment could be conducted in 2019. A routine update of the RY assessment was consequently conducted during 2019 to provide a basis for scientific advice for the management of the kingklip resource. The results of the update were used to recommend a PUCL of 3 905 t for the 2020 and 2021 fishing seasons.

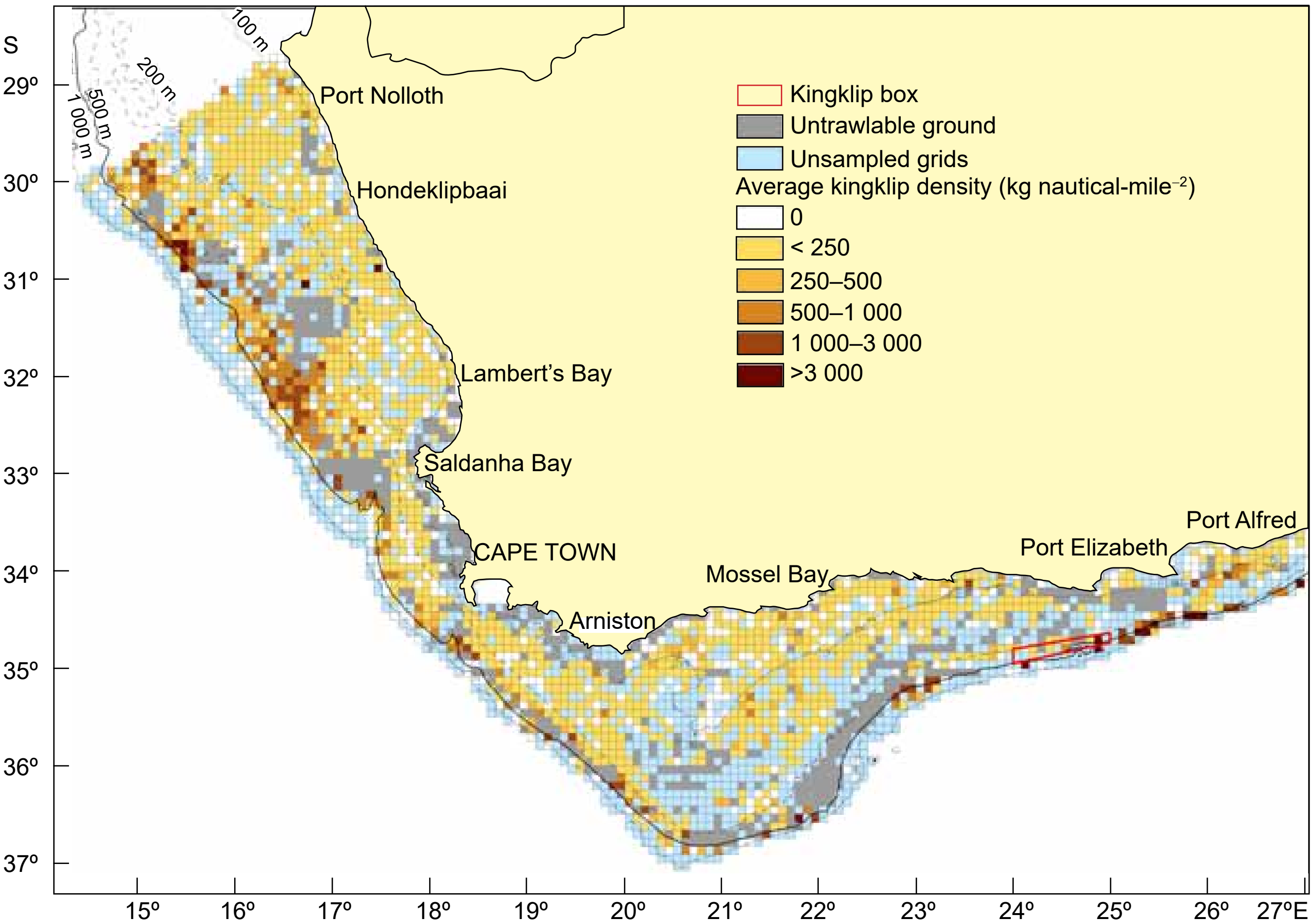

Figure 20: Distribution of kingklip *Genypterus capensis* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

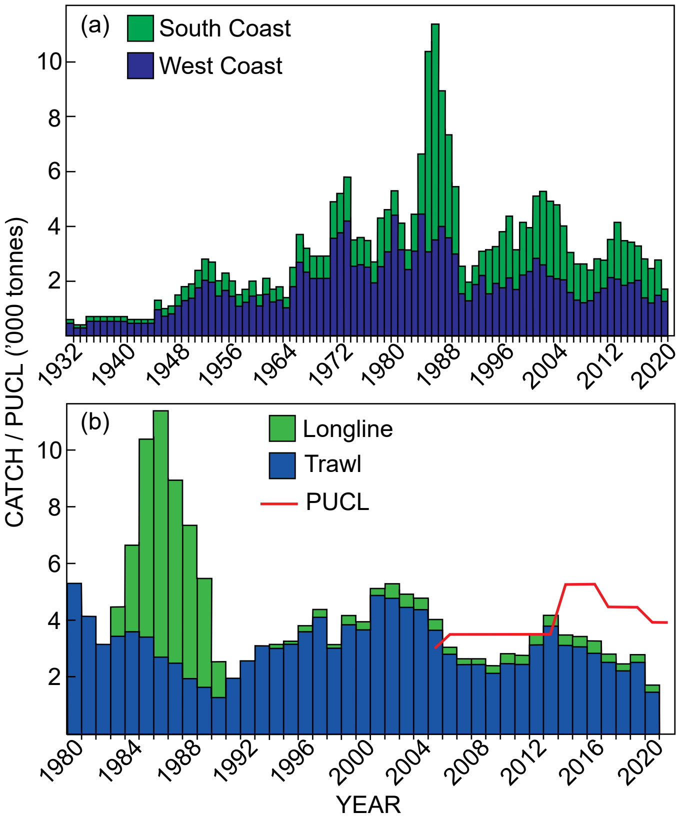

Figure 21: (a) Annual catches (tonnes) of kingklip *Genypterus capensis* on the West and South Coast for the period 1932–2020. (b) Annual catches per fishing sector for the period 1980–2020 (catches prior to 1983 were all made by the trawl fishery), and the precautionary upper catch limit (PUCL) that was introduced in 2005

Research and monitoring

Abundance estimates for kingklip (Figure 22) are derived from demersal research surveys conducted using the swept-area method. These surveys are designed to estimate the abundance of hakes, although other demersal species (including kingklip) are included in the data collection. Additional to the abundance estimates, the surveys provide length-frequency data and biological information on sex, maturity, age, body condition and diet. A detailed description of the surveys is provided in the section on Cape hakes.

There is some uncertainty concerning the stock structure of kingklip, a feature that has compromised the reliability of attempts to assess the status of the resource. Early studies using morphometrics and otolith shape suggested two, and possibly even three, stocks of kingklip; one on the West Coast, one on the South Coast and possibly a third stock on the central Agulhas Bank. Differences in growth and size/age-at-maturity estimates obtained from West and South Coast fish could be considered to provide some support for at least the two-stock hypothesis, but it must be recognised that such differences can be realistically obtained from a single breeding stock where the offspring move to different areas with different environmental conditions. A genetic study conducted in 2005 using analyses of allozyme markers indicated a single genetic stock. A recent study employing advanced genetic techniques (analyses of both microsatellites and mitochondrial DNA) indicated separate West and South Coast stocks of kingklip, but the data did indicate appreciable gene flow between the two components. Further work on this is being conducted using a single nucleotide polymorph (SNP) approach. A multiple-method study that includes parasite biotags, otolith shape and microchemistry, and meristic and morphometric characteristics, to examine kingklip population structure is also underway.

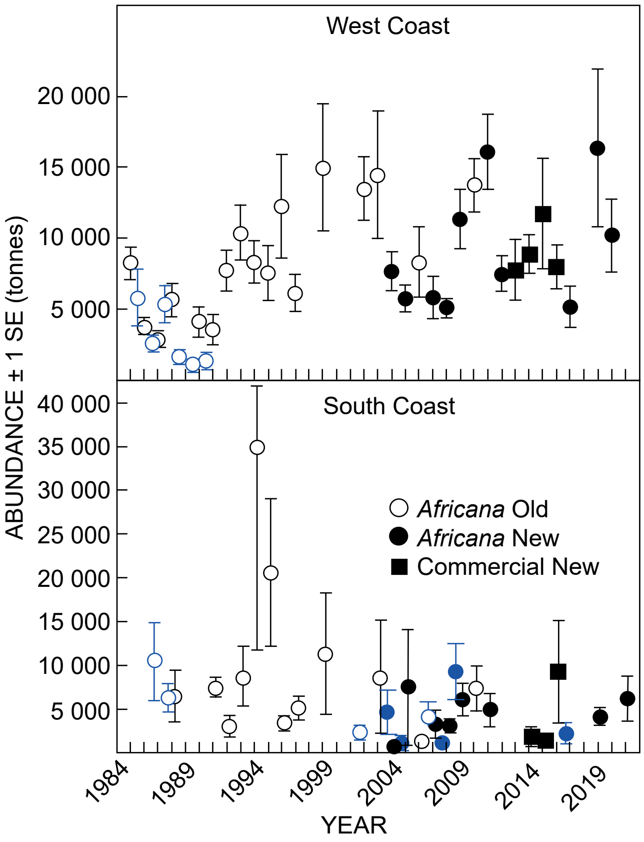

Figure 22: Kingklip abundance estimates derived from fishery-independent swept area demersal surveys. Estimates are illustrated by coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West Coast) and spring (South Coast) surveys are indicated with blue symbols. Note that surveys that only extended to the 200 m isobath have been excluded from the figures. Also note that estimates across the vessel-gear combinations cannot be directly compared due to differences in catchability. *Africana* = research vessel RS *Africana*, Commercial = commercial fishing vessel

Current status

The 2021 update of the kingklip RY assessment used catch data (coast-specific trawl and longline) extending to the end of 2020 (Figure 21) and fishery-independent survey abundance estimates encompassing the West Coast survey of the summer of 2020 and the South Coast survey of the autumn of 2021 (Figure 22). The assessment results suggested that the South Coast component of the resource is increasing in abundance at about 1.7% per annum while the West Coast component is increasing at about 2.9% per annum (Table 4, Figure 23). Estimates of RY generated by the assessment (medians of the posterior distributions) were 1 430 t for the South Coast component of the resource and 2 871 t for the West Coast component (Table 4). In view of the uninformative nature of the assessment in terms of resource status, a precautionary ap-

Table 4: Parameter estimates of kingklip coast-specific replacement yield (tonnes) and average percentage change in abundance per annum arising from the Bayesian analyses framework. The 95% probability intervals about each estimate are provided in parentheses

		South Coast	West Coast
Replacement yield	Median	1 430	2 871
		(1 065; 1 645)	(2 521; 3 430)
	25th percentile	1 316	2 731
Average % change in abundance per annum	Median	1.702	2.907
		(−0.288; 4.473)	(2.466; 3.418)

proach in setting the PUCL was adopted. The sum of the 25th percentiles of the posterior distributions of the South and West Coast RY estimates (1 316 and 2 731 t, respectively, see Table 4), corresponding to a total of 4 047 t, was set as the PUCL for the 2022 fishing season.

Ecosystem interactions

South Africa has committed to implementing an ecosystem approach to fisheries management (EAF). This approach extends fisheries management beyond the traditional single-species approach to the entire marine ecosystem. In 2006, the permit conditions for all sectors in the hake fishery contained a specific "ecosystem impacts of fishing" section for the first time. Given that kingklip are taken as bycatch in the hake fishery sectors, these conditions (see the section on Cape hakes) would also apply to kingklip.

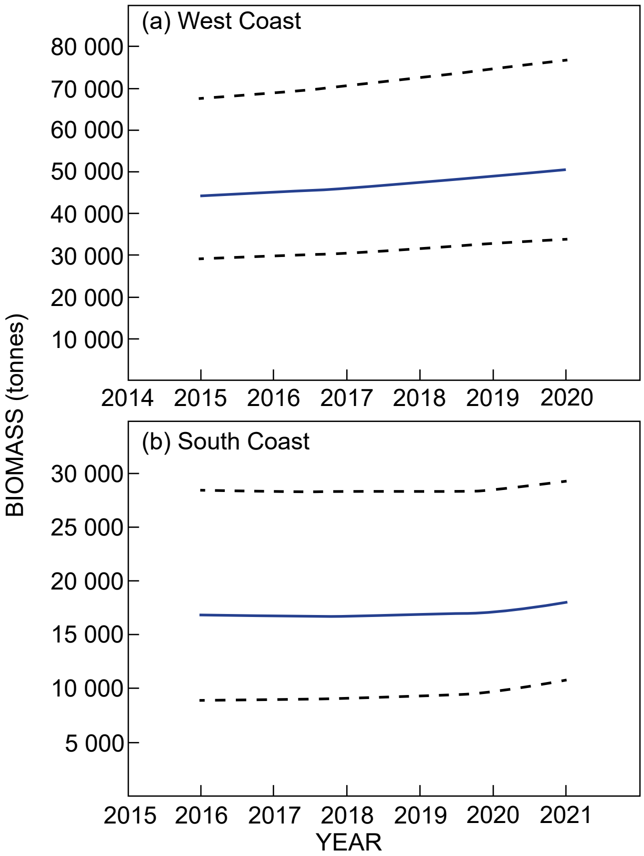

Figure 23: Bayesian posterior medians of abundance over the last five years for (a) the West Coast and (b) the South Coast kingklip resource off South Africa. 95% probability interval envelopes are shown as dashed lines

Further Reading

Henriques R, Nielsen ES, Durholtz D, Japp D, von der Heyden, S. 2017. Genetic population sub-structuring of kingklip (*Genypterus capensis* - Ophidiidae), a commercially exploited demersal fish off South Africa. *Fisheries Research* 1877: 86–95.

Japp DW. 1990. A new study on age and growth of kingklip *Genypterus capensis* off the south and west coasts of South Africa, with comments on its use for stock identification. *South African Journal of Marine Science* 9: 223-237.

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Payne AIL. 1986. Observations on some conspicuous parasites of the southern African kingklip *Genypterus capensis*. *South African Journal of Marine Science* 4: 163-168.

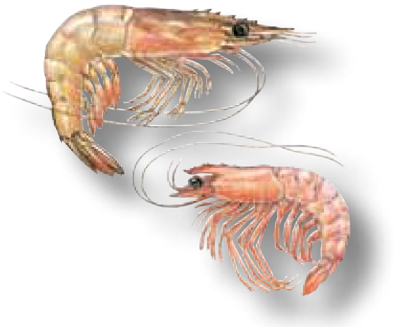
Useful statistics

Annual catches (tonnes) of kingklip *Genypterus capensis* by coast and fishing sector and the precautionary upper catch limit (PUCL) that was introduced in 2005. WC = West Coast; SC = South Coast.

	Catch (t) - trawl		
Year	WC	SC	Total
1932	436	164	600
1933	290	110	400
1934	290	110	400
1935	508	192	700
1936	508	192	700
1937	508	192	700
1938	508	192	700
1939	508	192	700
1940	508	192	700
1941	436	164	600
1942	436	164	600
1943	436	164	600
1944	436	164	600
1945	944	356	1 300
1946	726	274	1 000
1947	798	302	1 100
1948	1 089	411	1 500
1949	1 307	493	1 800
1950	1 379	521	1 900
1951	1 742	658	2 400
1952	2 032	768	2 800
1953	1 960	740	2 700
1954	1 452	548	2 000
1955	1 669	631	2 300
1956	1 452	548	2 000
1957	1 089	411	1 500
1958	1 234	466	1 700
1959	1 452	548	2 000
1960	1 089	411	1 500
1961	1 524	576	2 100
1962	1 234	466	1 700
1963	1 307	493	1 800
1964	1 016	384	1 400
1965	1 815	685	2 500
1966	2 686	1 014	3 700
1967	2 323	877	3 200
1968	2 105	795	2 900
1969	2 105	795	2 900
1970	2 105	795	2 900
1971	3 557	1 343	4 900
1972	3 774	1 426	5 200
1973	4 210	1 590	5 800
1974	2 532	956	3 488
1975	2 600	982	3 582
1976	2 519	952	3 471

	Catch (t) - trawl			Catch (t) - longline			
Year	WC	SC	Total	WC	SC	Total	PUCL
1977	1 953	737	2 690				
1978	2 551	1759	4 310				
1979	3 080	1532	4 612				
1980	4 415	878	5 293				
1981	3 149	963	4 112				
1982	2 410	721	3 131				
1983	2 246	1 169	3 415	842	200	1 042	
1984	2 558	1 034	3 592	1 881	1 159	3 040	
1985	1 750	1 650	3 400	1 314	5 656	6 970	
1986	2 287	399	2 686	1 231	7 453	8 684	
1987	2 083	392	2 475	1 948	4 504	6 452	
1988	1 519	408	1 927	2 091	3 311	5 402	
1989	1 407	223	1 630	1 607	2 209	3 816	
1990	1 002	266	1 268	557	708	1 265	
1991	1 271	680	1 951	0	0	0	
1992	1 884	676	2 560	0	0	0	
1993	2 207	884	3 091	0	0	0	
1994	1 445	1 560	3 005	92	48	140	
1995	1 863	1 275	3 138	65	48	113	
1996	1 596	1 981	3 577	170	60	230	
1997	1 972	2 128	4 100	155	120	275	
1998	1 632	1 366	2 998	53	87	140	
1999	2 104	1 737	3 841	141	171	312	
2000	2 166	1 465	3 631	199	103	302	
2001	2 651	2 210	4 861	183	57	240	
2002	2 280	2 479	4 759	312	202	514	
2003	1 870	2 558	4 428	317	160	477	
2004	1 823	2 539	4 362	266	141	407	
2005	1 790	1 851	3 641	255	121	376	3 000
2006	1 476	1 322	2 798	110	127	237	3 500
2007	1 213	1 223	2 436	105	85	191	3 500
2008	1 122	1 307	2 429	83	118	202	3 500
2009	1 153	958	2 111	138	140	278	3 500
2010	1 405	1 057	2 462	199	149	348	3 500
2011	1 540	891	2 431	212	126	338	3 500
2012	1 866	1 272	3 138	270	112	383	3 500
2013	1 801	1 995	3 796	281	84	365	3 500
2014	1 525	1 584	3 109	327	25	352	5 264
2015	1 610	1 441	3 051	335	28	363	5 264
2016	1 613	1 217	2 829	414	21	434	5 264
2017	1 085	1 412	2 497	297	2	299	4 450
2018	969	1 231	2 200	237	10	246	4 450
2019	1 231	1 278	2 509	253	14	267	4 450
2020	1 026	432	1 458	235	12	247	3 905
2021							3 905

KwaZulu-Natal crustaceans



Stock status	Unknown	Abundant	Optimal Deep-water	Depleted Shallow-water	Heavily depleted
Fishing pressure	**Unknown**	**Light** Shallow-water	**Optimal**	**Heavy** Deep-water	

Introduction

The KwaZulu-Natal crustacean-trawl fishery consists of two components: a shallow-water fishery (5–40 m) on the Thukela Bank and at St Lucia in an area of roughly 500 km^2, and a deep-water fishery (100–600 m) between Cape Vidal in the north and Amanzimtoti in the south, covering an area of roughly 1 700 km^2 along the edge of the continental shelf. Species captured in the shallow-water trawl fishery include white prawns *Penaeus indicus* (80% of the historic prawn catch), brown prawns *Metapenaeus monoceros* and tiger prawns *Penaeus monodon*. The abundance of shallow-water prawns on the fishing grounds is highly variable between years, depending on recruitment. Shallow-water prawns have a 1-year lifespan and the juvenile stages are spent in estuaries; recruitment therefore depends on rainfall and river run-off.

Species captured in the deep-water sector include pink and red prawns *Haliporoides triarthrus* and *Aristaeomorpha foliacea*, langoustines *Metanephrops mozambicus* and *Nephropsis stewarti*, rock lobster *Palinurus delagoae* and red crab *Chaceon macphersoni*. These species are longer-lived and do not have an estuarine juvenile stage.

More than 75% (by mass) of the total catch of both fisheries is discarded at sea because it has little commercial value. Discards include some cephalopods (octopus, squid and cuttlefish), fish (many species), elasmobranchs (sharks and rays), and lower value crustaceans.

History and management

Following a period of sporadic trawling, the fishery started in the mid-1970s and reached a peak in terms of vessel numbers in the mid-1980s. The fishery is relatively small, with a value of R32 million in 2017, and is based in Durban (KwaZulu-Natal). Landed catches totalled approximately 500 tonnes annually in the 1980s but has fluctuated strongly between approximately 200 and over 500 tonnes since then. Collection of regular statistics only began in 1988.

Management of the fishery is via effort-control which is effected by limiting the number of vessels allowed to operate in the two sectors of the fishery. Management previously had the objective to mitigate bycatch (mainly to protect juvenile linefish species) of the shallow-water part of the fishery. However, since fishing in the shallow-water sector has stopped owing to the promulgation of the uThukela MPA in 2019 and cannot be resumed anymore in this area, such considerations are no longer necessary. The main objective now is the setting of appropriate total allowable effort (TAE) levels for the remaining deep-water section of the fishery which considers all target species and bycatch.

Research and monitoring

In the absence of suitable biological data (growth rate, size at sexual maturity) on the various species targeted by this fishery, annual catch and effort data were used as input to a Schaefer surplus production model in order to produce a preliminary stock assessment. Initially, the landing (discharge) data were examined for suitability, but these were excluded because, based on the information recorded in the landing records, it was not possible to split the effort data (number of trawling days based on dates of the trip) into shallow- and deep-water sectors. There were also anomalous catch values, which may have resulted from the possible inclusion of landing data based on fishing in Mozambique. There were also numerous trips for which no dates were available. The catch and effort data which were finally used were those provided by skippers on the daily trawl drag sheets (logbooks), and which spanned the period from 1990 to 2006. Annual estimates of total catch were based on the annual sum of the total combined catch per trawl of four deep-water target species (pink prawn, langoustine, deep-water crab and deep-water rock lobster).

A range of surplus production models was therefore applied to the catch and catch per unit effort (CPUE) data for the KZN crustacean trawl fishery in 2009. This included a simple equilibrium model, fitting data separately to the Schaefer and Fox equations (on all four deep-water species combined and then individually). Unrealistically high levels of both maximum sustainable yield (MSY) and the fishing mortality that would produce this yield (F_{MSY}) were obtained. Data were therefore fitted to both simple and complex non-equilibrium surplus production models (Schaefer, Fox and Pella-Tomlinson), also resulting in unrealistic estimates of MSY and F_{MSY}. The inability of the models to produce reasonable estimates of MSY and F_{MSY} is probably a consequence of the time-series of data only commencing many years after the fishery began.

There was no comprehensive stock assessment in recent years. The catch and effort situations, however, reveal that there is urgent need for a full assessment of the resource at reasonable intervals.

Current status

In the last few years, fishing effort for deep-water crustaceans has more or less continuously increased, resulting in substantially higher landings. As a result, total CPUE and those for the main target species have been declining since 2018. The deep-water resource is therefore under heavy fishing pressure but its status is still regarded as optimal. Fishing pressure on shallow-water crustaceans is light but their status is depleted. However, there is still a need for more and better data collection and systematic research on the biology of the various prawn species and bycatches.

Historically, catches of shallow-water prawns strongly reflected annual recruitment from estuaries, and a predictive equation relating historical river flows to shallow-water prawn catch on the Thukela Bank was developed for the 1988–2000 period by the then Department of Water Affairs and Forestry. Very low catches since 2008 are attributed to drought conditions and the closure of the mouth of the St Lucia estuary by a sandbar. The exception was a five-month opening in 2007

Table 5: Total landings of the KZN crustaceans by species group, 1992–2021

		Total catch (tonnes)						
		Inshore fishery	Offshore fishery				Both fisheries	
Year	TAE (No. of permits)	Shallow-water (all prawns)	Deep-water (all prawns)	Langoustine	Red crab	Rock lobster	Landed bycatch	Total catch
1992		87	112	70	187	31		
1993		52	166	83	138	33		
1994		47	65	46	79	10		
1995		23	106	60	108	11	34	342
1996		53	80	58	82	10	24	307
1997		15	79	78	114	10	21	317
1998		90	72	49	100	6	22	338
1999		72	124	49	73	8	28	354
2000		107	142	76	53	10	34	422
2001		63	103	80	54	8	4	313
2002		93	102	56	28	9	10	298
2003		29	162	60	40	5	91	387
2004		40	116	42	24	4	82	308
2005		33	140	42	31	4	88	339
2006		21.3	123	49	31	4.7	47	276
2007	7	17.6	79.2	53.2	24.1	5.3	46.9	226.3
2008	7	9.2	104.6	31.4	17.0	4.7	34.9	201.8
2009	7	7.7	196.7	59.8	20.9	9.7	53.4	348.2
2010	7	7.3	172	51.2	23.2	22	69.4	345.1
2011	7	9.6	150.1	79.2	19.7	22.7	63.2	344.5
2012	7	7.6	153.4	81.6	21.6	18.5	71.4	354.1
2013	7	0	103.3	61.5	12.0	8.1	34.4	221.0
2014	7	0	149.6	56.2	11.5	4.9	25.2	247.7
2015	7	0	228.8	62.7	52.7	6.4	35.1	386.1
2016	7	0	160.5	35.9	42.5	4.3	24.8	269.5
2017	7	0	272.4	65.5	82.6	9.5	35.0	467.4
2018	7	0	287.6	108.9	104.6	7.4	54.7	565.3
2019	7	0	68.5	78.0	55.1	8.2	40.5	252.2
2020	7	0	66.6	114.5	70.6	7.7	62.7	324.7
2021	7	0	74.2	149.8	87.2	18.5	158.9	488.9

and very limited opening in 2020 and 2021. Recruitment of juvenile prawns from the estuary to the Thukela Bank was therefore blocked for many years. In the short periods following the opening of the estuary, no effort was directed in the shallow-water areas (< 100 m depth). The area is now largely within the iSimangaliso and uThukela MPAs and is therefore not accessible to the fishery. Consequently, there have been no catches in the shallow-water areas for more than a decade (Table 5, Figure 24).

Trends in catches in the deep-water fishery relate both to abundance and targeting practices, where specific depths or substratum types are selected to achieve a desired species mix for highest economic value. In the recent decade, landings fluctuated between about 220 and 565 tonnes, averaging around 340 tonnes (including retained bycatch of fish and cephalopods). In 2021, however, landed catch increased from 2020 by more than 50% to 489 tonnes (Table 5, Figure 24). Main contributors to this growth are the landings of langoustines (+ 30% or 150 t) and retained by-catch (+ 153% or 159 t). Deep-water prawns (+ 11% or 74 t), red crabs (+ 24% or 87 t) and rock lobsters (+ 140% or 19 t) also had substantially higher landings in 2021. As in the most recent years, there were no landings of shallow-water prawns.

The total fishing effort in the deep-water fishery remained relatively constant from 2012 to 2014 (at about 1 100 drags per year) but increased gradually to 1 879 drags in 2018. In 2019, the effort declined again to 1 462 drags, likely as a result of only 3 vessels fishing (down from 4 in 2019). The decreased effort in 2019 partly explains the decreased landings of all deep-water species compared with the record year of 2018 (Figure 24). In 2020 and 2021, 5 vessels were fishing, the highest number in 14 years. The number of drags increased to a record 2 029 and 3 606 drags, respectively. In 2021 the number of trawl hours also reached a record level of about 16 500 hours, an increase of 75% from 2020. Since 2019, this figure has more than doubled. This increased nominal effort likely contributed to the substantial increases in total catch in the most recent two years, and also does reflect effort creep stemming from the sustained use of larger vessels which has not been the case previously. Furthermore, logbook data reveal that the CPUE for the main target species, especially prawn and red crab but most recently also langoustine, are seriously declining (Figure 25). Action is therefore required to arrest or reverse these trends.

More than 75% (by mass) of the total catch of both fisheries is discarded at sea because it has little commercial value (such as some cephalopods, many species of bony fish, sharks and rays, and lower-value crustaceans) but a substantial amount of bycatch is also landed. The mitigation of this bycatch is a huge challenge and an aim of the management of this resource. In the past, the fishing season for the shallow-water fishing grounds (Thukela Bank) was therefore restricted to March–August to reduce bycatch of linefish species. However, such considerations are no longer required since the zone is no longer accessible to fishery. There is ongoing research on the bycatch composition of this fishery but more knowledge on their biology is needed to develop further mitigation strategies. The amount (Table 5; Figure 24) and composition (Figure 26) of landed bycatch shows marked seasonal fluctuation. Of the 159 t of bycatch landed in 2021, more than 60% were fish species and more than 30% molluscs. Almost 70% of the fish bycatch consisted of three species: greeneye *Chlorophthalmus punctatus*, deep-water hake *Merluccius paradoxus* and jacopever *Helicolenus dactylopterus*. The mollusc bycatch consisted of the three cephalopod species: common cuttlefish *Sepia officinalis vermiculata*, Natal deep octopus *Velodona togata* and Indian squid *Loligo duvauceli*.

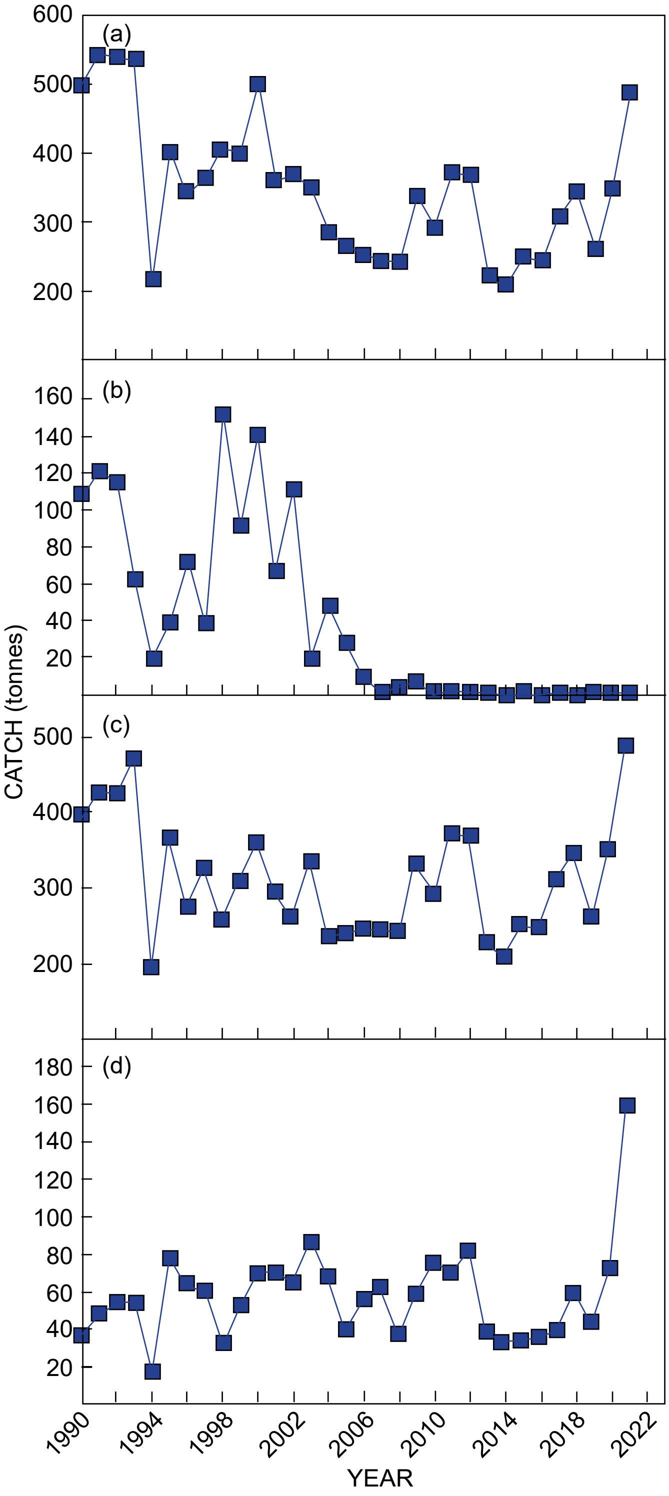


Figure 24: Total annual catches of (a) the entire fishery, (b) the shallow-water fishery, (c) the deep-water fishery and (d) landed bycatch in of the KZN crustacean trawl fishery for the period of 1990–2021

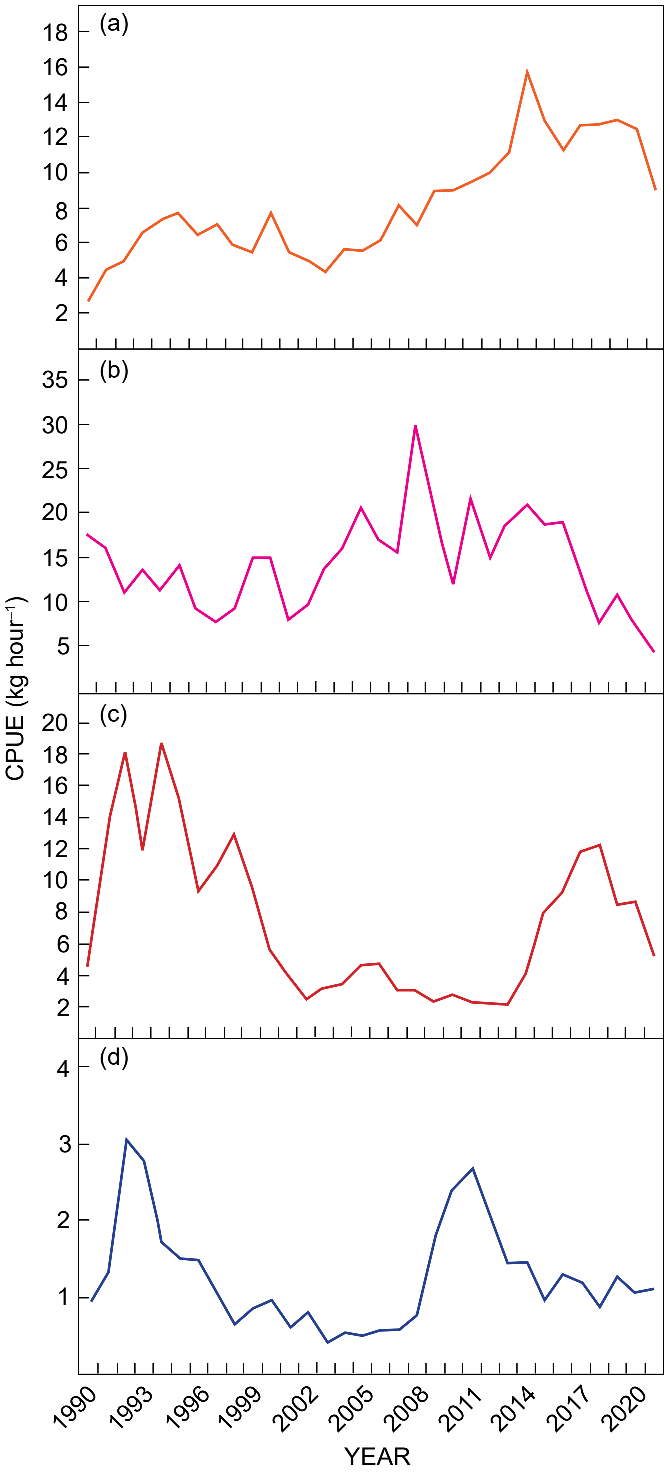


Figure 25: Abundance trends according to CPUE of (a) langoustine, (b) pink prawns, (c) red crabs and (d) deep-water lobsters for the period 1990–2021

Ecosystem interactions

The crustacean fisheries take high amounts of bycatch. In the past, the fishing season for the shallow-water fishing grounds (Thukela Bank) was therefore restricted to March–August to reduce bycatch of linefish species. However, such considerations are no longer required since the zone is no longer accessible to the fishery.

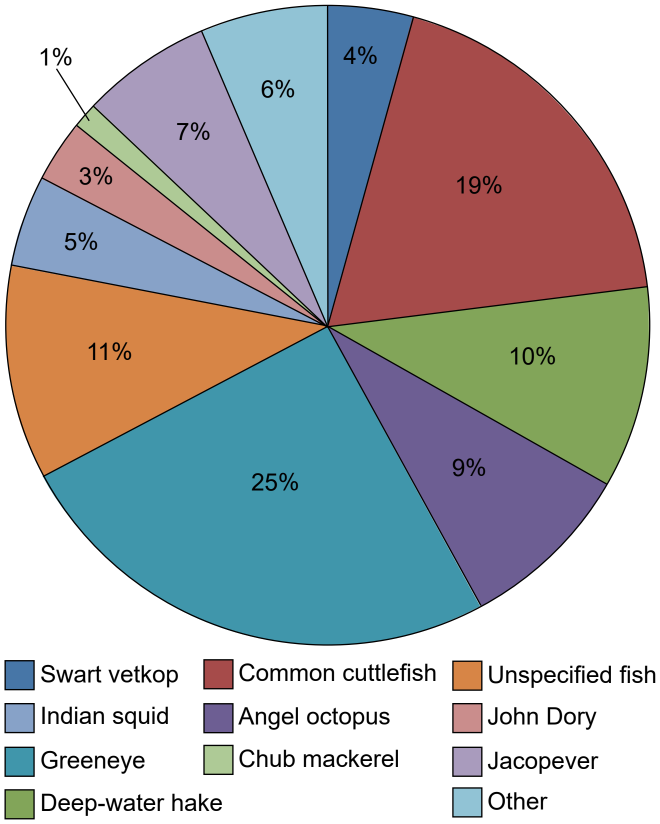


Figure 26: Species composition (by mass) of landed bycatch of the KwaZulu-Natal crustacean trawl fishery for the 2021 fishing season.

The situation around the closing of the mouth of the St Lucia estuary is most likely impacted by aspects of climate change. However, this only affects the shallow-water part of the fishery that has ceased to exist. Little is known regarding the biology of the deep-water species, such as reproduction. It is therefore difficult to estimate the current and potential future impact of climate change on this remaining part of the resource. This indicates the need for more research and a precautionary approach in management.

Further Reading

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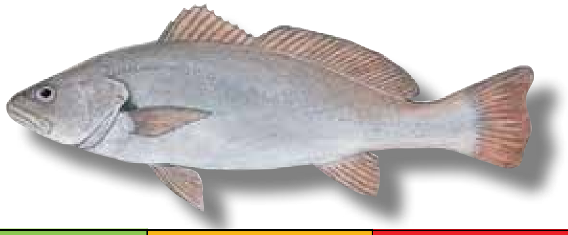
Groeneveld JC, Melville-Smith R. 1995. Spatial and temporal availability in the multispecies crustacean trawl fishery along the east coast of South Africa and southern Mozambique, 1988–1993. *South African Journal of Marine Science* 15: 123–136.

Linefish



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
	Black musselcracker	Hottentot seabream Snoek	Yellowtail Santer Slinger Carpenter Roman	Silver kob Geelbek White stumpnose	Seventy-four Dageraad Red steenbras Dusky kob
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
	Black musselcracker	Hottentot seabream	Snoek Yellowtail Santer Slinger Carpenter Roman	Silver kob Geelbek White stumpnose	

Introduction

Linefishing in South Africa is defined as the capture of fish with hook and line, but excludes the use of longlines. Together, the three sectors of the linefishery (commercial, recreational and small-scale) target between 95 and 200 of South Africa's 2 200 marine fish species. Species targeted in the linefishery display diverse life-history strategies, including many traits that cause these populations to be particularly vulnerable to overfishing, e.g. long lifespans (>20 years), estuarine dependence, sex change and aggregating behaviour. Furthermore, many of the species are endemic to South Africa. Target species of the linefishery include temperate, reef-associated seabreams (e.g. roman *Chrysoblephus laticeps*, hottentot seabream *Pachymetopon blochii*, santer *Cheimerius nufar* and slinger *Chrysoblephus puniceus*), coastal migrants (e.g. geelbek *Atractoscion aequidens* and dusky kob *Argyrosomus japonicus*) and nomads (e.g. snoek *Thyrsites atun* and yellowtail *Seriola lalandi*). More than 90% of the current linefish catch is derived from the aforementioned eight species. Most of the linefish caught are not targeted exclusively by this fishery but form important components of the catch or the bycatch of other fisheries. Effective management of linefish resources that are shared among different fishery sectors can be complex.

The commercial linefishing sector is exclusively boat-based. The total number of registered vessels operating in this sector was estimated at 700 in the late 1990s, which accounted for 37% of all boats operating in marine fisheries in South Africa. From 2006 a maximum commercial allocation of 455 boats has been maintained; however, the number of boats allocated per zone has varied. Line-fishing is a low-earning, labour-intensive industry and therefore important from a human livelihood point of view. Employing an estimated 27% of all fishers, it has the lowest average employment income of all South African fisheries. Although the commercial linefishery has the largest fleet, it contributes only 6% of the total estimated value of all South African marine fisheries.

After the introduction of the towable skiboat in the late 1940s, the recreational boat-based sector expanded rapidly. Landings from this open-access recreational fishery are not reported throughout the region, and for some areas and species the total catch from this sector could be equivalent to that reported by the commercial sector. The recreational linefishery has by far the largest number of participants (>450 000) of all fishery sectors in South Africa and consequently has great economic value. This is especially important to coastal regions dependent on the tourist trade, but also to industries associated with the small craft, outboard motor, fishing tackle and bait trades.

Recently, the small-scale sector was legally created to recognise those fishers who depend on marine living resources for direct food security – usually from very poor coastal communities or those using simple traditional methods. There are approximately 7 200 active small-scale fishers along the South African coastline and an estimated 85% of them harvest linefish. The small-scale fishery is described in detail in a separate section within this report.

History and management

The origins of linefishing in South Africa can be traced back to the fishing activities of indigenous Khoi people and European seafarers in the 1500s. Despite an abundance of fish, the fishery was slow to develop in the 1700s due to various restrictions implemented by the Dutch administration. These fishing restrictions were removed when the British captured the Cape Colony in 1795, and during the 1800s boat-based linefishing developed into a thriving industry.

Fishing effort in the Cape at the turn of the 19th Century was already considerable (between 0.12 and 0.37 boats per kilometre of coastline). This increased dramatically during the 20th Century and peaked in the 1980s and 1990s (>3 boats per kilometre of coastline). The sharp increase in fishing effort, together with an increase in operational range and the rapid development in fishing technology (echosounders, nylon line, etc.), as well as the additional offtake by other fishing fleets such as trawl and purse-seine, led to overfishing of most of the linefish resources around the coast towards the end of the 20th Century.

Despite its long history, the first comprehensive management framework for the linefishery was only introduced in 1985 when this fishery was formally recognised. However, successive research surveys indicated continuing declines in linefish resources. In December 2000, the Minister of Environmental Affairs and Tourism, taking cognisance of the critical status of many linefish stocks, declared linefish resources to be in a State of Emergency, as provided for in the Marine Living Resources Act (MLRA, Act 18 of 1998). Effort was reduced in the commercial sector and fixed at 450 vessels and the hake and tuna components were developed into separate sectors. To rebuild collapsed stocks and to achieve a sustainable level of catch, a linefish management protocol was developed in 1999 to base regulations in the linefishery on quantifiable reference points. This remains the basis of linefish management.

Several regulations were put in place to manage fishing pressure on linefish resources. To accommodate the large number of users, launch sites and species targeted, and to allow flexibility of the operational range, the commercial linefishery is currently managed through a total allowable effort (TAE) allocation, based on boat and crew numbers. The level of commercial effort was reduced to the levels stipulated in the declaration of the emergency when linefish Rights were allocated in 2003 (for the medium-term) and in 2005 for the long-term fishing Rights (Figure 26; Table 6). The TAE was set to reduce the total catch by at least 70%, a reduction that was deemed necessary to rebuild the linefish stocks. Although this appears to be a substantial reduction in the commercial linefish effort, it must be noted that trends in the catch information derived from the historic commercial landings for the period 1985–1998 indicated that a relatively small number (20%) of the vessels in the fishery accounted for the majority (80%) of the reported catches, and these highly efficient vessels remained in the fishery. On the other hand, the number of Right Holders who activate their annual permits has steadily decreased in recent years, indicating that the TAE might be exceeding the number of economically viable fishing units. The most recent commercial linefish fishing rights allocation process (FRAP) took place in early 2022, and the subsequent appeals process was not finalised at the time of writing.

The recreational fishery is managed by several species-specific output restrictions, such as size and bag limits, closed areas and seasons. The regulations defining these restrictions sit within the MLRA, which is far less adaptable than permit conditions – the means by which restrictions are applied to commercial fisheries. Consequently, many output restrictions for the recreational sector are outdated and need to be revised to offer the appropriate restrictions necessary for the sustainability of species targeted by the recreational sector.

In 2016, the Department called for expressions of interest in the formalisation of the small-scale fishery. A total of 316 communities from four coastal provinces registered their interest. In 2020, 109 small-scale fishing co-operatives were allocated 15-year fishing rights in the Northern Cape, Eastern Cape and KwaZulu-Natal. Many species allocated to the small-scale basket are primary targets of the commercial and recreational linefish sectors, and these shared resources must be carefully monitored given the increased fishing pressure expected.

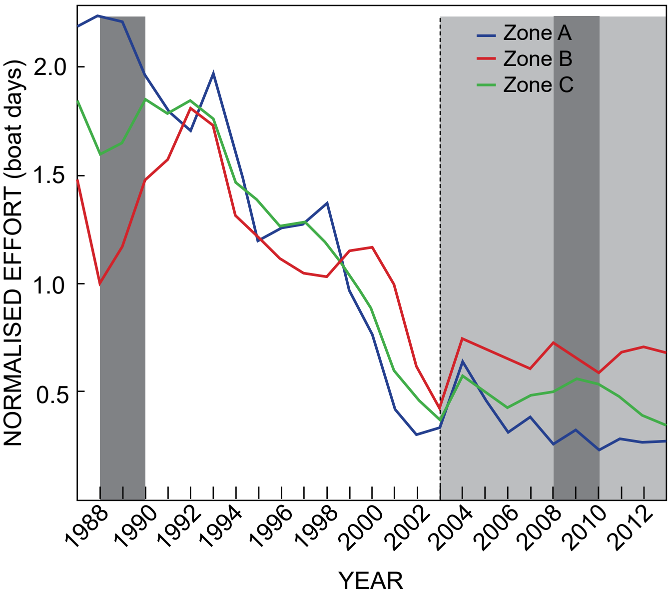


Figure 26: Trends in normalised linefish effort (boat days) for the three linefishery management zones: A, B and C. Individual trips were sourced from the NMLS database (1987–2013). The dark grey shaded areas indicate periods of size-data collection from dedicated observer programmes. The dashed line indicates the initiation of the commercial fishing Right allocation after the linefish emergency, while the light grey shaded area indicates the "post emergency" period of relatively stable linefish effort

Research and monitoring

Monitoring of the boat-based linefishery in the Cape was introduced by Dr JDF Gilchrist in 1897, in the form of a shore-based observer programme that aimed to record statistics on catch and effort at all the fishing centres. Comprehensive per-species catch-and-effort data from the boat-based commercial fishery have been collected since 1985 and stored in the national marine linefish system (NMLS). A national observer programme was implemented from 2008 until 2010, in which scientific observers recorded catch-and-effort data and collected size frequencies per species from the boat-based fishery at access points around the country. With the increased focus on formalising the small-scale fishery around the country, a national, shore-based monitoring programme was implemented from June 2012 to May 2013. Data from this programme were used to assess the stocks of seven of the most important target species along the Eastern Cape coast - two of these species (bronze bream *Pachymetopon grande* and stone bream *Neoscorpis lithophilus*) are sustainably fished, but the population status of dusky kob is estimated to be at only 1.3% of pristine spawner biomass.

In addition to the use of fisheries-dependent data, alternative methods to investigate fish abundance and species composition are being employed. A comprehensive comparison of monitoring methods, including standardised angling, underwater visual census by divers and remote underwater video, suggests that the latter provides the most unbiased census method. After successful application of this method in selected areas, an even more sophisticated version, the stereo baited remote underwater video (sBRUV) technique, has been used in a nationwide investigation of fishing hotspots and marine protected areas to determine fish abundance, species composition and size frequencies of reef-associated linefishes.

The biology of the fishes caught in the linefishery has been remarkably well-studied considering the large variety of target species in comparison with other fisheries, as evident from the published linefish species profiles that contain information on life-history, ecology and population status of 139 linefish species.

Assessing the status of linefish stocks has been a priority in recent years. Drawing on the enormous body of data contained in the NMLS, a novel method to standardise catch-per-unit-effort (CPUE) data that accounts for targeting in the multi-species linefish sector has been developed. Following on, a comprehensive Bayesian state-space surplus production model framework (JABBA: Just Another Bayesian Biomass Assessment) was developed and its extension (JABBA-Select) was applied to the eight most-important species, namely slinger, carpenter *Argyrozona argyrozona*, hottentot seabream, geelbek, snoek, yellowtail, santer and silver kob *Argyrosomus inodorus* (for recent catches see Table 7).

The type of stock assessment applied is determined by the nature and quality of data available. In situations where traditional stock assessment methods are not applicable, alternative methods must be developed. Length-based analyses, such as spawning potential ratio (SPR), are often the only option to determine stock status for many linefish species due to the lack of long-term catch and effort data. In a recent study, observer-collected length-frequency data from two time-periods 20 years apart (1988–1990 and 2008–2010; see Figure 27), before and after management regulations were implemented, in combination with life-history information, were used to estimate the SPRs for 17 linefish species. The general increase in SPR between the 1980s, when the fishery was essentially open-access, and the 2000s, after the fishery was declared to be in

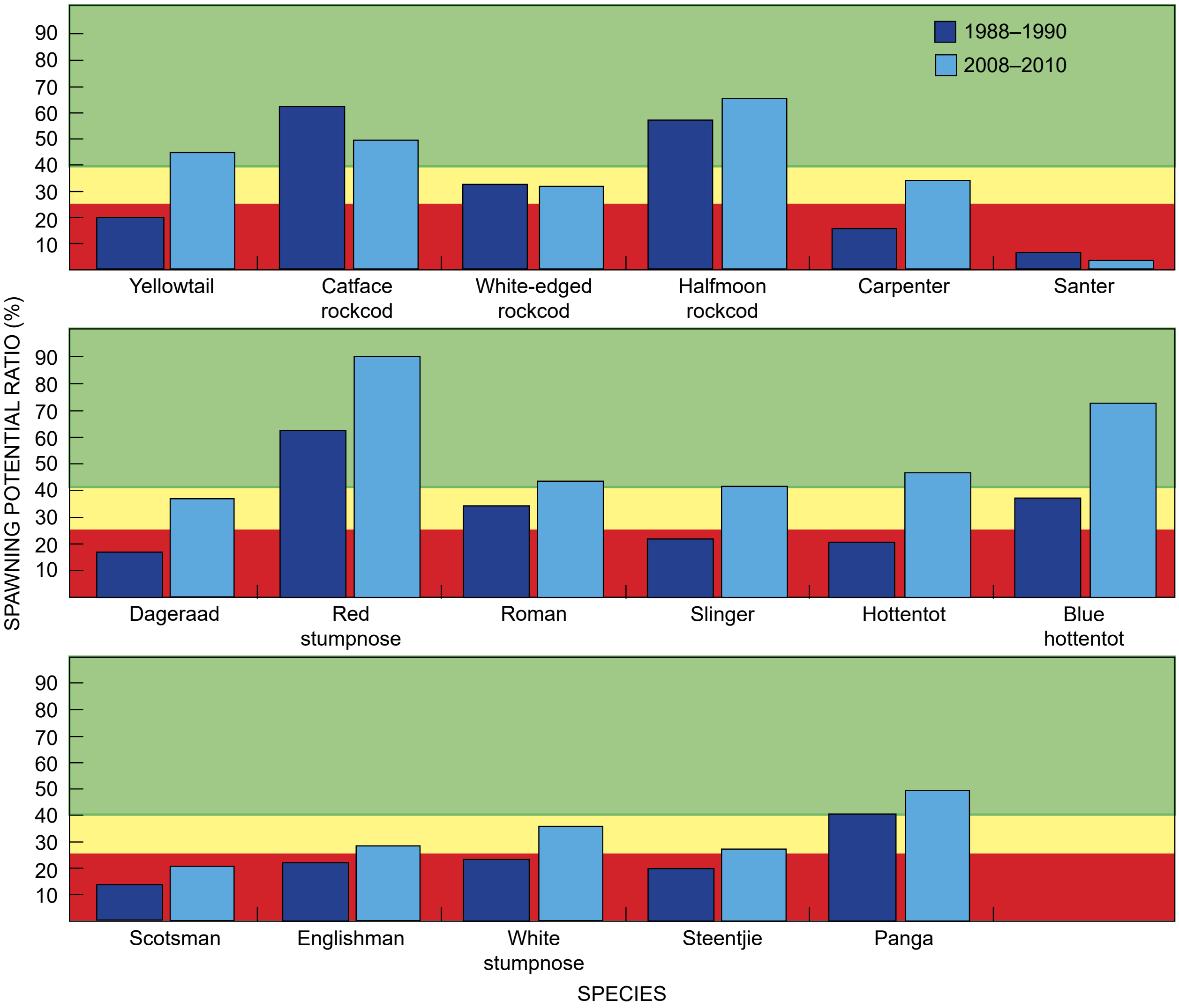


Figure 27: Spawning potential ratio (SPR%) of 17 South African linefish species for the periods 1988–1990 and 2008–2010. Green, yellow and red shading represent SPRs that are considered to be underexploited, overexploited and collapsed, respectively, as defined under the linefish management protocol

a state of emergency, is encouraging (Figure 27). However, the observed increases were not consistent among species and there were three species that showed a decrease in SPR between the two periods: white-edged rockcod, catface rockcod and santer. To understand why certain species are predisposed to depletion, the stock-status estimates were correlated to species-specific life-history traits to identify length-based indicators of susceptibility to exploitation. The results have shown that simple measures, such as catching fish at optimum length, or at least above length-at-maturity, as well as limiting fishing mortality to be lower than natural mortality, succeed in increasing stock status in most fishes.

For rare linefish species, such as red steenbras and dageraad, which are caught infrequently and are subject to stringent bag and size limits, a novel approach based on encounter probabilities in the catch has been applied. Application of this robust method confirms the continuous decline of these once-abundant species to critically low levels (Figure 28). These two species are now of serious conservation concern and have been included on the IUCN Red List of Threatened Species as Endangered. Furthermore, a unique spatio-temporally disaggregated model has been successfully applied to geelbek as this species undertakes a complex, size-dependent migration. Sector-specific assessments, such as that of white stumpnose *Rhabdosargus globiceps* which quantifies the relative contribution of the commercial and recreational fishing sectors to the species' decline in Saldanha Bay, seek to address equality issues that arise in a multi-sector fishery.

Current status

The results of stock assessments conducted in 2017 indicate that the drastic reduction of fishing effort from 2003 onwards resulted in the partial recovery of some species, such as the slinger, santer, hottentot seabream and carpenter (Figure 29; Table 8). However, other important stocks such as silver kob are still being overfished, given the cumulative impact of the linefishery and inshore-trawl fishery on this species. The yellowtail assessment suggests that the stock is optimally exploited, while snoek remains underexploited. The annual catch of the nomadic yellowtail and snoek is dependent on their availability to nearshore linefishers and is, therefore, highly variable. Moreover, the inconsistent quality of yellowtail and snoek landed by the linefishery detracts from the optimal use of these important stocks. There is also considerable inter-fishery conflict around these species which are also caught by other fisheries (i.e. tuna pole-line and trawl fishery in the case of snoek, and tuna pole-line and beach seine-net fisheries in the case of yellowtail).

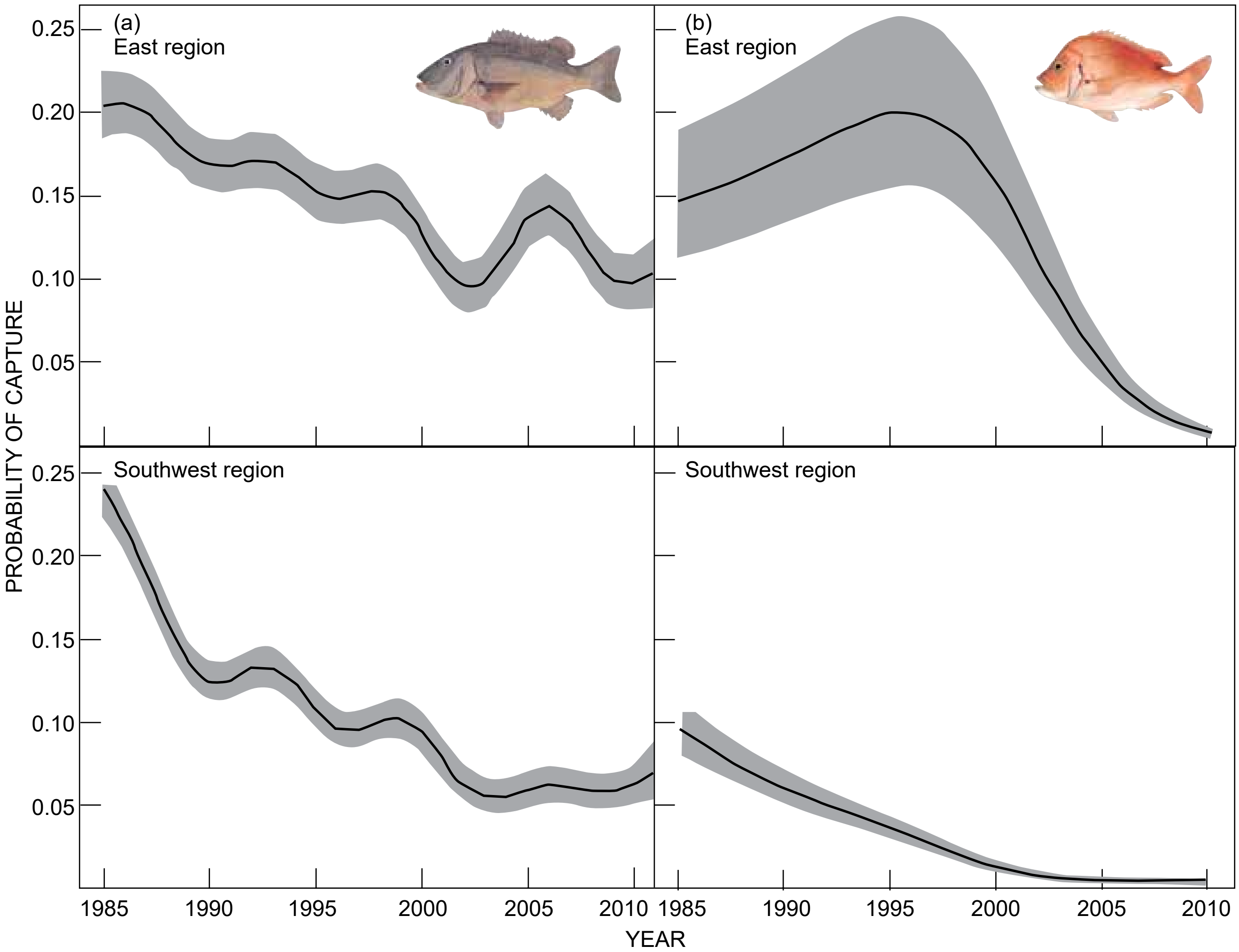


Figure 28: Time-series of standardised capture probability for (a) red steenbras *Petrus rupestris* and (b) dageraad *Chrysoblephus cristiceps* in commercial linefish catches for the period 1985–2011 along the South African East (top panel) and Southwest coasts (bottom panel)

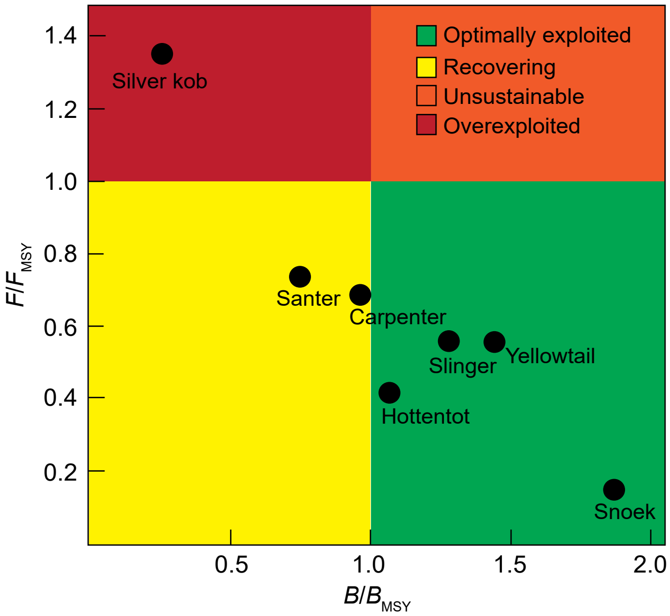


Figure 29: Kobe phase plot summarising the stock status estimates of fishing mortality relative to F_{MSY} and biomass relative to B_{MSY} for linefish species. Only results from stock assessments conducted by the Linefish Scientific Working Group (LSWG) in 2017 are included

Quantifying trends in population abundance is central to ecological research and resource management. JARA (Just Another Red-List Assessment) was designed as an IUCN Red List decision-support tool that utilises formal stock assessment outputs (biomass), or standardised or nominal CPUE, to quantify the percentage change in a population and assign a probability of satisfying each of the Criterion A categories adopted by the IUCN Red List procedure: Least Concern, Near Threatened, Vulnerable, Endangered or Critically Endangered. Using JARA, IUCN Red List assessments were produced for several linefish species (Figure 30). Carpenter and red roman showed increasing population trends of 112% and 83%, respectively, and each had a 100% probability of being classified as Least Concern. In contrast, the Englishman seabream population decreased by an estimated 53%, resulting in a 70% probability that it is categorised as Endangered. The red steenbras population was estimated to have declined by 88%, resulting in a 99% probability that it is categorised as Critically Endangered.

Ecosystem interactions

The linefishery has the potential to be one of the most ecologically and economically viable fisheries in South Africa, due to the following factors: (i) the fishing method can be highly selective and bycatch of undersized fish and unwanted species can be avoided; (ii) the labour-intensive, low-technology, low-investment method maximises employment opportunities; (iii) the product is potentially of high quality and many species command a high price on local and international markets; and (iv) linefishing inflicts comparatively minimal impact on the broader ecosystem.

However, the linefishery predominantly targets large, predatory species that occupy the upper trophic levels of the marine system. The systematic removal of these apex predators can therefore have a detrimental effect on the coastal functional ecology. Furthermore, the removal of large, fecund individuals may also weaken the genetic resilience of a species.

Linefish resources are at risk of overutilisation as they are exploited by numerous fishing sectors, many of which do not consistently report linefish catch. These include the traditional commercial, recreational and small-scale linefishery, as well as the inshore and offshore trawl fisheries, the tuna pole-line fishery, the inshore netfishery and the demersal shark longline fishery. The increased expectation of commercial access to linefish resources combined with the localised anticipation of community ownership of adjacent recourses increases the likelihood of stock depletion, to the detriment of all. Of particular concern is the bycatch of linefish species by the trawl fishery, both inshore and offshore. Undersized linefish, caught as trawl bycatch, can be legally sold and compete directly with linefishers who consequently are frequently unable to obtain economically viable prices for their catches, given market saturation from trawl bycatch and mariculture product. Furthermore, trawl gear also damages benthic habitat that may be critical to linefish life histories.

The recovery of overexploited species hinges on the increased protection of juveniles and spawning stock inside marine protected areas (MPAs) and offshore refugia. In August 2019, 20 new MPAs within the South African economic exclusive zone (EEZ) came into effect – a bold and positive step towards promoting sustainability of our marine resources. MPAs not only provide reference areas for research on the effects of fishing and climate change but can enhance and sustain surrounding fisheries. A local study has previously shown that catch rates of fishers that targeted reef fish near the boundary of a newly established marine reserve increased slowly at first and then more rapidly due to the export of larger fish and, five years later, spillover of eggs and larvae.

However, for some severely depleted linefish species such as seventy-four, red steenbras and dageraad, the existing regulations may not be sufficient to induce a recovery. Notably, numerous species that are important to shore- and estuarine-based subsistence fishing, such as dusky kob, are considered collapsed.

Many linefish species are piscivores that are heavily reliant on abundant small pelagic fish (sardine, anchovy, round herring, etc.) as a source of nutrients. The small pelagic fishery is the largest of all South African fisheries, by weight landed, and the sardine stock is currently considered to be depleted/optimal. Recent research demonstrated the importance of sardine as a prey species for geelbek and emphasised the need for conservative management of small pelagic fisheries, given the dependence of many predatory species on small pelagic fish as forage. A functional relationship between sardine and geelbek (Figure 31) indicates that low levels of sardine biomass east of Cape Agulhas have a negative impact on geelbek CPUE in the southwest region in the following year. It is postulated that the juvenile geelbek survival rate is dependent on sufficient availability of prey, i.e. local sardine biomass. This dependency eventually manifests in geelbek CPUE in the southwest region after a minimum lag of one year, when the juvenile geelbek first recruit into the linefishery.

As many as 80 species caught in the linefishery are associated with estuaries and rely on these for feeding, refuge or reproduction. Consequently, the wellbeing of these fish stocks is linked to the ecological status of the estuaries. Reduced or regulated freshwater input, coastal development and pollution are altering estuarine habitats and threatening the wellbeing of dependent fish populations.

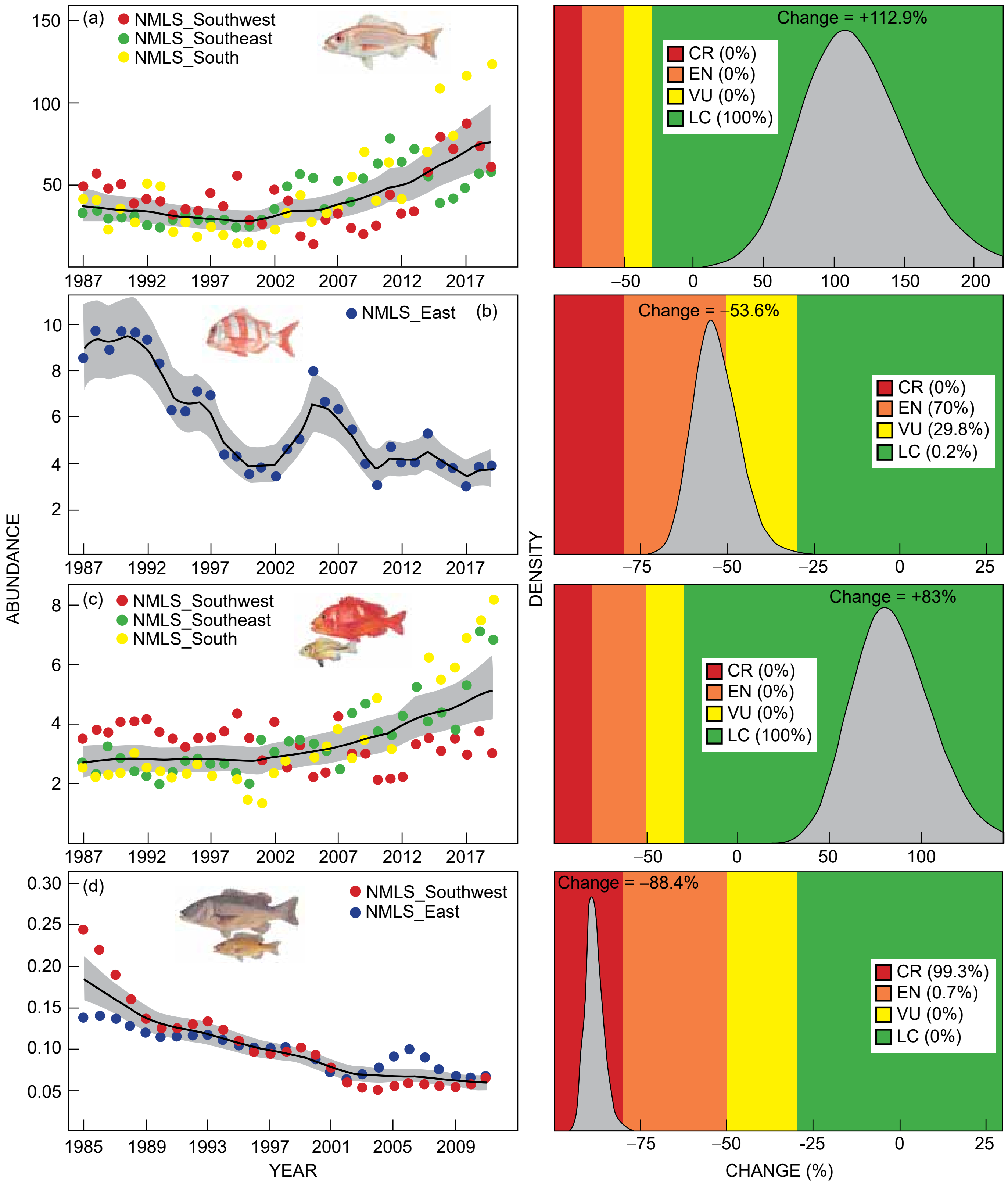


Figure 30: Results of the 'Just Another Red-List Assessment' (JARA) analysis for four important commercial linefish species (from top to bottom): carpenter, Englishman, red roman and red steenbras. On the left is the JARA fit (black line) and 95% credible intervals (grey polygon) when applied to the area-specific catch per unit effort (CPUE) estimates. On the right, the median change in relative abundance of each species and the Bayesian posterior probability for that change is shown by the grey polygon, which is overlaid on the IUCN Red List category thresholds for the Red List Criterion A2. The values in the key show the percentage of the posterior probability distribution falling within each Red List Category (LC = Least Concern; VU = Vulnerable; EN = Endangered; CR = Critically Endangered)

Conservation awareness among recreational anglers has increased dramatically in recent years. Many anglers now practice 'catch and release' and competitive angling formats are constantly adapting to minimise fish mortalities. That said, the number of recreational anglers remains high (in excess of 450 000 individuals) and a recent study found that although captured fish are often released, there may still be significant (up to 20% observed) post-release mortality due to barotrauma, extreme fatigue and hook damage.

Climate change

The linefishery, specifically the small-scale and commercial sectors, are the two fisheries most vulnerable to the effects of climate change. Changes in temperature are likely to be the biggest driver of change in coastal/inshore ecosystems, especially in fishes as they are ectotherms, but long-term changes in winds, upwelling, storm frequency and intensity, and ocean acidification are likely also to play an important role. Predicting how species will respond to climate change has thus become a prerequisite for sustainable management. Species will likely respond through changes in distribution ranges, growth and reproduction, community composition, and possibly behaviour.

To predict species responses, scientists have generally used lab and modelling experiments and extrapolated results onto future climate scenarios. However, an emerging theory suggests that an increase in acute (day to day) environmental variability, termed "ocean weather", associated within long-term mean changes, may have a more pervasive effect on fish populations. Recent research highlighted the importance of acute environmental variability in moderating the physiological performance of the endemic seabream red roman and how the frequency and intensity of these events influence life history parameters (i.e. growth rates) and how tolerance to "ocean weather" may be a more-important indicator of climate resilience. A follow-on study introduced fisheries-induced evolution (i.e. the selective removal of competitive individuals through fishing) and found that red roman from exploited populations were less able to expend energy at temperature extremes than the protected population within Tsitsikamma National Park (TNP) MPA. The study concluded that exploitation has the capacity to alter climate responses of fish populations on a physiological level.

At a broad temporal scale, range extensions of more than 40 linefish species have been documented in the past four decades, largely due to overwintering of tropical, estuarine-associated species in the cool-temperate bioregions. Some of these range extensions persist, establishing viable populations in the new range, such as spotted grunter *Pomadasys commersonii*, which were rare in the Southwestern Cape but are now commonly caught in this cool-temperate bioregion.

Increased CO_2 production and the consequent ocean acidification have been identified as one of the greatest threats to both calcifying and non-calcifying marine organisms. In their early life stages, marine fishes lack well-developed ion regulatory mechanisms for maintaining homeostasis and are potentially vulnerable to elevated partial pressure of carbon dioxide. A study tracking the survival of larval dusky kob *Argyrosomus japonicus* concluded that, in isolation, ocean acidification levels predicted to occur between 2050 and 2090 will not negatively affect size-at-hatch, growth, development, and metabolic responses of larval dusky kob.

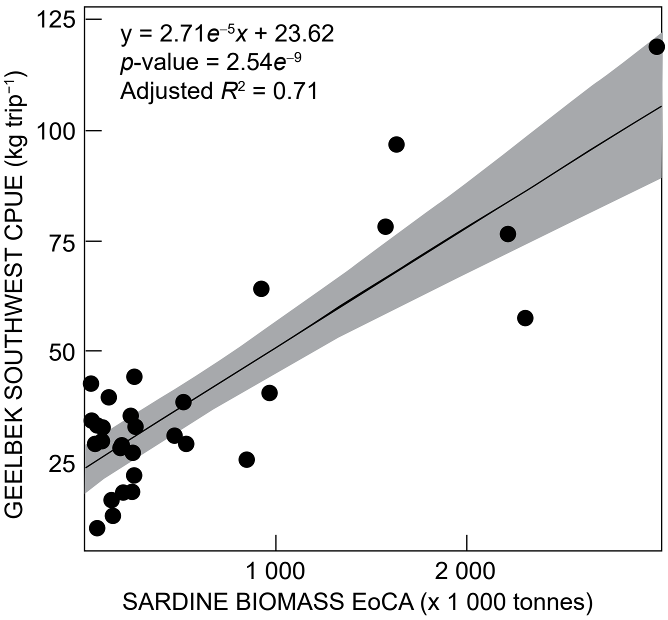


Figure 31: Scatterplot of geelbek southwest CPUE in year$_{n+1}$ plotted against sardine biomass east of Cape Agulhas (EoCA) (x 1 000 t) in year$_n$, with the fitted linear regression, its associated statistical parameters and 95% confidence interval shown in grey

Increased wind strength and storminess will limit the number of sea days for the small-boat fleet. This has already been shown for the traditional Arniston fishers, as detailed in the small-scale fisher section of this report.

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Table 6: Annual total allowable effort (TAE) and activated commercial linefish effort per management zone from 2006 to 2022

Total TAE boats (fishers). Upper limit: 455 boats or 3 450 crew			Zone A: Port Nolloth to Cape Infanta		Zone B: Cape Infanta to Port St Johns		Zone C: KwaZulu-Natal	
Allocation	455 (3 182)		301 (2 136)		103 (692)		51 (354)	
Year	Allocated	Activated	Allocated	Activated	Allocated	Activated	Allocated	Activated
2006	455	385	301	258	103	78	51	49
2007	455	353	301	231	103	85	51	37
2008	455	372	301	239	103	82	51	51
2009	455	344	300	222	104	78	51	44
2010	455	335	298	210	105	82	51	43
2011	455	328	298	207	105	75	51	46
2012	455	296	298	192	105	62	51	42
2013	455	289	301	189	103	62	51	38
2014	455	399	340	293	64	58	51	48
2015	455	356	340	291	64	61	51	45
2016	455	378	340	274	64	59	51	45
2017	455	329	340	232	64	60	51	37
2018	455	324	340	232	64	50	51	42
2019	455	306	340	218	64	50	51	38
2020	455	415	340	314	64	59	51	42
2021**	455	415	340	314	64	59	51	42
2022**	325	TBC	236	TBC	46	TBC	43	TBC

** In the finalisation of the 2021 FRAP, operators were granted exemptions to continue fishing. Furthermore, the FRAP 2021 appeals process was not completed at the time of writing so the ‘allocated’ numbers are preliminary, and the numbers of active vessels were not available.

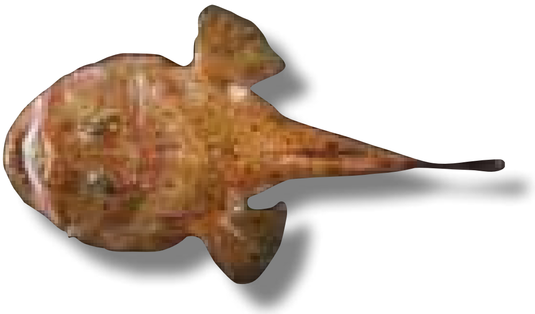
Table 7: Annual catch (t) of the eight most-important linefish species for the period 1985–2021

Year	Snoek	Yellowtail	Kob	Carpenter	Slinger	Hottentot seabream	Geelbek	Santer
1985	1 063	324	1 504	588	312	399	152	73
1986	3 143	817	2 016	768	268	811	262	99
1987	5 642	809	1 902	831	246	915	436	99
1988	4 919	722	1 822	877	132	953	482	57
1989	4 039	868	2 097	775	199	739	810	60
1990	7 892	585	2 540	1 228	262	542	513	86
1991	6 556	542	2 082	1 210	249	522	457	89
1992	5 692	591	1 799	873	305	496	530	114
1993	2 948	888	1 867	695	298	614	610	124
1994	7 759	868	1 348	638	217	815	468	82
1995	9 618	801	1 422	758	235	252	396	85
1996	7 063	497	1 415	879	179	276	384	80
1997	6 623	488	1 471	841	128	322	524	68
1998	7 872	565	1 331	518	114	408	684	64
1999	8 348	339	1 026	574	160	270	467	60
2000	6 543	320	1 093	441	186	234	894	75
2001	6 839	327	831	285	139	109	395	69
2002	3 837	242	784	231	101	79	315	48
2003	4 532	329	544	177	88	106	513	48
2004	7 278	883	720	228	184	254	672	87
2005	4 787	739	647	184	169	168	580	84
2006	3 529	310	800	159	192	87	419	79
2007	2 765	478	841	265	157	128	448	84
2008	5 223	313	715	226	194	120	403	82
2009	6 322	330	884	282	186	184	495	66
2010	6 360	171	838	263	180	144	408	69
2011	6 205	204	625	363	214	216	286	62
2012	6 809	382	441	300	240	160	337	82
2013	6 690	712	313	481	200	173	263	84
2014	3 863	987	289	522	201	192	212	74
2015	2 104	609	246	522	186	143	244	69
2016	1 681	475	277	713	211	211	250	66
2017	1 888	361	199	820	215	188	148	72
2018	2 095	654	213	728	174	215	214	69
2019	1 879	439	454	604	215	188	132	78
2020	2 356	548	635	533	183	222	158	66
2021	2 747	239	352	441	186	151	88	64

Table 8: Detailed status of the South African linefish resources assessed by the Linefish Scientific Working Group in 2017

	Carpenter	Hottentot seabream	Santer	Silver kob	Slinger	Snoek	Yellowtail
Stock Assessment	2017	2017	2017	2017	2017	2017	2017
MSY	1 004 t (807 5–1 319)	446 2 t (298 7–657 4)	147 7 t (111 1–199 4)	784 7 t (557 7–1 196)	347 5 t (273 7–521 5)	24 396 t (16 060–42 422)	1 087 t (757 2–2 613)
Total yield for stock	812 4 t (2015)	196 35 t (2015)*	69 3 t (2015)	295 38 t (2015)	241 8 t (2016)*	6 674 8 t (2015)**	748 5 t (2016)
Relative biomass	$B_{2015}/ B_{MSY} = 0.96$	$B_{2015}/B_{MSY} = 1.07$	$B_{2015}/B_{MSY} = 0.75$	$B_{2015}/B_{MSY} = 0.26$	$B_{2015}/B_{MSY} = 1.28$	$B_{2015}/B_{MSY} = 1.87$	$B_{2015}/B_{MSY} = 1.44$
Relative fishing mortality	$F_{2015}/F_{MSY} = 0.69$	$F_{2015}/F_{MSY} = 0.42$	$F_{2015}/F_{MSY} = 0.74$	$F_{2015}/F_{MSY} = 1.35$	$F_{2015}/F_{MSY} = 0.56$	$F_{2015}/F_{MSY} = 0.15$	$F_{2015}/F_{MSY} = 0.56$
Summary	Carpenter was severely overfished prior to 2000, which resulted in stock decline. However, results from all scenarios in the current assessment indicate that the carpenter stock is rebuilding following many years of decreased fishing mortality ($F < F_{MSY}$). The current biomass is estimated as 38% (25–53%) of the unfished biomass level and the stock is considered optimally exploited. Further recovery is expected under current fishing mortality levels.	Results from the base-case scenario indicate a 90.1% probability that the hottentot stock is above the target biomass ($B/B_0 = 0.4$) and that the stock is being fished below F_{MSY}. The most pessimistic scenario estimates this probability to be marginally less (89.6%) and the most optimistic approaches certainty (99.7%). The stock could likely sustain an increase in fishing mortality of approximately 20% without there being a significant risk of overexploitation.	Results from the base-case scenario indicate a 34% probability that the santer stock is above the target biomass ($B/B_0 = 0.4$) and that the stock is being fished below F_{MSY}. It must be noted that the base case is the most pessimistic of the four scenarios produced, and the remaining three scenarios estimate this probability to be between 82% and 89%. The results imply the santer stock is rebuilding and should reach B_{MSY} by 2021 if current catch levels are maintained. It is unlikely that the stock could currently sustain an increase in fishing mortality without there being a significant risk of overexploitation. Increases in annual catch should be avoided until the biomass target B_{MSY} is reached.	The results are explicit in that all four scenarios indicate a 100% probability that the silver kob stock is severely depleted and continues to be overexploited. The current biomass was estimated as 10.4% (5–17%) of the unfished biomass level. According to the linefish management protocol the silver kob stock has collapsed. Overfishing, and subsequent stock depletion, of silver kob occurred prior to 1987 and despite there having been a trend towards reduced fishing mortality since 1991, this decrease has not been sufficient to initiate stock rebuilding.	Results from the base-case scenario indicate a 83% probability that the slinger stock is above the target biomass (B/B_0 = 0.4) and that the stock is being fished below F_{MSY}. The remaining three scenarios suggest this probability ranges from 39% to 98%. There is little evidence to suggest slinger is overexploited and the stock could potentially sustain a 5% increase in fishing mortality without there being a significant risk of overexploitation.	The results are explicit in that all four scenarios indicate that there is a 100% probability that snoek has been fished below H_{MSY} for the entire assessment period. There is no anecdotal evidence or data to suggest that snoek has been overexploited over the last century and snoek biomass has been increasing for the past 10 years. In contrast, linefish catch in 2014 was unusually low and the 2015 catch was the lowest ever recorded in the linefishery - despite relative consistency in annual offshore trawl catches over the same period. The linefishery targets the nearshore component of the snoek stock, which is renowned for inter-annual variability. This variability is seemingly driven by resource availability and, to a lesser extent, the market price - as opposed to overall biomass. Snoek is the single largest component of the linefishery and has the capacity to sustain increased fishing mortality. However, the current TAE framework of the linefishery is restrictive in that introducing more participants to the fishery is the only viable means of increasing harvest, assuming current fishers make full use of their Right. This would likely have negative impacts, such as increased sector competition and unsustainable exploitation of other species during periods when snoek is unavailable to the linefishery.	According to the base-case scenario, there is a 70.8% probability that the yellowtail biomass is above the target reference point. However, annual catch has exceeded sustainable levels at regular intervals (e.g. 1989, 1993/4, 2004, 2014). This assessment is characterised by an unusually high degree of uncertainty in biomass and harvest estimates as a result of inter-annual variability in CPUE and catch data, which must be acknowledged in the associated scientific recommendations. The remaining three model scenarios in the JABBA-Select assessment suggest that the probability of yellowtail being overexploited is low–between 5.9% and 32.8%. A conservative sustainable yield estimate for this stock would be approximately 700 tonnes per annum. Annual catches exceeding 850 tonnes are not sustainable.

Monkfish



Stock status	**Unknown**	**Abundant**	**[✓ Optimal]**	**Depleted**	**Heavily depleted**
Fishing pressure	**Unknown**	**Light**	**[✓ Optimal]**	**Heavy**	

Introduction

The most common monkfish species occurring in southern African waters is *Lophius vomerinus*, commonly known as the Cape monkfish or devil anglerfish (the latter name referring to the modified dorsal spine near the front of the head that the fish uses as a lure to attract prey). Monkfish are well camouflaged predators characterized by an unusually wide mouth with numerous sharp teeth, a large head and a relatively small body. They live a sedentary life lying on the sea bed and often burrow under the surface sediment while awaiting potential prey (Figure 32). Their diet comprises primarily other demersal fish species and crustaceans. *Lophius vomerinus* occur on both the West and South coasts of southern Africa, their distribution extending from KwaZulu-Natal (KZN) in South Africa to northern Namibia. They occur at depths ranging from about

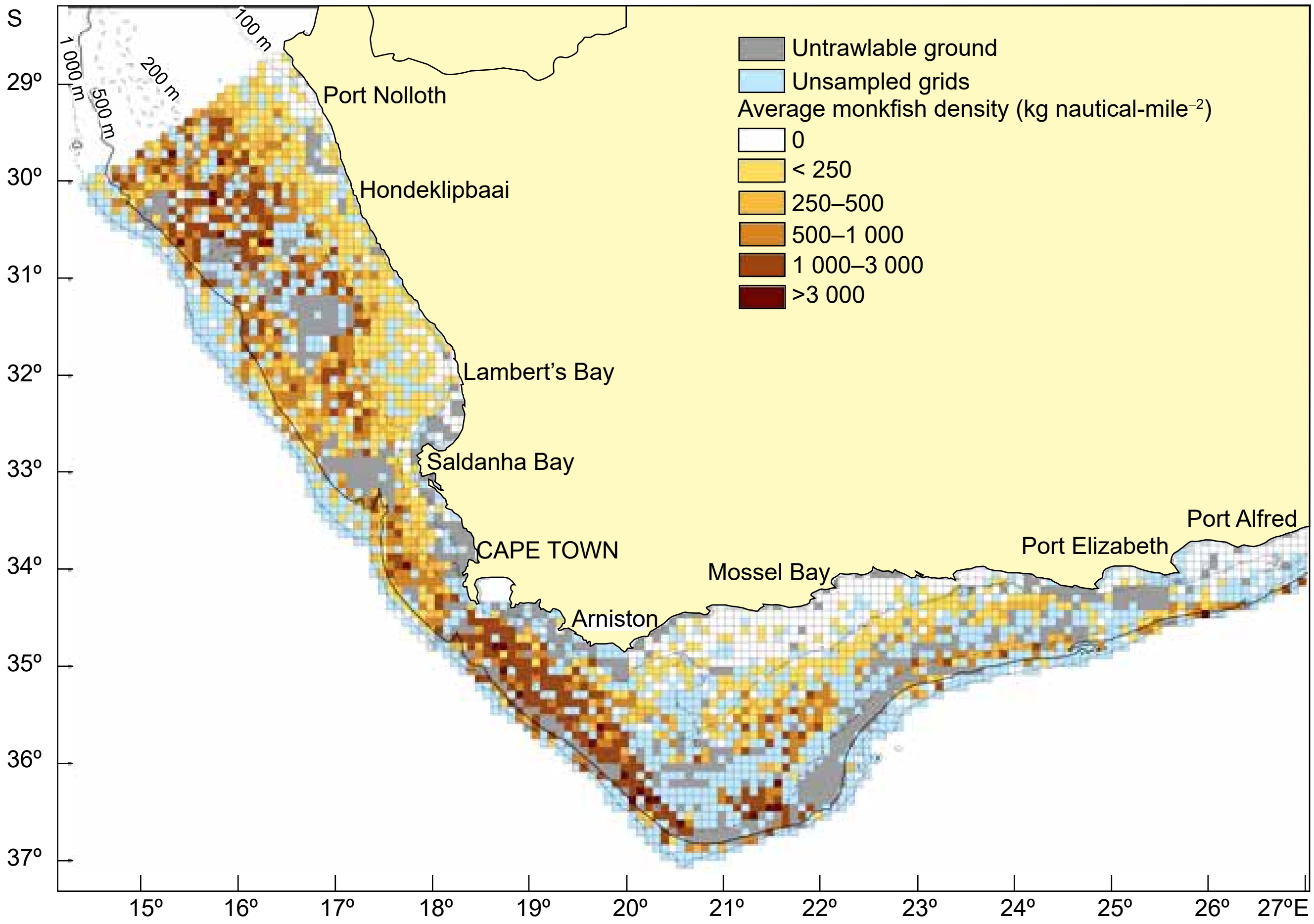


Figure 33: Distribution of Cape monkfish *Lophius vomerinus* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

50 m to 1000 m (Figure 33) and larger individuals tend to be found deeper and further offshore.

The lifespan of Cape monkfish is approximately 17 years, with fish reaching up to 1 m in length. The peak spawning period is in September, based on trends in the female gonadosomatic index (GSI; the weight of the gonads relative to whole body weight). The length at 50% maturity does not differ markedly between the sexes and is estimated to be approximately 37 cm, corresponding to an age of about six years for both sexes.

The species is a high-value product, often marketed as “mock crayfish”. Monkfish is caught almost exclusively as bycatch during hake- and/or sole-directed fishing by the hake trawl fishery, both deep-sea and inshore sectors. Catches are made predominantly on the West Coast.

History and management

Annual catches of monkfish in the hake trawl fishery fluctuated around 4 700 t over the period 1974 to 1994, and subsequently increased to a peak of over 10 000 t in 2001 (Figure 34). The increased catches raised concerns of overexploitation and efforts were directed at assessing the status of the resource to establish a basis for sustainable management. An initial attempt to apply a modified version of a hybrid age-structured surplus production model was unsuccessful as the model failed to converge due to the uninformative nature of the data. Subsequently a coast-disaggregated replacement yield (RY) approach was employed, the results of which indicated that annual catches should not exceed 7 300 t. A precautionary upper catch limit (PUCL) was formally introduced into the demersal trawl fishery permit conditions in 2006 and remains the primary means of regulating catches of monkfish. The initial PUCL in 2006 was set at a level of 7 000 t per annum. However, this was generally exceeded during the early years of its implementation (Figure 34), largely due to difficulties associated with real-time monitoring and management. Co-management procedures have been developed and implemented over time and catches subsequent to 2011 have generally been well below the PUCL (Figure 34).

The RY analysis is generally updated every two years. Although the 2011 RY assessment suggested that the PUCL could be increased to 8 300 t, this increase was delayed until the 2013 fishing season while improved monitoring of catches and implementation of a co-management procedure with the hake trawl industry associations was being developed. Updated assessments conducted in 2013 and 2015 provided no grounds to alter the PUCL and it was consequently maintained at 8 300 t (Figure 34) for the 2014 to 2016 fishing seasons. The assessment conducted in 2017, however, resulted in replacement yield estimates of 7 652 t and 402 t for the West Coast and South Coast components of the resource, respectively. Based on these results, the PUCL for the 2018 and 2019 fishing seasons was set at 8 054 t. The results of the assessment update conducted during 2019 led to a recommendation to reduce the monkfish PUCL to 7 972 tonnes for the 2020 and 2021 fishing seasons.

Figure 32: A monkfish in its natural habitat. Photograph courtesy of SAEON

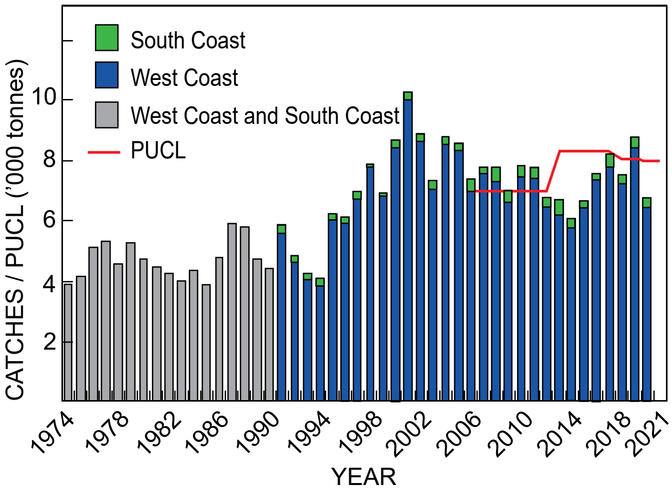


Figure 34: Annual catches (tonnes) of Cape monkfish made by the hake trawl fishery for the period 1974–2020, and the precautionary upper catch limit (PUCL) that was introduced in 2006. Catches after 1990 can be split by coast

Research and monitoring

Abundance estimates for monkfish (Figure 35) are derived from demersal trawl research surveys conducted using the swept-area method. These surveys are designed to estimate the abundance of hakes, although data on other demersal species, including monkfish, are collected. The surveys also provide length-frequency data and biological information on sex, maturity, age, body condition and diet. A detailed description of the demersal trawl surveys is provided in the Cape hakes section. Commercial landings of monkfish from the hake demersal trawl fleets are also monitored.

Morphometric and meristic analyses on Cape monkfish indicated potential stock structuring between the West and South Coasts. However, this hypothesis was not supported by genetic evidence derived from an analysis of allozyme markers and uncertainty regarding monkfish stock structure still remains. A research project investigating stock structure of monkfish using parasites as biotags is ongoing.

Current status

The most recent assessment of the monkfish resource was conducted in 2021, again using a coast-disaggregated RY approach applied to data ending in 2020. The resultant replacement yield estimates ranged from 7 745 tonnes to 8 100 tonnes across both coasts (Table 9), depending on assumptions regarding the overall catchability (q) of the demersal surveys that provide the fishery-independent abundance data. The base-case model (q = 1.0) indicated that the resource has shown

Table 9: Maximum likelihood estimates of coast-specific replacement yield (RY, tonnes) for the South African Cape monkfish resource for different assumed values of survey catchability (*q*) from the 2021 updated assessment. The associated log likelihood (–lnL), asymptotic normal 90% confidence intervals (90% CI, upper and lower) and the CV (%) corresponding to each estimate are also shown

q	West Coast				South Coast			
	–lnL	RY(t)	CV(%)	90%CI	–lnL	RY(t)	CV(%)	90%CI
0.7	–28.6	7 682	2.0	7 387, 7 958	–13.9	418	24.2	224, 598
1.0	–28.3	7 474	1.4	7 285, 7 676	–13.7	401	17.6	266, 527
1.3	–27.1	7 354	1.1	7 207, 7 511	–13.5	391	13.8	288, 488

a slight decrease on the West Coast over the period 2017–2020 followed by a slight increase in 2021 (Figure 36), while the South Coast component of the resource appears to have remained stable over the period 2017–2021. In view of these results, it was considered appropriate to reduce the PUCL to 7 875 tonnes per annum for the 2022 and 2023 fishing seasons. The monkfish assessment will be updated again in 2023, the results of which will be used to provide advice for the 2024 and 2025 fishing seasons.

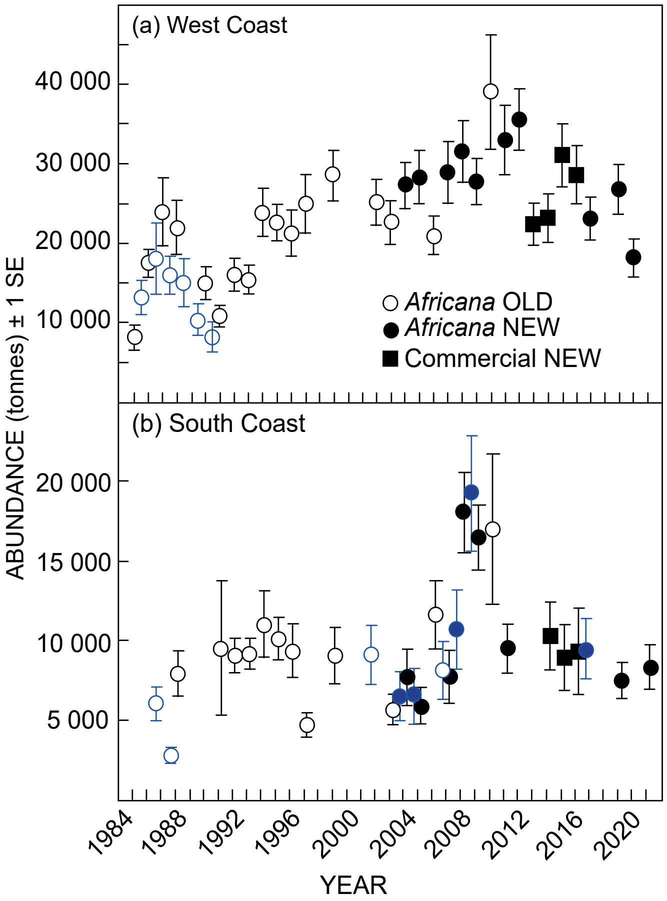


Figure 35: Cape monkfish abundance estimates (tonnes ± 1 SE) derived from fishery-independent swept area demersal surveys. Estimates are illustrated by coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West Coast) and spring (South Coast) surveys are indicated with blue symbols. Note that surveys that only extended to the 200-m isobath have been excluded from the figures and that estimates across the vessel-gear combinations cannot be directly compared due to differences in catchability. *Africana* = research vessel RS *Africana*, Commercial = commercial fishing vessel

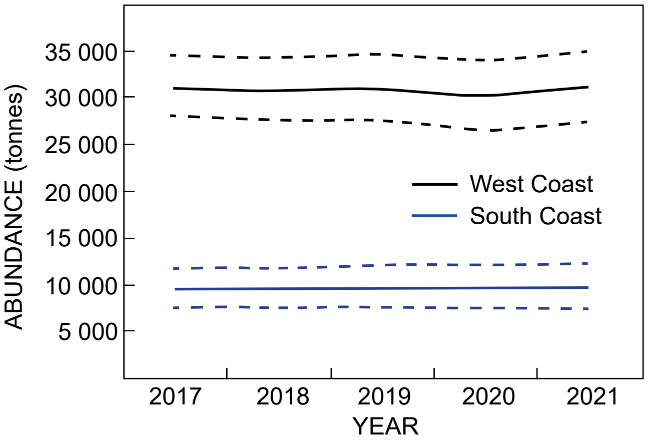


Figure 36: Median annual estimates of abundance and associated 90% probability intervals per coast for monkfish for the most recent 5 years derived from Bayesian analyses

Ecosystem interactions

South Africa has committed to implementing an ecosystem approach to fisheries management (EAF). This approach extends fisheries management beyond the traditional single-species approach to the entire marine ecosystem. In 2006, the permit conditions for all sectors in the hake fishery contained a specific Ecosystem Impacts of Fishing section for the first time. Given that monkfish are taken as bycatch in the hake fishery, these conditions would also apply to this species (see section on Cape hakes).

Further reading

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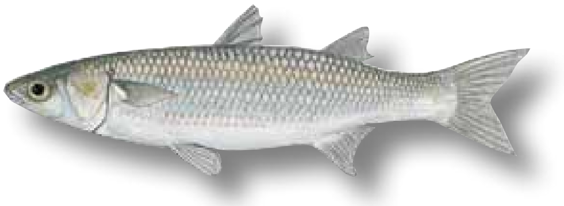
Useful statistics

Annual catches of monkfish (tonnes) made by the hake trawl fishery for the period 1974–2020, and the precautionary upper catch limit (PUCL) that was introduced in 2006. Catches prior to 1990 cannot be separated by coast. WC = West Coast, SC = South Coast.

Year	WC	SC	Total	PUCL	Year	WC	SC	Total	PUCL
1974			3 920		1998	7 766	137	7 903	
1975			4 190		1999	6 805	145	6 950	
1976			5 110		2000	8 440	227	8 667	
1977			5 350		2001	10 035	222	10 257	
1978			4 590		2002	8 638	242	8 880	
1979			5 260		2003	7 049	328	7 377	
1980			4 736		2004	8 545	274	8 819	
1981			4 478		2005	8 294	312	8 606	
1982			4 287		2006	6 973	443	7 416	7 000
1983			4 009		2007	7 568	220	7 788	7 000
1984			4 369		2008	7 329	470	7 799	7 000
1985			3 893		2009	6 594	461	7 055	7 000
1986			4 785		2010	7 453	397	7 850	7 000
1987			5 901		2011	7 392	399	7 791	7 000
1988			5 812		2012	6 461	303	6 764	7 000
1989			4 754		2013	6 209	491	6 700	8 300
1990			4 433		2014	5 767	315	6 082	8 300
1991	5 593	290	5 883		2015	6 428	244	6 972	8 300
1992	4 646	212	4 858		2016	7 338	214	7 552	8 300
1993	4 051	198	4 249		2017	7 787	422	8 209	8 300
1994	3 853	236	4 089		2018	7 253	255	7 508	8 054
1995	6 008	238	6 246		2019	8 412	396	8 808	8 054
1996	5 900	239	6 139		2020	6 471	301	6 772	7 972
1997	6 723	235	6 958		2021				7 972

Netfish



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
					Harders
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
				Harders	

Introduction

There are a number of active beach-seine and gillnet fisheries, legal and illicit, throughout South Africa. By far the biggest is the fisher for harders (or mullet) *Chelon richardsonii* (Figure 37), with 28 beach-seine and 162 gillnet Right Holders operating on the West Coast from Port Nolloth to False Bay. This fishery is managed on a total allowable effort (TAE) basis with a fixed number of operators in each of 15 defined areas. Permits are issued solely for the capture of harders, St Joseph *Callorhynchus capensis* and species that appear on the 'bait list'. The exception is in False Bay, where Right Holders are also allowed to target linefish species that they traditionally exploited. All evidence points towards the harder resource being overexploited, and sector conflict arises due to real and perceived impacts on linefish resources from associated bycatch. Excessive effort granted under Interim Relief as well as a substantial illegal component, which in most years equals or exceeds legal catches of harders, results in negative perceptions of management and negates most attempts to rebuild these stocks.

History and management

Beach-seine nets were introduced into the Cape during the mid-1600s and gillnets in the late 1800s. The main beach-seine targets then were large linefish species, particularly white steenbras *Lithognathus lithognathus* and white stumpnose *Rhabdosargus globiceps*. The advent of gillnets in the 1800s saw effort directed at geelbek *Atractoscion aequidens*, with reports of gillnets being strung between Robben Island and the mainland to intercept shoals of these fish seasonally moving along the West Coast. This directed fishery appears to have collapsed in less than 10 years. Harders were largely used for fertiliser or salted to victual passing ships and to feed farm labourers, including slaves. Abolishment of slavery in the 1800s saw many "fishing rights" transferred to former slaves and indentured labourers, many of whose descendants are active in the fishery in the present day.

Until 2001, some 450 licensed permit-holders used about 1 350 nets, and an unknown number (perhaps a further 100) used another 400 nets illegally. The vast majority of these fishers were not reliant on netfishing but were occupied with this activity for a short period over the summer and autumn months, and either had other occupations such as teaching or farming, or spent the rest of the year in other branches of the fishing industry, such as the pelagic, rock lobster and linefish (snoek and Cape seabream) fisheries. Many of the participants (including crew members) had retired from other fishing activities and participated in the netfishery to supplement incomes and food supplies. Many, both historically advantaged and disadvantaged, were desperately poor and were employed seasonally as crew or factory workers. Overall, there was an excess of effort in the fishery. Many only went to sea a few times each year, catching small quantities of fish. They went to sea when they heard from the active participants about harders being plentiful. They then flooded the few small factories with fish, which maintained the price but refused to take any more fish than could be processed or sold fresh. This extra effort interfered considerably with the viability of the regular full-time fishers.

Back then, approximately 6 000 t were landed per annum by the beach-seine and gillnet fisheries. The gillnet fishery accounted for, on average, 3 250 t of harders, 650 t of St Joseph and 130 t of bycatch consisting of at least 27 species. Illegal gillnetting landed approximately 100 t of smoothhound shark *Mustelus mustelus* and 50 t of linefish (mostly galjoen *Dichistius capensis*). Beach-seine permit-holders landed approximately 1 950 t of harders and in excess of 200 t of bycatch, also consisting predominantly of linefish.

At that time, the beach-seine and gillnet fisheries seldom generated more than R20 million annually. Most of the operators were running at a loss of between 20 and 60%, especially in over-subscribed areas. The financial loss experienced by most fishers also indicated the part-time or "recreational" nature of many of the participants. Indeed, in the Berg River estuary, fewer than 4% of interviewed original permit-holders regarded themselves as netfishers and were either retired or employed elsewhere in other fishing sectors and various jobs.

It was evident that the beach-seine and gillnet fisheries were operating at a loss brought about by effort subsidisation, unfair competition between part-timers and *bona fide* fishers,

Figure 37: A beach-seine catch of harder *Chelon richardsonii* taken at Sunrise Beach, False Bay

and declining catches due to overfishing. Consequently, from 2001 onwards, Rights were allocated to those reliant on the fishery, and the numbers of legal beach-seine operations were reduced from around 200 to 28 and gillnet operations from just over 1 500 to 162.

Prior to this reduction in effort, length-frequency distributions of the harders caught suggested that the stock was overexploited on a local and national scale, with a strong negative correlation between effort (number of nets) and the length of fish caught. The allocations of medium- and long-term Rights saw the removal of part-timers from the beach-seine and gillnet fisheries. The 80% reduction in the number of net permits amounted to an effective 40% reduction in fishing effort, the target set by the Minister in 2001 to facilitate rebuilding of the harder stock.

Also relevant was the linefish bycatch, most of which was composed of species assessed as being overexploited or collapsed. In turn, most of the catches of overexploited or collapsed species were juveniles below the minimum legal length, i.e. before they recruited into the linefishery and before they were able to reproduce, thus considerably compromising replenishment of linefish stocks. In turn, most of the targeted species are estuary-dependent, requiring estuarine nursery areas for their early life-history stages. Recognising that estuarine gillnetting was severely compromising the nursery function of estuaries and impacting negatively on the fisheries for many other species, the management policy was to phase out all estuarine gillnets in the long-term. This was implemented in all estuaries with the exception of the Olifants River estuary on the West Coast.

More recently, in 2010, by order of the Equality Court, three Interim Relief gillnet exemptions were issued to 15 fishers in Langebaan and two beach-seine exemptions in Struisbaai and Simonstown. The latter was awarded to more than 50 fishers who failed to fish due to inter-crew conflict and lack of a catch agreement between them. The Struisbaai exemption was awarded despite there being no TAE to the east of Cape Hangklip, specifically due to the unsustainable bycatch of linefish there. The three shared gillnet exemptions in Langebaan have contributed to an escalation in fishing effort in an area where the TAE had already been exceeded. The nett result has been a more than 50% increase in gillnet fishing effort with growth overfishing and a 10% and 20% decline in the average length of harders in Saldhana Bay and Langebaan Lagoon, respectively, and the collapse of that population or stock (see ‘Current status’, below). FRAP (fishing rights allocation process) 2015 and the small-scale implementation were intended to see these fishers formally incorporated into the beach-seine and gillnet fishery within the limits of the TAE, thus reducing effort in an attempt to arrest the decline in growth rate. This management intervention to rebuild the stock never materialised.

Research and monitoring

Fishery-dependent data sources consist of ongoing measurement of the length-frequency distributions of captured fish, observer data, compulsory monthly catch returns by Right Holders and intermittent net- and linefishery surveys. The most important of the fishery-dependent data sources (and now historical reference) was the National Linefish Survey, as this provided comparable and combined catch, effort, compliance and socio-economic information for the beach-seine and gillnet fisheries, as well as the commercial, recreational and small-scale (including subsistence) linefisheries. It has not been possible to repeat this survey, however, since 1995.

Fishery-independent data are currently collected through sampling estuarine and surf-zone fish assemblages to ascertain the links between environmental and fishery variables and juvenile recruitment. Sample fish densities are compared across estuaries and surf-zones in relation to the different levels of fishing and environmental variables, such as freshwater inflow, in each of these systems. From these data, a predictive capability that can be incorporated into existing linefish stock assessment models will be developed. This is a relatively novel approach as the existing assessments are largely based on adults caught by the fishery and often ignore the anthropogenic and environmental influences experienced by fish in their earlier life-history stages. In all, 22 high-priority estuaries have been monitored once to four times annually from 2001 onwards, until the present.

In addition, recruitment sampling is complemented by netting with gillnets of identical mesh-size and dimensions to those used by the commercial and illegal fisheries to provide catch estimates independently of those unobtainable from the illicit gillnet fishery. Fishery-independent length frequency information, which allows comparison between areas with different levels of fishing effort, is validated by length-frequency distributions from the observer programmes. Past work shows that this approach provides a good indication of the status of local populations and the stock as a whole, as there is a strong negative correlation between the level of netfishing effort and average fish length.

Current status

Prior to the reduction in effort implemented after 2001, length-frequency distributions of the harders caught suggested that the stock was overexploited on a local (netfish area) and national scale. There was a strong negative correlation between effort (number of nets) and the length of fish caught. This was not surprising considering that effort ranged from 0.5 nets per kilometre of coastline in Langebaan to 15 nets per kilometre in St Helena Bay. Also relevant was the linefish bycatch, most of which comprised species regarded as overexploited or collapsed. Furthermore, most of this catch comprised juveniles below minimum legal length, i.e. before they recruited into the linefishery and before they were able to reproduce and thus contribute to replenishment of the linefish stocks.

There was some evidence, albeit briefly, for recovery of the harder stock in some areas. For example, in the Berg River estuary, continued monitoring before and after effort reduction indicated a recovery in the numbers and length of harders and bycatch species such as elf *Pomatomus saltatrix*. An increase in the numbers and mean length of harders caught in St Helena Bay was also reported by fishers and observers employed at that time. This success was, however, short-lived, as observer and compliance data indicated that the illegal gillnet fishery in the Berg River estuary soon escalated. These data suggest that at least 400 t are harvested illegally from the Berg River estuary alone each year. A total reduction of 600 t in reported catches by the legal fishery in the sea strengthens the veracity of this and highlights the predicted impact of this recruitment- and growth overfishing on the legal fishery.

To reiterate, the area-specific beach-seine and gillnet fisheries are assessed on an ongoing basis by monitoring changes in length frequency distributions, catch-per-unit-effort (CPUE), total catch, and species composition from fishery-independent surveys and, for a brief three years, from one observer based at the centre of the industry in St Helena Bay. These data and the nature of the fishery indicate that formal area-specific stock assessments are integral for providing scientific advice on the TAE. This was most evident for harder *Chelon richardsonii* in Langebaan and Saldanha where a 50% increase in gillnet fishing effort over and above the TAE was followed by a >40% drop in CPUE and a 15–20% decline in the average length of harders caught.

Consequently, an assessment of the Saldanha and Langebaan harder gillnet fishery was conducted in 2019. The per-recruit assessment applied looked at changes in sex ratio, mean length (mm) and standardised CPUE. Analyses of sex ratios over time indicated a significant switch between two periods (1998–2002 and 2017), from a predominantly female- (larger individuals) to a male- (smaller individuals) biased population (1.7 males: 1 female). Three period-specific length frequency distributions of commercial catch of *C. richardsonii* (1998–2002, 2009–2011 and 2017) indicated a reduction in mean total length (TL) of 36.5 mm over time (Figure 38). The standardised CPUE of harder for the period 2008–2016 declined, indicating a reduction in relative abundance of *C. richardsonii* of approximately 30% over this time (Figure 39). A spawner-biomass-per-recruit model revealed that the stock is heavily depleted, with the stock currently collapsed and at only 24% of estimated pristine spawner biomass or breeding potential (Figure 40), a level at which recruitment is likely to be seriously impaired.

The multifaceted diagnostic assessment approach applied to the Saldanha and Langebaan harder gillnet fishery highlights several characteristics of overfishing. Together, the change in sex-ratio and reduction in both CPUE and mean TL characterise an overexploited fishery. These negative results are likely due to the combined effects of the TAE being exceeded by 50%, illegal catches occurring in the Restricted and Sanctuary zones of the Langebaan MPA, and fishers reducing mesh size to maintain catch rates.

Exacerbating the problem was an anomalous series of 1-in-50-year floods in quick succession on the South and West coasts in 2013–2014, followed by the severe 1-in-100-year drought since then, which considerably reduced juvenile recruitment into estuaries and ultimately into fisheries, over the last six years. This had a negative impact on the adult stocks of harders and many other estuary-associated species, including dusky kob *Argyrosomus japonicus*, elf *Pomatomus saltatrix* and white steenbras *Lithognathus lithognathus*. Ultimately, the impact on the beach-seine and gillnet fisheries will depend on the linkages between the South, East and West coast populations of these species.

Ecosystem considerations

Obvious from the above is that environmental drivers also play a role in harder growth, which varies between estuaries, islands and the nearshore, and between the cool West Coast and warm-temperate South Coast of South Africa. The sex ratios of harders in estuaries and the nearshore, subject to low fishing pressure, are skewed towards females and may be as

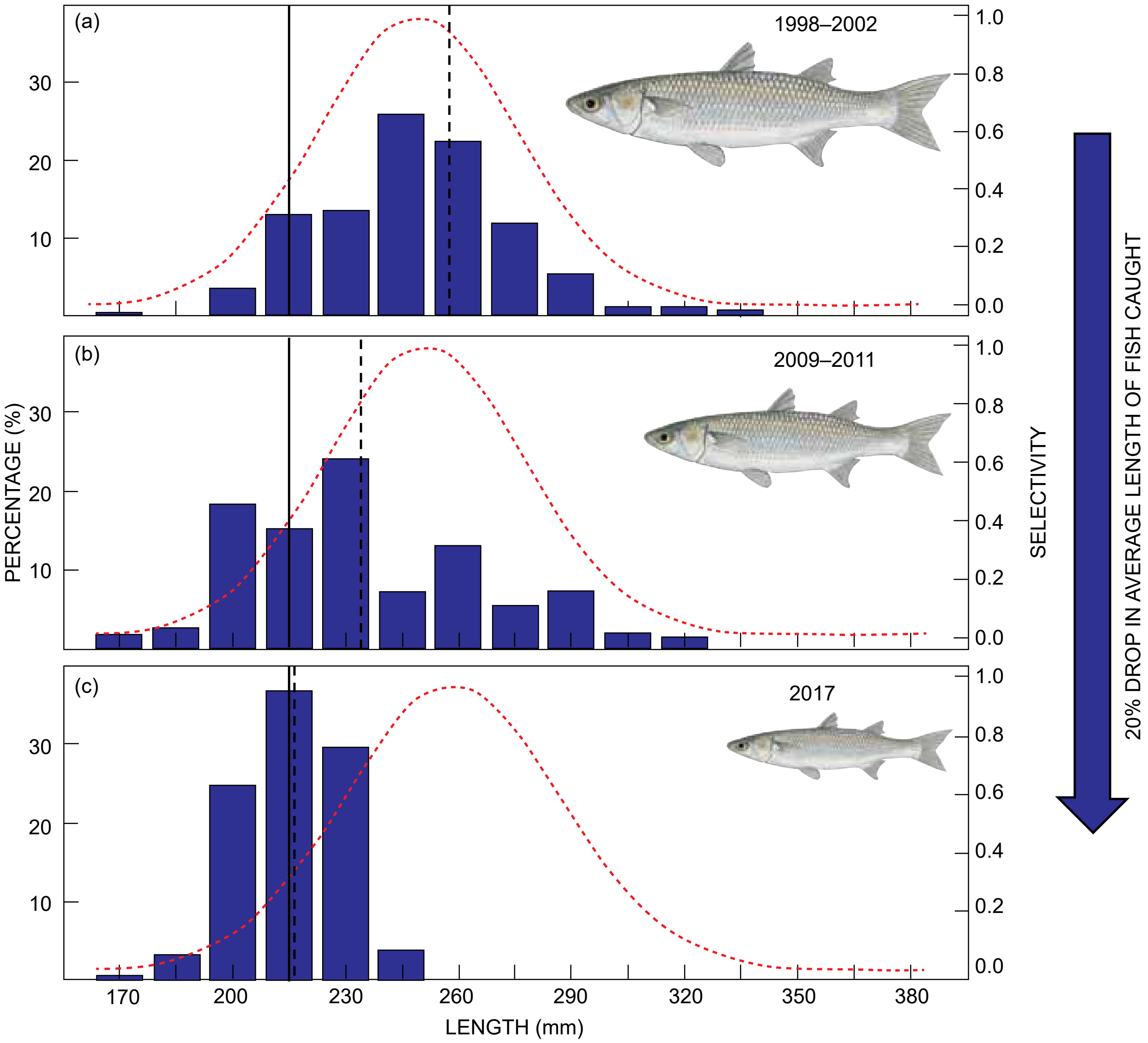


Figure 38: Length-frequency distributions of *Chelon richardsonii* caught in Saldanha and Langebaan by the commercial gillnet fishery fleet for three different time-periods. The solid vertical line represents length-at-50% maturity (215 mm total length [TL]) and the dotted vertical line is the mean TL for that length-frequency series. The bell shaped selection curve is the selectivity of the gillnets that were deployed during that particular time-series. After Horton et al. (2019). For comparison, the harder pictures are to scale and illustrate the average length in each of the time-series

much as 9 females:1 male in some localities. This contrasts with fished areas where sex ratios are skewed towards males or the gender parity of 1 female:1 male around the offshore islands. Spawning occurs in the nearshore throughout the summer but with early and late season peaks. Females and males grow at the same fast rate to maturity during the first year, whereupon female growth slows considerably and that of males becomes negligible. Females attain larger length-at-age in all regions and habitats. South Coast female fish are larger than West Coast ones and estuary female fish are larger at age than those in the sea. Females from islands on the West Coast appear to grow faster than those from the nearshore. Observed differences in growth are likely attributable to the interplay between harder life-history strategies and response to the environment and fishing. Females grow larger than males and continue to grow after maturity to maximise reproductive output. South Coast fish are larger than West Coast ones due to the West Coast net fisheries catching larger fast-growing fish (and females), thereby selecting for slow growth. Warmer temperatures and higher productivity in the South Coast nearshore may also play a role. Similarly, favourable environmental conditions and lower fishing intensity around the offshore islands and in estuaries may account for the faster growth and larger fish there.

Ecosystem interactions and climate change

Estuaries and freshwater flow

All South African estuaries are important nurseries for exploited marine and estuarine species before they recruit into marine fisheries, and more than 90% of the beach-seine and gillnet catch comprises estuary-associated species. This is illustrated

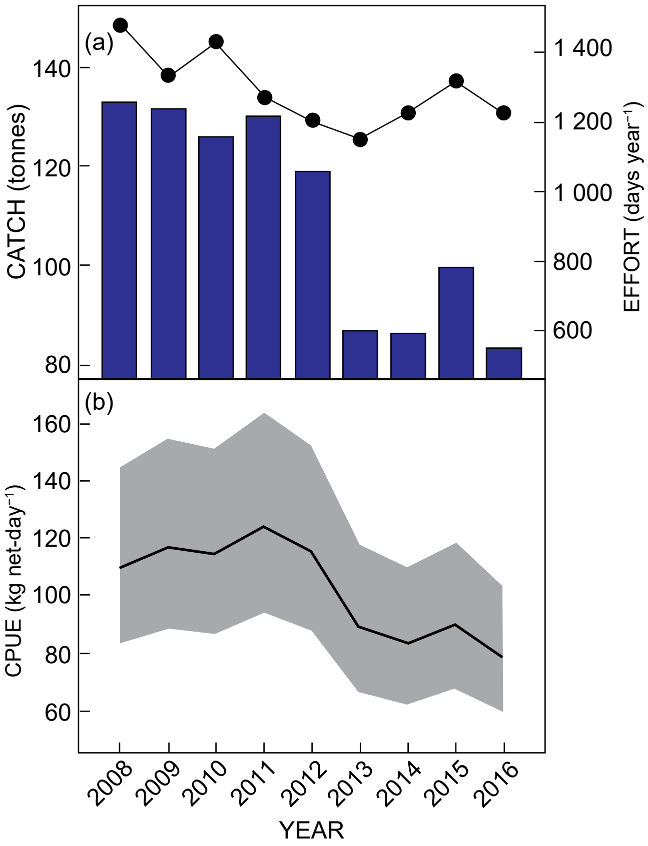


Figure 39: (a) The annual total catch (t) (shaded bars) and fishing effort (days year^{-1}) (line) of *Chelon richardsonii* by the commercial net fishery in Saldanha Bay and Langebaan, and (b) the standardised CPUE (kg net-day^{-1}) estimates (±95% CI) of the commercial *Chelon richardsonii* net fishery in Saldanha Bay and Langebaan derived from mandatory catch records between 2008 and 2016. After Horton et al. (2019)

by the declines in the *Chelon richardsonii* stock and marine gillnet fishery catches on the West Coast, which have been directly attributed to recruitment over-fishing in the legal and illicit Olifants River and Berg River estuary gillnet fisheries. Fishing aside, the health of estuarine habitat determines juvenile fish recruitment, survival and ultimately catches in the sea. Estuarine health is largely driven by catchment management and the quantity and quality of fresh water reaching the estuary and sea. Reductions in freshwater flow are accompanied by declines in primary production, shrinkage of the warm-water plume entering the sea, narrowing of the stream channel, and an overall reduction in available habitat and refugia and loss of estuary nursery function for juvenile fish.

There are only nine estuaries on the West Coast, of which only three, the Orange, Olifants and Berg, are large and permanently open to the sea. Overall, there has been an approximate 40–80% reduction in freshwater flow and a 60% loss of floods to these estuaries. Climate change, increased hydropower demands and freshwater abstraction will see these losses become even greater in the future. In the present day, juveniles of obligate estuary-dependent fish such as springer/flathead mullet *Mugil cephalus* and white steenbras *Lithognathus lithognathus* in West Coast estuaries have declined in abundance to <10% of reference (pristine level) and are likely to decline to <5% under future-flow projections. Partially estuarine-dependent fish, most importantly harders, the mainstay of the netfishery, have estuarine juvenile populations that are now at 60% of pristine levels.

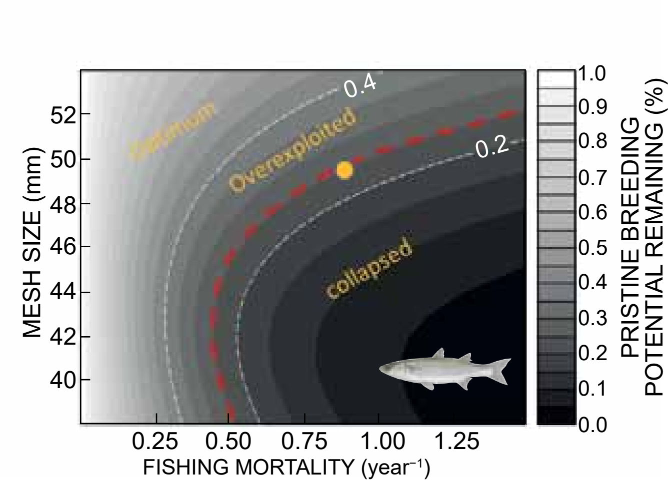


Figure 40: An isopleth illustrating the response of the percentage of spawner-biomass-per-recruit (SBR) to unexploited levels (SB_0) of *Chelon richardsonii* according to varying levels of fishing mortality (*F*, year^{-1}) and different combinations of mesh sizes (mm). Critical reference depletion points (SB_{40} and SB_{20}) are represented by dashed white lines. The current SBR is denoted by ●; SBR depletion = 0.245, F_{curr} = 0.881 year^{-1}. After Horton et al. (2019)

Drought, acidification and 100% fish mortality in Verlorenvlei Estuarine Lake

Compounding the above was the recent extended drought on the West Coast and throughout the country. On the West Coast, the drought and continued water abstraction resulted in 100% fish mortality in the Verlorenvlei Estuarine Lake and the Rietvlei-Diep Estuary and loss of the estuarine nursery function of these two systems. This represents a loss of 22% of total estuarine open water area and 50% of brackish fish nursery on the West Coast. The dominant fish in these two estuaries were harder *C. richardsonii*.

The Verlorenvlei Estuarine Lake is a temporarily open-closed estuary that flows into the sea at Elands Bay. It is a Ramsar Site and wetland of international importance. Extended drought and over-abstraction of freshwater inflow has resulted in unprecedented low water levels, fish kills and loss of birdlife. In February 2019 there was a fish kill of large fish in the system, coincident with very low water levels. Of fish species that are harvested, the kill comprised about 90% flathead mullet *Mugil cephalus*, 5% Mozambique tilapia *Oreochromis mossambicus*, 3% carp *Cyprinus carpio* and 2% other. Small dead fish comprised 99% estuarine round-herring *Gilchristella aestuaria*. Surprisingly, no dead juvenile or adult harder *C. richardsonii* were recorded even though these dominate fish biomass in Verlorenvlei. However, harders are opportunistic species, very resilient to poor water quality, often feeding on *Microcystis* and other harmful blue-green algae, so they may have been taking refuge in the deeper areas of the estuary.

During the low-water-level fish-kill event, salinity was markedly elevated from the usual 1 to 2 in the estuary to 16 to 19. Daytime oxygen levels were 6–8 mg l^{-1}, but this was probably due to algal photosynthesis and wind mixing. Night oxygen levels were below 3 mg l^{-1} due to algal respiration, and fish would have had to surface breathe. pH was high at 7.9 to 8.4 which may indicate some ammonium toxicity in the system. Water temperatures were 18 to 24°C, which was normal for the time of year. Overall, the fish kill was likely a combination of exhaustion from repeatedly having to surface breathe at night and high pH and/or ammonium toxicity.

As the drought continued, receding water exposed extensive areas of organic sulphide soils/peats along the estuary margins which previously had been submerged. Natural sulphate reduction processes in aquatic sediments can result in an accumulation of sulphide minerals such as pyrite (FeS_2). Upon exposure to air, pyrite ("fools' gold") can oxidise to produce sulphuric acid and dissolved ferrous iron. Consequently, strongly acidic conditions developed with the first rainfall and runoff over the exposed organic-rich sediments, water becoming close to vinegar when pH dropped to <3.5, and all fish and invertebrates were extirpated from Verlorenvlei.

Whilst slight recovery of vegetation has been seen after recent rains no fish or invertebrate life has been recorded and birds that feed upon them have moved elsewhere. Recovery time is likely to be at least at the decadal scale. Acidification of Verlorenvlei has resulted in the loss of >22% of estuarine-nursery area for harders on the West Coast, of which the stock implications have yet to be measured. In turn, Verlorenvlei was the site for an experimental seine-net fishery directed at introduced Mozambique tilapia and alien carp in the system. This was aimed at invasive species control whilst providing opportunities for the developing small-scale fishery. Loss of this opportunity may partly be remedied by identification and assessment of these species in other West Coast catchments and estuaries.

Range expansions and shifts in abundance

Range expansions and/or shifts in abundance have been documented for more than 50 nearshore and estuarine fish in southern African waters over the past 30 years. Most of these shifts can be attributed to various global and climate-change drivers, including changes in rainfall, freshwater flow, wind regimes, water chemistry and catchment and sea temperatures. Until recently, most of these shifts in southern Africa have been of tropical, subtropical and warm-temperate fish moving south and west to the cool-temperate biogeographical region, ostensibly due to warming there. However, there are more and more instances of cool-temperate fish expanding northeastward and westward into the warmer bioregions. By example, there are about 12 species of mullet occurring in our coastal waters, only one of them cosmopolitan, and the rest with their core range in each of their preferred bioregions. Tropical/warm-temperate groovy mullet *Chelon dumerili* from the East Coast have increased from less than 10% to more than 30% of total mullet abundance in Cape South Coast estuaries over the past 25 years. Similarly, freshwater mullet *Pseudomyxus capensis*, originally limited to the Southeast and East Coast, have expanded past Cape Agulhas, are abundant in Table Bay estuaries and now also occur in the Orange River estuary on the West Coast. Harder *Chelon richardsonii* are cool-temperate fish and comprise 98% of mullet biomass on the West Coast and, until recently, about 90% of that on the South Coast. They have dropped to 50–70% of mullet abundance on the cool- and warm-temperate South Coast but have increased from less than 1% to 5–10% of that in the warm-temperate/subtropical transition zone of the East Coast. Similarly, *C. richardsonii* have increased from about 10% to more than 30% of mullet biomass in the warm-temperate/subtropical region of northern Namibia and southern Angola.

Bird, seal, shark, cetacean and reptile interactions and bycatch

Concerns around frequent, excessive gillnet catches of 100 or more penguins *Spheniscus demersus* around Dassen and Robben Islands prompted management intervention in the late 1990s. Gillnet fishers were setting their nets across penguin approaches because of the guano slicks on which harders feed. Gillnet exclusion zones now prohibit gillnets being set within 1–2 km of each island.

High bird-bycatch mortality, especially in unattended nets, led to legislation and permit conditions that prohibit unattended gillnets (either set or drift). The most-vulnerable species are crowned cormorant *Microcarbo coronatus* and penguins in the sea, and African darters *Anhinga rufa*, reed cormorants *Microcarbo africanus* and great crested grebes *Podiceps cristatus* in the estuarine environment. Exacerbating the "bycatch" issue has been the recent proliferation of very cheap "single-use" gillnets in KwaZulu-Natal southwards to the Wild Coast. The resultant upsurge in poaching with gillnets has been accompanied by an increase in bird, reptile and mammal bycatch and retention of these species for food and the African and Asian "traditional medicine" trade. This issue needs to be prioritised for management intervention.

Seal depredation of catches is frequent in the beach-seine and gillnet fisheries. Catch loss is similar in both fisheries but damage to beach-seine nets is negligible compared to the costly repairs or replacement of gillnets. Fishers are permitted to request management authorities to cull problem animals but this rarely happens and is usually limited to the Olifants Estuary. Some fishers successfully use bullwhips to keep seals away from their nets. There are limited seal mortalities, mostly of pups, in the beach-seine and St Joseph gillnet fishery.

Cetacean bycatch and mortality, especially of Heaviside's dolphin *Cephalorhynchus heavisidii*, has long been a problem with the larger-mesh setnets used to target St Joseph and with the illegal galjoen gillnet fishery. Up until the 1980s most cetaceans caught, sometimes through targeted sets, were kept and eaten. These mortalities occurred mainly in the Cape Columbine region. Consequently, since 1999 there has been an effective 25-km exclusion zone for the gillnet fishery from North Head at Saldhana Bay to Cape Columbine.

Shark interactions with the netfishery range from being bycatch to depredation of catches by sevengill cowsharks *Notorynchus cepedianus* and bronze whalers *Carcharhinus brachyurus*. Despite claims to the contrary, white sharks *Carcharodon carcharias* do not home in on beach-seine activity in False Bay, thereby posing a safety risk to beach-goers. Analysis of more than 11 000 catch records suggest that these sharks actively avoid beach-seine nets once set. Beach-seine fish-spotters in False Bay are used as auxiliary shark-spotters at Fish Hoek and Simon's Town and were consulted on the design and deployment of the bather protection "shark exclusion net" at Fish Hoek beach. The design and deployment of the exclusion net is strictly to rules that prevent interference with beach-seine operations and target species (e.g. yellowtail *Seriola lalandii*) in Fish Hoek Bay.

Sustainability of historical, culturally significant stonewall fishtraps

Stonewall fish traps or "visvywers" were once an integral part of the "netfishery" on the Cape South Coast (Figure 41). Visvywers were perhaps first built by aboriginal peoples, but no links have been found between midden- and visvywer catch composition and nor is there any evidence for construction of these traps by them. This said, any traps built by these peoples were likely to have been according to need and therefore small. Peak "industrial-scale" construction occurred in colonial times with most visvywers constructed after 1880 and permits held by farmers adjacent to the shore. Then, as in the present day, the traps were characterised by infrequent very large and lucrative catches. Inter-sector conflict (and a lack of mounted police monitors) saw the banning of all visvywers in 1890 that lasted 12 years. Thereafter, visvywers were constructed on all available rocky-platform, boulder beach and mixed shore on the Cape South Coast. Demand soon exceeded available area and trap construction spread to sandy beaches. These latter traps, which were constructed of other material – railway tracks, steel cable and concrete – have all but disappeared. The most productive traps were fished to the early 1980s, the Still Bay ones legally to 1999 and, with those at Arniston, informally to the present day.

About 70 sets of these traps existed on the Cape South Coast, limited by the extent of rocky platforms and boulder beach habitat. Only two of these sets are currently maintained and fished, albeit illicitly, but there have been numerous requests for access to fish traps throughout their historical extent, including in False Bay, Still Bay, and Arniston and from Skipskop to Koppie Alleen in the De Hoop MPA. The Still Bay visvywers are recognised as a heritage site of cultural significance and an integral part of the Still Bay MPA. Consequently, under

Figure 41: Historical "visvywers "or stonewall fish-traps in the Still Bay MPA

Table 10: Catch composition of the Still Bay stone-wall fish traps over 13 dark-moon spring tides

Species	%Number	%Mass (kg)	%Occurrence
Harder	56.39	58.41	17.38
Elf	2.01	12.48	3.03
Strepie	23.85	12.35	6.21
Dassie	6.20	6.43	5.40
White musselcracker	1.81	4.69	4.22
Zebra	0.34	0.89	1.85
Dusky kob	0.04	0.74	0.30
Baardman	0.06	0.74	0.59
Eagle ray	0.03	0.55	0.30
White steenbras	0.05	0.26	0.22
Sand steenbras	0.09	0.22	0.52
Cape stumpnose	0.16	0.15	1.04
Other	8.98	2.10	58.95
Total	14 038	2 711	1 352

an ongoing project, one set of visvywers of 24 traps is being maintained within the Still Bay MPA and catches recorded (and released) with a view to assessing the possible impact of this fishery on the resource. Also being assessed is the feasibility of visvywer harvesting being offered as one of the cultural experiences available to visitors in the Still Bay MPA. Catch monitoring will help inform decisions with respect to applications for access to visvywers elsewhere on the Cape South Coast.

Historically, all fishing was on dark-moon spring tides from late autumn to early spring where falling tides commence during dark, thus trapping more fish, and the duration of the low tide around dawn is at a maximum. Thirteen dark-moon springs during 2017–18 saw 14 000 fish of 30 species caught in the traps. Numerically, catches were dominated by harder *Chelon richardsonii* (56%), strepie *Sarpa salpa* (24%), dassie (blacktail) *Diplodus sargus* (6%) and elf *Pomatomus saltatrix* (2%). Harder (58%), elf (12%) and strepie (12%) dominated by mass, with dassie (6%) and white musselcracker *Sparodon durbanensis* (5%) also important (Table 10). The fishery is characterised by low catches punctuated by 1-in-50 catch events. Conditions during these events were low wave-height, recent cool upwelling and relatively warm water on the inshore. Very low catches coincided with high seas.

Monitored traps at Still Bay (2017–2018) yielded about 5.1 t caught per annum. This suggests that the 68 trap sets between Cape Point and Mossel Bay could potentially catch 340 t per annum. On the other hand, reported Still Bay commercial trap catches (1983–1999) were 12.6 t per annum. Extrapolated to the region from Cape Point to Mossel Bay, 68 trap-sets could potentially catch 856 t per annum. In all, trap fishing and participation in maintenance could be a cultural and archaeological feature of the Still Bay MPA, but a potential 40–60% linefish bycatch of >500 t suggests against re-establishing the fishery on the Cape South Coast.

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Oysters

Stock status	**Unknown** (KwaZulu-Natal and Southern Cape)	**Abundant**	**Optimal**	**Depleted**	**Heavily depleted**
Fishing pressure	**Unknown**	**Light**	**Optimal** (KwaZulu-Natal)	**Heavy** (Southern Cape)	

Introduction

The Cape rock oyster *Striostrea margaritacea*, which is targeted in this fishery, has an extensive geographic distribution and occurs on rocky reefs from Cape Agulhas to Mozambique. These oysters are found in the intertidal zone down to about 6 m water depth. The Cape rock oyster occurs naturally and is sold in South African restaurants. Another species that is available in restaurants is the Pacific oyster *Crassostrea gigas*. Cape oysters along the KwaZulu-Natal (KZN) coast have been found to take 33 months (almost three years) to reach marketable size (60 mm right-valve length). Oysters are broadcast spawners and those along the KZN coast spawn throughout the year, with peaks during spring and summer. Harvesting takes place during spring low tides and has traditionally been restricted to the intertidal zone. In recent years, however, this has gradually been expanded towards the fringes of the subtidal zone (see below). Oysters are dislodged from rocks by means of a pointed steel crowbar (oyster pick). Harvesters are allowed to wear a mask, snorkel and weight-belt, and commonly use an oyster pick to dislodge oysters from the rocks. The use of fins and artificial breathing apparatus is not allowed. No harvesting is permitted from the subtidal beds, which are considered to seed the intertidal oyster reefs.

History and management

The commercial fishery for oysters dates back to the late 19th Century. Prior to 1998, only a few individuals (less than 8 people) held concessions to harvest oysters and employed large

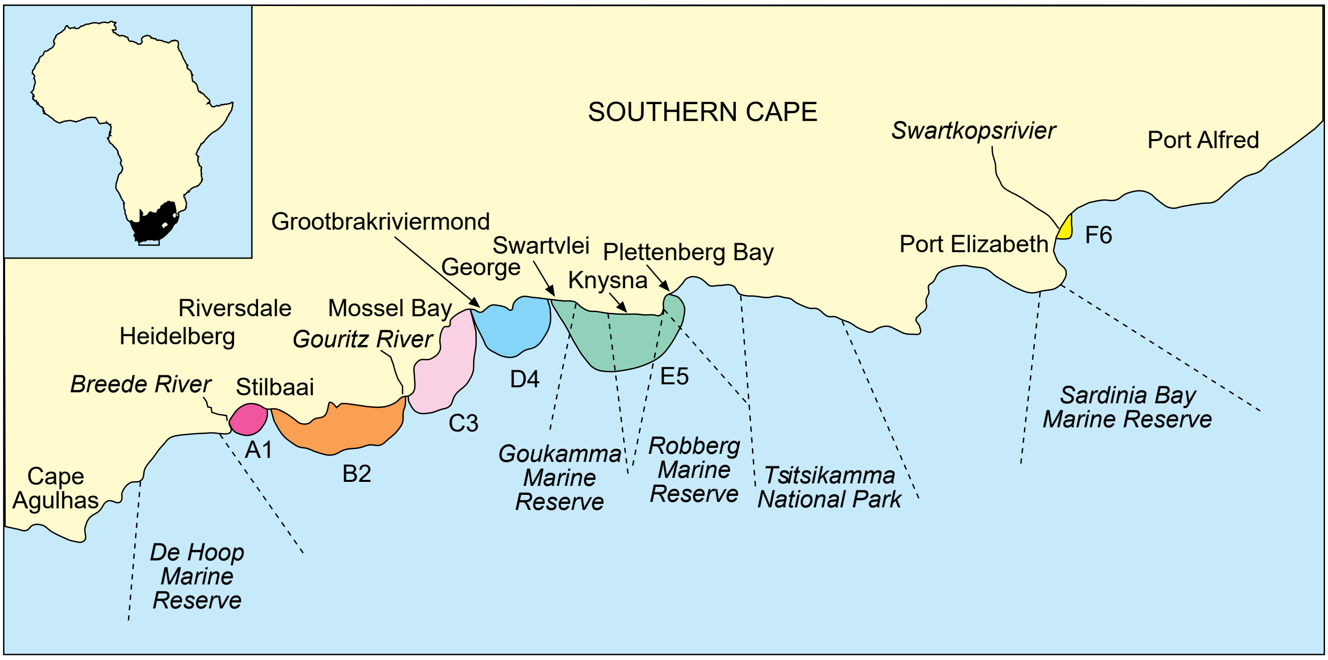

Figure 42: Spatial divisions of the oyster fishery at Port Elizabeth and in the Southern Cape. The colour-coded areas indicate dedicated oyster-collection zones

numbers of "pickers" to assist with collections. In 2002, Rights were redistributed and medium-term (4-year) Rights were allocated to 34 Right Holders, the majority of whom held limited commercial Rights and were allowed to employ up to three pickers each. A few Right Holders held full commercial Rights and could employ a maximum of 10 pickers each. In total, 114 pickers were permitted to harvest oysters during this period.

In the 2006 Rights allocation process, the sector was further transformed and 3-year commercial Rights were allocated to 121 individuals. A large number of pickers were accommodated in this process, the idea being that pickers were granted Rights as a means of empowering those who were dependent on oyster harvesting for their livelihood. In this system, Right Holders were required to harvest the oysters themselves and were no longer allocated additional effort (pickers) to assist with harvesting. In 2013, the "fishing rights allocation process" (FRAP 2013) for this fishery started and, after an appeal process, confirmed the previous number of harvesters and their split across the various fishing areas in 2015. In 2017, 73 Rights were allocated to the new small-scale sector, leaving 72 Rights for allocation to the commercial sector. During all the allocation changes in recent years, the TAE was split between the different areas so that it remained constant (see Useful Statistics).

The oyster fishery was previously managed as two separate fisheries related to their areas of operation: the Southern Cape Coast and the KZN Coast. Since 2002 the oyster fishery has been managed as a national fishery. Under this new management system, four commercial oyster-harvesting areas were officially recognised: the Southern Cape, Port Elizabeth, KZN North and KZN South (Figures 42 and 43). Regional differences regarding regulations and harvesting patterns were retained.

Research and monitoring

Oysters are of relatively low value compared to other commercially exploited species. In the past, the fishery was not prioritised in terms of research effort and management attention. The consequence is that the total allowable effort (TAE) for the oyster fishery is currently determined according to historical effort levels and not based on the assessed stock or status of the resource.

Oyster research has been lacking. Recently a concerted effort has been made to improve the quality of catch and effort data, and to do a resource assessment. To this end, a focus was placed on site selection and appropriate sampling methods for assessing the oyster resource. Their patchy distribution and often inaccessibility made accurate sampling of this resource, in the intertidal zone, exceedingly difficult. Plans are underway to start an assessment in 2024 lasting between 3-5 years, thus, a full assessment could be expected in 2030.

Priority is given to the Southern Cape because of evidence of overexploitation while, in KZN, monitoring is undertaken by the Oceanographic Research Institute (ORI), under contract to the Branch: Fisheries Management. Their mandate is to provide information on which to base recommendations for the KZN region.

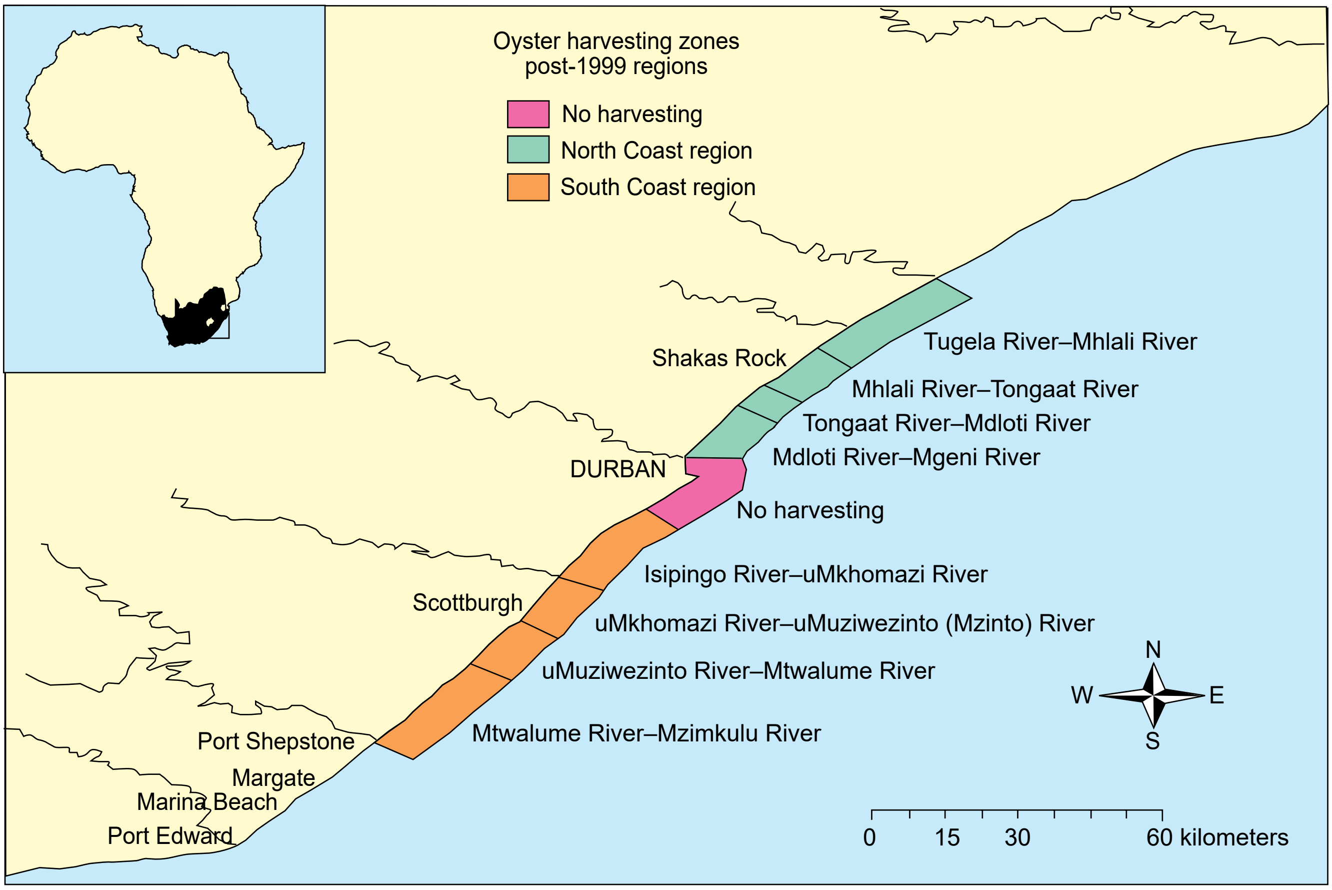

Figure 43: Spatial divisions of the oyster fishery in KwaZulu-Natal (re-zoning of South Coast included)

Current status

Currently, the overall TAE is 145 pickers. In the last seven years, however, on average only 60% of Right Holders have actively fished in all areas. The status quo is being maintained until further data become available.

Total catches between 2002 and 2005 were between approximately 600 000 and 730 000 oysters, the majority of which were harvested in the Southern Cape (Figure 44). Data for 2006 are not available because catch reporting was poor on account of the new Rights allocation and the change of Right Holders. The low catches in KZN in 2008 (3 491 oysters) was an exception, caused mainly by problems during the permit processing. Between 2009 and 2019, total catch stabilised at above 350 000 oysters harvested annually. It is noteworthy; however, that these come mainly from the Southern Cape, because catches in KZN are at very low levels and have declined consistently during the last three decades (Figure 44). This is thought to be caused by reduced effort (non-activation of permits), poor catch reporting (especially along the KZN South Coast) or a decline in resource availability. Further research is required for an updated assessment. The oyster resource along the KZN coast is considered to be fully exploited. Resource assessments undertaken in 2006 during a research project outsourced to ORI showed that, although the oyster stocks had declined since 1980, they were stable or showed only a slight decline for approximately 20 years prior to the study. Age-structured production models for oyster population assessment in KZN showed that rotational harvesting (with zones being commercially harvested two years out of five) was sustainable, since rapid population recovery was observed in fallow years. In the Southern Cape there is concern that the intertidal zone is being denuded of oysters as a result of being overharvested. The oyster density and size-composition data, collected during surveys undertaken between 2000 and 2004, suggested that the intertidal oyster stock along the Southern Cape Coast appeared to be overexploited. Moreover, there were reports of divers illegally harvesting oysters from subtidal “mother beds”.

Catch-per-unit-effort (CPUE) data for the Southern Cape oyster fishery fluctuated strongly from 2008 (Figure 45) and are considered unsuitable for the purposes of stock assessment. Similarly strong fluctuations in CPUE occurred on the KZN coast during the aforementioned time-period. In 2016, the Department put a temporary hold on oyster harvests in KZN and no permits were issued for that year, resulting in no returns being submitted to the Department. Once harvesting was allowed to resume, CPUE for the area has been relatively stable from 2017 to 2020. Catches in 2019 and 2020 were the lowest observed over the past decade (Figure 44), partly due to substandard data submissions and the effect of the Covid-19 pandemic, and CPUE fluctuated between 68 and 83 oysters per hour (Figure 45). No data were collected for 2021 and 2022 due to flooding, waste-water spillages (due to load shedding) and toxic river runoff due to looting events. The status of this resource thus remains uncertain, but efforts are underway to conduct fishery independent surveys in the commercially harvested areas, to obtain a better understanding of the oyster population fluctuations.

Ecosystem interactions

The sustainable harvesting of rock oysters involves the direct picking of individual organisms from the rocks, and the use of diving masks by pickers allows more-precise fishing, thereby reducing the potential for dislodgement of non-target species. Oyster harvesting is therefore considered to have minimal significant disturbance on the surrounding biological communities, although research is required to substantiate this view.

Climate change implications

Oyster beds and reefs dominated the majority of temperate coastlines before the start of the 19th Century, but an estimated 85% of oyster beds globally have been lost since then

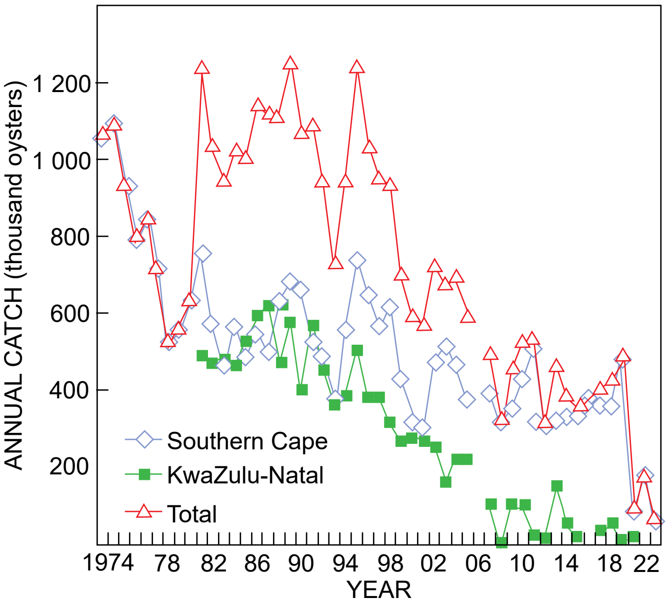

Figure 44: Annual commercial oyster catch (number of oysters) for the Southern Cape and KZN areas and the total collection for South Africa, 1972–2022

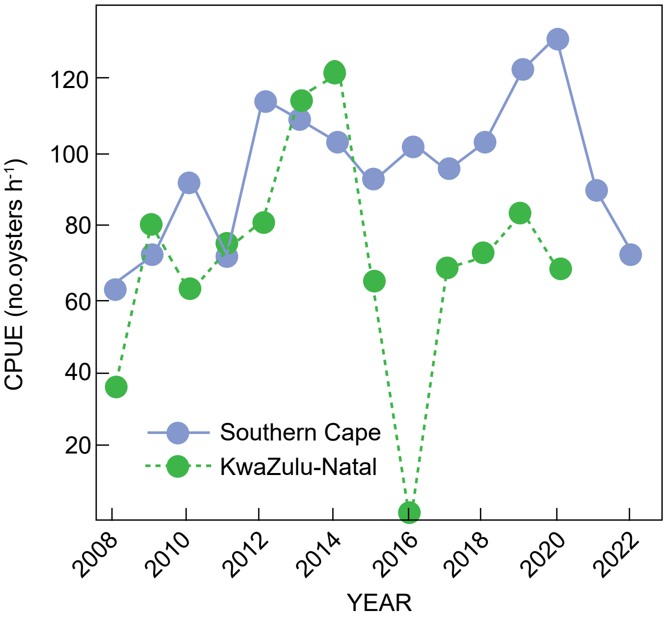

Figure 45: Nominal CPUE (number of oysters per hour) trends for oyster in the two commercial areas of operation (Southern Cape and KZN), 2008–2022

because of destructive and unsustainable resource extraction and coastal degradation. This loss has had serious ecosystem consequences because of the oyster's role as ecosystem engineers. Increasing seawater temperatures and acidification arising from climate change appear likely to further negatively impact oysters through reduced growth and survival, although there is no available information on the impacts of climate change on *Striostrea margaritacea* in South Africa at present. However, climate change appears to accelerate range expansion of the Pacific oyster *Crassostrea gigas*, which is the world's most cultivated shellfish and was imported into South Africa in the 1970s and now supports the country's oyster aquaculture industry. Present Pacific oyster culture sites are in Saldanha Bay and Algoa Bay, but because of difficulties in inducing spawning and subsequent settling under South African conditions, the industry has been reliant on spat imported from Chile, the United Kingdom, and France. *Crassostrea gigas* was considered as non-invasive because of its inability to complete its life cycle under local environmental conditions, but naturalised and apparently self-sustaining populations of this species have been reported from several estuaries along the South African coast since the early 2000s, most recently in the Swartkops and Kaaimans estuaries. The *C. gigas* population in the Swartkops Estuary was sufficiently large to stimulate an application to the Department for the development of a new fishery there for this species, but this was declined pending a review of the policy for the establishment and management of new fisheries. However, should climate change facilitate the development of large populations of *C. gigas* in South African estuaries, and because this is an alien species and harvesting it would be highly targeted and with no bycatch, then a commercial fishery for this species could become feasible.

Further reading

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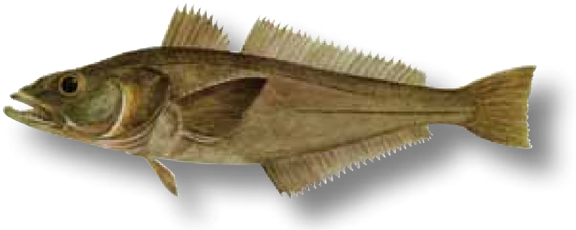
Useful statistics

Total allowable effort (TAE) (number of pickers) and total catch (number of oysters) for the oyster fishery for the period 2002 to 2022.

	Southern Cape and Port Elizabeth		KwaZulu-Natal	
Year	TAE	Catch	TAE	Catch
2002	105	471 360	40	257 238
2003	105	511 946	40	163 357
2004	105	468 485	40	227 067
2005	105	373 322	40	222 864
2006	105	–	40	–
2007	105	387 831	40	105 552
2008	105	315 807	40	2 796
2009	105	350 853	40	103 684
2010	105	426 649	40	102 168
2011	105	508 422	40	24 928
2012	105	311 186	40	13 695
2013	105	320 312	40	149 863
2014	105	327 120	40	52 620
2015	105	330 392	40	20 833
2016	105	374 698	40	–
2017	105	368 270	40	34 171
2018	105	373 306	40	54 131
2019	51	487 130	21	9 280
2020	51	87 539	21	18 147
2021	51	182 254	–	–
2022	51	60 223	–	–

Patagonian toothfish



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
Fishing pressure	Unknown	Light	Optimal	Heavy	

Introduction

Patagonian toothfish *Dissostichus eleginoides* (Figure 46) belong to the family Nototheniidae, a family of fish that occurs in the Southern Ocean. Unlike other species in the family, Patagonian toothfish appear to lack antifreeze molecules in the blood and are consequently not found in waters colder than 2° C. They are slow–growing, reaching sexual maturity at about 90 to 100 cm (9 to 10 years old) and attain a maximum total length of over 200 cm. Patagonian toothfish occur at depths between 70 and 1 600 m around sub-Antarctic Islands and seamounts, mainly between 40° S and 55° S. A longline fishery for this species has developed in the South African exclusive economic zone around the Prince Edward Islands (PEI-EEZ).

Patagonian toothfish fetch a high price on markets in the United States and Japan and have consequently been the target of extensive fishing, primarily using longline gear. As a large part of their distribution is on or around remote seamounts and islands where surveillance is difficult, they have been subjected to substantial illegal, unreported and unregulated (IUU) fishing. The implementation of a catch-documenting scheme that enables buyers to identify product from legal fisheries has led to a marked reduction in levels of IUU fishing. Fisheries for Patagonian toothfish are further characterised by losses through marine mammals (mostly orcas *Orcinus orca*) taking fish off the lines (termed "depredation"). In some fisheries this depredation can be substantial. During a single fishing trip in the PEI-EEZ, it was estimated to represent a loss of as much as 80% of the catch on a single day, and 30% to 50% of the catch during that trip.

Figure 46: A Patagonian toothfish *Dissostichus eleginoides*, with an individually-numbered tag inserted just below the dorsal fin

Patagonian toothfish are largely distributed within the area managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). As an original member of CCAMLR, South Africa remains committed to its objectives, and has voluntarily applied the CCAMLR conservation measures within the PEI-EEZ. According to CCAMLR CM 32-01 "the fishing season for all Convention Area species is 1 December to 30 November the following year"; thus a split-year fishing season applies within the PEI-EEZ.

History and management

An experimental fishery for Patagonian toothfish in the PEI-EEZ was initiated in October 1996. Five Permit Holders participated in the experimental fishery from its inception until 30 November 2005. In 2006, the experimental fishery was converted to a commercial fishery through the allocation of five long-term fishing Rights. At the start of the commercial fishery there were two active vessels, one representing the largest Right Holder and a second, larger vessel operating for a consortium of the other four Right Holders. The consortium soon withdrew their vessel from the fishery, advising that fishing was uneconomical due to poor catch rates and high losses to marine mammals. Consequently, only a single vessel operated in the PEI-EEZ from 2006 until the consortium re-introduced a second vessel into the fishery in late 2010.

Various gear configurations have been employed to exploit the resource since the inception of the fishery. At the commencement of the fishery in the 1990s, the primary fishing gear employed was a form of longline known as an "autoline", with a few vessels using the Spanish double-line system. Apart from a brief period (2004–2005) when one vessel deployed pots, the period from 2000 onwards was characterised by an increasing shift to the use of Spanish longlines, and autolines were eventually phased out altogether by 2008 (Figure 47). Another shift in the gear employed began with the introduction in 2008 of a modified longline gear, the trotline, which appreciably decreases the loss of catch to marine mammal depredation and has a higher retention of large fish. Use of this gear has subsequently increased to the extent that no Spanish longline gear has been used subsequent to the 2012/2013 fishing season (Figure 47). These gear changes have complicated the assess-

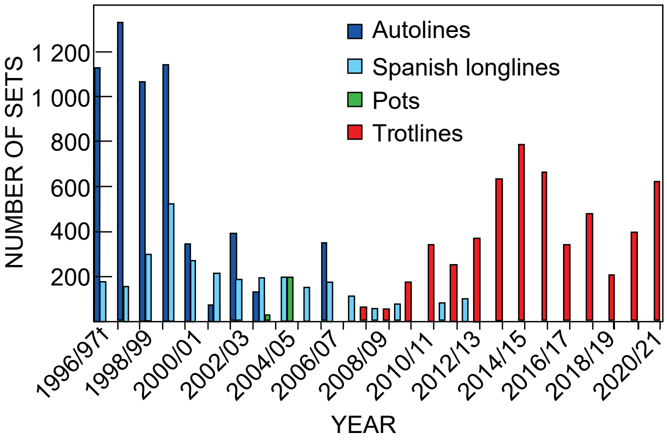


Figure 47: Number of sets deployed per fishing season in the Prince Edward Islands EEZ. Data are shown for pot lines and for three different longline gear configurations deployed in the fishery over time. † Note that data for the 1996/97 season include fishing during the months of October and November 1996

ment of the status of the resource (see below), and hence its management. An experiment to calibrate catch rates between Spanish longlines and trotlines was initiated in the 2011/2012 season and continued through to the end of the 2012/2013 fishing season. Currently, trotlines are the only gear deployed in this fishery.

During the two years prior to the start of the experimental fishery the Patagonian toothfish resource in the Prince Edward Islands area was subjected to heavy exploitation by a fleet of illegal vessels that ranged throughout the Southern Ocean. The estimated IUU catch during those initial two years was more than double the total legal catch taken over the subsequent 20 years. The IUU activity in the area declined in response to reduced catch rates and the establishment of the legal fishery, and the last recorded IUU activity in the PEI-EEZ was the sighting of a single vessel in 2004. Although there has been no indication of IUU activity since 2004, there is a possibility that IUU activity could go undetected because of the limited presence of legal vessels in the PEI-EEZ. Consequently assessments of the PEI toothfish resource conducted prior to 2013 assumed a continued, constant IUU take of 156 t per annum (i.e. the same level as that estimated in 2004) over the period 2005 to 2009. On the basis of information that subsequently became available, recent assessments of the resource (2013 onwards) have assumed no IUU catches in the PEI-EEZ after 2005.

Regulation of the fishery was initiated in the 1996/97 season with a 2 500 t TAC (Figure 48). The TAC was increased to 3 000 t for the 1997/98 season to promote year-round presence in the PEI-EEZ in an effort to deter IUU fishing activity. The TAC was reduced to 2 750 t for the 1998/99 and 1999/2000 seasons, and then further reduced to 2 250 t for the 2000/01 season since resource indicators (CPUE) suggested that sustainable harvest levels had been greatly reduced due to illegal catch levels. The first assessment of the status of the resource was conducted in 2001 and used an age structured production model (ASPM) that was based on catch-per-unit-effort (CPUE) data derived from Spanish longline sets. The results of the assessment indicated severe depletion of the stock, which led to a decrease in the TAC to 600 t for the 2001/02 season. At its October 2002 meeting, the CCAMLR Scientific Committee suggested that a TAC of not more than 400 t would be appropriate for the 2002/03 season. In consultation with industry representatives, a compromise was reached between the 400 t suggested by CCAMLR's Scientific Committee and the 600 t TAC that was set in the 2001/02 season. This compromise was firstly to demonstrate South Africa's commitment to CCAMLR, and secondly to provide sufficient catch to maintain a year-round legal fishing presence in the Prince Edward Islands EEZ as a means of deterring further IUU fishing in the area. The TAC was thus set at 500 t for the 2002/03 season and maintained at that level for the 2003/04 fishing season.

The ASPM was extended to incorporate catch-at-length (CAL) data as a basis for TAC recommendations in 2003. Despite refinements to the model, the two primary resource monitoring indices (CPUE and CAL) yielded conflicting estimates of resource status. While the CPUE data indicated that the resource was severely depleted, the CAL data suggested that the situation was less serious. Attempts to reconcile these two indices were unsuccessful. These circumstances led to major difficulties in making scientific recommendations for appropriate catch limits for this resource, and a pragmatic approach was adopted that led to a reduction in the TAC to 450 t for the 2004/05 season. The consortium of four Right Holders withdrew their vessel in 2006 due to economic pressures, leaving only a single Right Holder, with an allocation of 27% of the TAC, active in the fishery. Consequently the TAC was maintained at 450 t per annum until 2010 when the consortium of four Right Holders re-entered the fishery. The annual catches over the 2006 to 2010 period were well below the TAC (Figure 47) as a result of only one Right Holder being active in the fishery.

An updated analysis of the status of the resource incorporating additional catch data (2007–2010) was conducted in September 2011. The analysis was complicated by the gear change (Spanish longline to trotline) in the fishery in recent years that had compromised the only index of abundance, namely the time-series of commercial CPUE. Depending on the data and approach used in the analysis, standardised CPUE dropped by between 16% and 34% in 2010 relative to preceding years. On

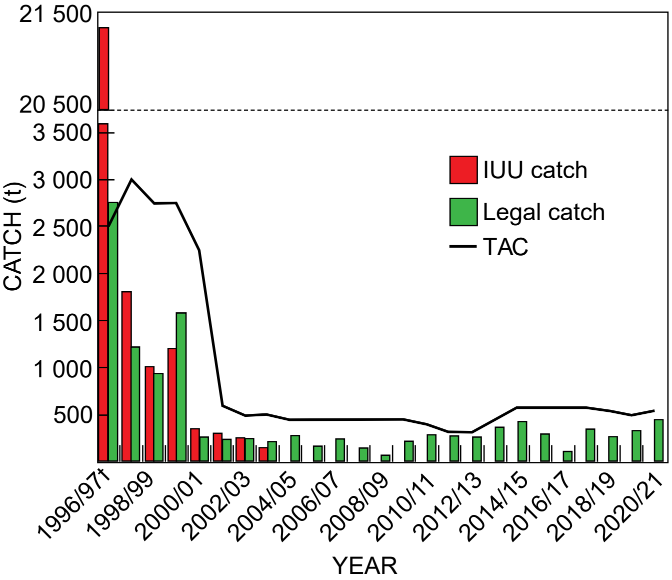


Figure 48: Catches (tonnes) of Patagonian toothfish estimated to have been taken from the Prince Edward Islands EEZ. Catches are split into those from the legal fishery and estimates of illegal (IUU) catches. † Note that data for the 1996/97 season includes legal catches during the months of October and November 1996

the basis of these results, the TAC for the 2011/2012 fishing season was reduced by 20% from the 2010/2011 level to 320 t, and this level was maintained for the 2012/2013 season, pending further work on calibrating the Spanish longline and trotline CPUE indices.

A research strategy was implemented during the 2011/2012 and 2012/2013 fishing seasons with the objective of calibrating the trotline CPUE against that for Spanish longline. The strategy involved operators deploying paired sets of both Spanish longline and trotline gear in close spatial (3 nautical mile) and temporal (2 weeks) proximity to each other in order to compare catch rates obtained with the two gear types. The data collected during this exercise enabled the calculation of a calibration factor for the two gear types, which could then be applied to the general linear mixed model (GLMM)-standardised CPUE time-series for each gear type to obtain a calibrated overall "longline" CPUE abundance index for the entire duration of the legal fishery.

The assessment of the Prince Edward Islands toothfish resource was updated during 2013 to take account of further catch, GLMM-standardised CPUE and catch-at-length information that had become available for the years 2007 to 2013. The assessment allowed for three fleets to accommodate data from the pot fishery that operated in 2004 and 2005 and the trotline fishery since 2008, in addition to the Spanish longline operations. Results from the updated model indicated that the resource was healthier than had been suggested in previous assessments, yielding estimates of current depletion (spawning biomass relative to pre-exploitation levels) ranging from 43% to 87% depending on various assumptions of recruitment variability and pre-exploitation abundance. Based on these results, the TAC for the 2013/2014 fishing season was increased to 500 t.

In addition to updated catch data and the improved standardised CPUE index of abundance, the 2014 assessment model update involved several improvements over previous assessments. Tag-recapture data (Table 11) were incorporated for the first time, and a new basis for estimating the extent of depredation by cetaceans was used. The updated model yielded a changed perception of depletion, with estimates ranging from 55% to 60% of the average pre-exploitation spawner biomass. Although projections using the assessment model indicated that the resource would increase in abundance under catches of up to 700 t per annum, the poor fits to longline CPUE data, coupled with uncertainties regarding the stock-recruit relationship, led to the decision to set the TAC for the 2014/2015 season at 575 t, with further increases dependent on a review of updated datasets. The TAC was subsequently maintained at this level until the 2018/2019 season due to concerns related to the declining trotline CPUE index despite projections from assessments indicating that the TAC might be safely increased to some extent. The 2018 update of the assessment was conducted in circumstances where the trotline CPUE had continued to decline, and used a new basis to estimate the extent of cetacean depredation. The assessment yielded a somewhat more pessimistic perception of resource status than did that conducted in 2017, and projections under a suite of alternative scenarios of future resource dynamics indicated that a 5.5% reduction in the TAC (to 543 t) for the 2019/20 fishing season would be appropriate.

Table 11: Number of Patagonian toothfish tagged and released per year in the Prince Edward Islands EEZ, and the number of tagged fish recaptured per year

Season	Released	Recaptured
2004/2005	175	4
2005/2006	179	3
2006/2007	120	8
2007/2008	140	12
2008/2009	74	1
2009/2010	131	9
2010/2011	206	8
2011/2012	162	12
2012/2013	254	30
2013/2014	380	57
2014/2015	473	44
2015/2016	345	13
2016/2017	115	7
2017/2018	363	17
2018/2019	285	8
2019/2020	366	9
2020/2021†	502	0
Total	4 270	242

† Up to 20 November 2021

Differing perceptions of resource status arising from conflicting trends in CPUE and catch at length (and more recently mark-recapture) data have led to major difficulties in making scientific recommendations for appropriate catch limits for this resource. Efforts have consequently been directed at developing an operational management procedure (OMP) for the resource that would enable resource recovery if the stock was indeed very depleted (as indicated by the CPUE data), but that would allow catches to increase if future data support a more optimistic appraisal of resource status. Work on such an OMP was completed in 2009, but that OMP was not adopted due to concerns that it was too conservative and assumed levels of IUU fishing and cetacean depredation that were too high, leading to TAC recommendations that were lower than needed to be the case. Further work on the OMP has been conducted in the subsequent period, resulting in an OMP that was adopted in October 2020.

This OMP (referred to hereafter as OMP-2020) modifies the TAC each year in synchrony with the trends in the two available resource abundance indices (CPUE and tag-recapture data). It has the primary objectives of:

- achieving a median depletion (current spawning biomass relative to pre-exploitation level) of 40% in the long term to promote resource conservation, and
- restricting interannual changes in the TAC to less than 10% to promote industrial stability, except in circumstances where resource indices fall below specified threshold levels.

OMP-2020 has been used to calculate the TACs for the 2020/21 (542.9 t) and 2021/22 (548.5 t) fishing seasons.

Research and monitoring

Catch and effort data are reported by the fishing vessels on a set-by-set basis (i.e. per longline deployed). In compliance with CCAMLR conservation measures, there is 100% observer coverage in this fishery. Catch and effort records and observer reports are submitted to CCAMLR.

Some toothfish were tagged during 2005 as a trial, and a tagging programme was initiated in 2006. Vessels are required to tag and release one fish per tonne of catch (in line

Table 12: Estimates of resource status provided by the 2021 and 2022 reference case model updates

Parameter	Description	2021 reference case	2022 reference case	2019 intermediate case	2019 pessimistic case
K^{sp}	Pre-exploitation spawning biomass (t)	25 616	25 886	22 458	13 115
MSY	Maximum sustainable yield (t)	1 087	1 102	946	554
B^{sp}_{2020}/K^{sp}	Depletion	0,398	0.403	0.336	0.161
B^{sp}/B_{MSY}	Spawning biomass relative to B_{MSY}	1.615	1.632	1.365	0.655

with CCAMLR Conservation Measure 41-01). Fish should be selected at random for tagging (every 100th fish, for example) so that a range of sizes is tagged. However, fishermen tend to select the smaller fish to tag because they are less valuable and are easier to handle – it is difficult to bring a large (70 kg) fish onboard without using a gaff and thereby injuring the fish. A tag-overlap statistic has been developed by CCAMLR to measure the degree to which the length distribution of tagged fish matches that of all fish caught, and a requirement for a tag-overlap statistic in excess of 60% was introduced. These regulations have resulted in a marked improvement in the size range of tagged fish. As of November 2021, 4 270 fish have been tagged and 242 have been recaptured (Table 11).

About 88% of recaptures of tagged toothfish have been within 10 nautical miles of the tag-and-release locations. This observation suggests that toothfish do not move between seamounts and hence could be susceptible to serial depletion. If this was the case, then standardising the CPUE over a large area would mask the serial depletion and lead to an artificially stable CPUE trend. To address this concern a new CPUE standardisation was developed during 2014, using a finer spatial scale for fishing areas. The results did not support the hypothesis of serial depletion and showed no evidence of systematic shifts in fishing effort over time, but did show a larger decline in CPUE over the last five years than that estimated by previous standardisations.

Current status

A routine update of the toothfish reference case (RC) model (the assessment model that is considered to provide the most plausible measures of stock status and dynamics) is conducted every year to ensure that the resource has not deviated appreciably from what was predicted during OMP testing. Results of the RC assessments conducted in 2021 and 2022 (using data that extended to the end of the 2020 and 2021 fishing seasons, respectively) showed relatively small differences (Table 12), with the 2022 assessment suggesting a slight improvement in resource status. The slight decline in abundance over the last few years observed in previous assessments remains (Figure 49), although the resource's abundance remains well above B_{MSY} (Table 12).

Ecosystem interactions

South Africa has voluntarily undertaken to implement the CCAMLR conservation measures within the Prince Edward Islands EEZ. These include 100% observer coverage, move-on rules to limit bycatch and specifications for mandatory bird-scaring lines (tori lines). In addition, the total catch of rat-tails (*Macrourus* spp.) and skates (Rajiidae) may not exceed 16% and 5% of the toothfish TAC, respectively.

Since 2010 the total catch per fishing season for rat-tails has ranged between 7 and 28 t and for skates between 0.1 and 3 t. There have been no reported seabird mortalities for the past three years.

A marine protected area in the PEI-EEZ, which contains a no-take area within 12 nautical miles of Prince Edward and Marion islands and three limited-access areas, was promulgated in 2013. The marine protected area is primarily aimed at protection of biodiversity.

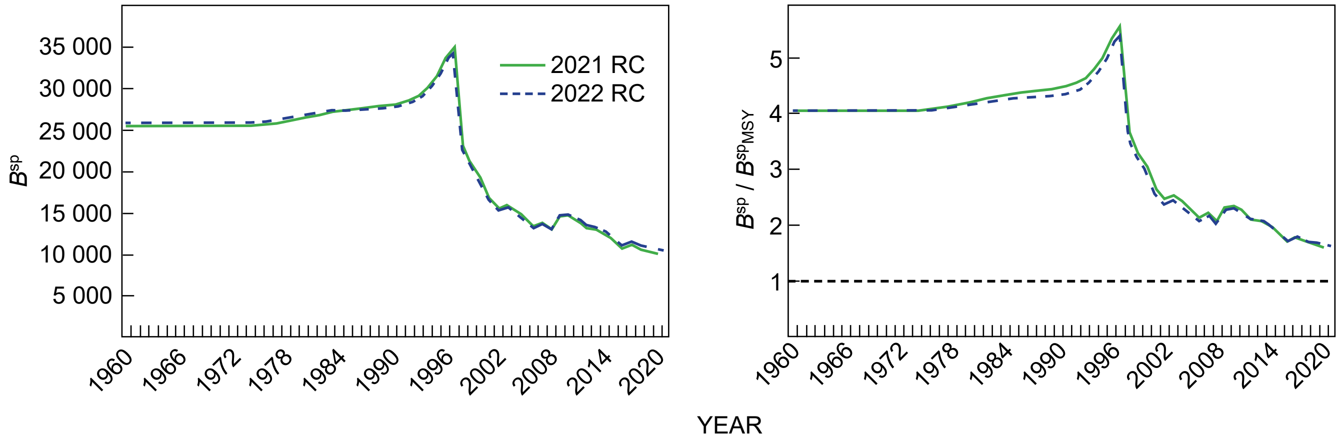


Figure 49: Spawning biomass trajectories estimated by the 2021 and 2022 reference case assessment updates. Estimates are shown in absolute terms (tonnes; left-hand panel) and relative to the spawning biomass yielding maximum mustainable yield (B^{sp}_{MSY}; right panel)

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Useful statistics

Catches (tonnes) of Patagonian toothfish estimated to have been taken from the Prince Edward Islands EEZ and the total allowable catch (TAC) limit.

Fishing season	Legal catch			Illegal	Total	TAC (t)
	Longline	Pot	Trotline			
1996/97[†]	2 754.9			21 350	24 104.9	2 500
1997/98	1 224.6			1 808	3 032.6	3 000
1998/99	945.1			1 014	1 959.1	2 750
1999/00	1 577.8			1 210	2 787.8	2 750
2000/01	267.8			352	619.8	2 250
2001/02	237.3			306	543.3	600
2002/03	251.1			256	507.1	500
2003/04	182.5	34.3		156	372.8	500
2004/05	142.6	141.9			284.5	450
2005/06	169.1				169.1	450
2006/07	245.0				245.0	450
2007/08	88.8		56.4		145.2	450
2008/09	41.8		30.7		72.5	450
2009/10	49.2		174.6		223.7	450
2010/11	1.0		290.4		291.4	400
2011/12	52.4		223.5		276.2	320
2012/13	49.7		215.6		265.3	320
2013/14			366.9		366.9	450
2014/15			431.3		431.3	575
2015/16			298.0		298.0	575
2016/17			110.8		110.8	575
2017/18			346.1		346.1	575
2018/19			269.5		269.5	543
2019/20			336.7		336.7	502
2020/21			451.8		451.8	542

[†] Note that data for the 1996/97 season includes catches during the months of October and November 1996

Seaweeds

Stock status	**Unknown**	**Abundant** Non-kelps	**Optimal** Kelp	**Depleted**	**Heavily depleted**
Fishing pressure	**Unknown**	**Light** *Gelidium*	**Optimal** Kelp	**Heavy**	

Introduction

The South African seaweed industry is based on the commercial collection of kelps and the red seaweed *Gelidium*, and small quantities of several other species. All commercially exploited seaweeds are found between the Orange (Northern Cape) and Mtamvuna (Eastern Cape) rivers. In the Western Cape and Northern Cape, the South African seaweed industry is currently based on the collection of beach-cast kelps and harvesting of fresh kelps. In the past, beach-cast gracilarioids (agar-producing red seaweeds of the genera *Gracilaria* and *Gracilariopsis*) were collected in Saldanha Bay and St Helena Bay, but there has been no commercial activity there since 2007. *Gelidium* species are harvested in the Eastern Cape.

The South African seaweed sector is small compared to many other fisheries but is estimated to be worth at least R45 million annually and to provide at least 400 jobs. Much of the harvest is exported for the extraction of gums. The international seaweed industry is controlled by large international companies that can manipulate prices. Marketing of these raw materials is complicated and requires overseas contacts to sell seaweed or to obtain a good price. As a result, returns for South African companies that do not process locally may be marginal, and they often stockpile material while negotiating prices.

Collection and drying of seaweed is a low-tech activity, while secondary processing is more technical. Extraction and manufacture of end-products (e.g. plant-growth stimulants, alginate, agar, or carrageenan) is technical and expensive, but although only plant-growth stimulants are currently produced (from kelp) in South Africa, production of other extracts should be encouraged because of potentially higher earnings.

Fresh kelp is now harvested in large quantities (about 5 000 t fresh weight per annum) in the Western Cape as feed for farmed abalone. This resource, with a market value of over R6 million, is critically important to local abalone farmers. Fresh kelp is also harvested for high-value plant-growth stimulants that are marketed internationally and nationally.

History and management

Commercial interest in South African seaweeds began during World War II, when various potential resources were identified, but commercial exploitation only began in the early 1950s. The South African industry has historically been based almost entirely on three groups of seaweeds: the kelps *Ecklonia maxima* and *Laminaria pallida*, several species of the red seaweed *Gelidium*, and the red seaweeds *Gracilaria* and *Gracilariopsis* (together referred to as "gracilarioids").

The coastline between the Orange and Mtamvuna rivers is divided into 23 seaweed Rights Areas (Figure 50). In each area, the Rights to each group of seaweeds (e.g. kelp, *Gelidium*, or gracilarioids) can be held by only one entity, to prevent competitive overexploitation of these resources. Different entities may hold the Rights to different resources in the same area.

Management of most seaweed resources is based on total allowable effort (TAE), except for fresh kelp, for which a maximum sustainable yield (MSY) is set in annual permit conditions. The commercial season for permits and reporting of seaweed harvests is from 1 March of year 1 to end February of year 2.

Kelps

Until the mid-1990s, kelp use in South Africa was restricted to the collection, drying and export of beach-cast kelp for the

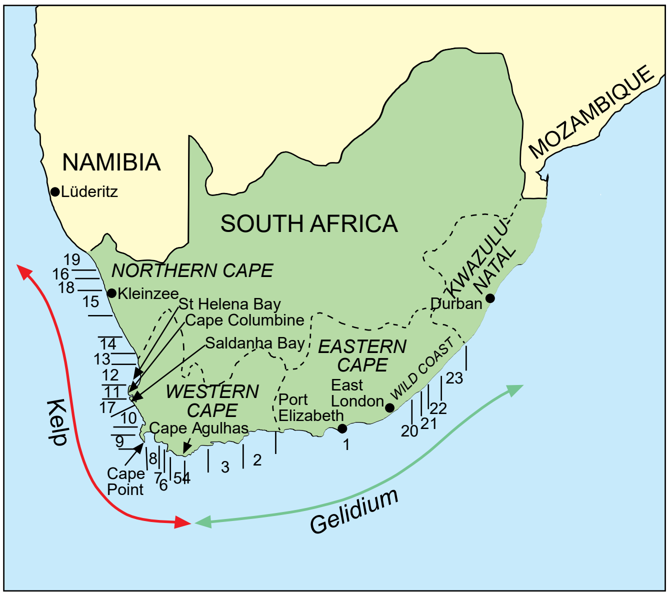

Figure 50: Map of seaweed Rights Areas in South Africa

extraction of alginate, a colloid used in the food and chemical industries. Annual yields varied with international market demands, but peaked in the mid-1970s, with maxima of around 5 000 t dry weight. Since then, yields of <1 000 t dry weight per annum have been more usual (Table 13).

Since the early 1980s, a local company has been producing a liquid plant-growth stimulant from *Ecklonia maxima* and marketing this nationally and internationally. A second local company now also produces a similar extract.

The growth of abalone farming in South Africa since the early 1990s has led to increasing demands for fresh kelp as feed. In 2021 a total of 3 182 t of fresh kelp fronds was supplied to farmers. Demand for kelp as feed is currently centered around the two nodes of abalone farming activity, at Cape Columbine and the area between Danger Point and Hermanus. Kelp harvesters are supplied with a “kelp harvesting manual”, which sets out best practices to ensure sustainability.

Gelidium

Gelidium species contain agar, a commercially valuable colloid with many food and cosmetic uses, and the only medium for cultivating bacteria in medical pathology. The *Gelidium* resource in South Africa comprises *G. pristiodes*, *G. pteridifolium* and *G. abbottiorum*, all most abundant in the Eastern Cape (seaweed Rights Areas 1, 20, 21, 22 and 23; Figure 50), where they have been harvested from intertidal areas since the mid-1950s. Yields, which come almost entirely from Area 1, vary with demand but were usually about 120 t dry weight annually. Since 2010 there has been little or no harvesting from areas 20, 21, 22 and 23 because of low prices for some of the species and access and security problems on the Wild Coast (i.e. northern part of the Eastern Cape coast).

Gracilarioids

Gracilarioids produce agar of a lower quality than that from *Gelidium*. Only Saldanha Bay (seaweed Rights Area 17) and St Helena Bay (Areas 11 and 12 in part) contain commercially viable amounts of these seaweeds. Only beach-cast material may be collected commercially because harvesting of the living beds is not sustainable. In Saldanha Bay, large yields (>1 000 t dry weight, annually) were obtained until the ore jetty and breakwater were built in 1974, after which yields fell dramatically. Occasional small wash-ups are obtained in St Helena Bay. Since 2001, total annual yields of gracilarioids ranged from zero to a few hundred tonnes dry weight, and the resource is regarded as unreliable. No gracilarioids have been collected commercially since 2007.

Other resources

Other seaweeds have been harvested commercially on occasion, including species of *Porphyra*, *Ulva*, *Gigartina* and *Mazzaella*. However, local resources of these species are small by international standards and harvesting has not been economically viable. Nevertheless, there is potential for local use of some species, for example in food products.

Research and monitoring

It is not practical to monitor the amounts of kelp cast up on beaches along the approximately 1 000 km of the West Coast where they occur. Collection of beach-cast kelp has no impact on the living resource and is driven by market demands. Monthly returns are, however, submitted and monitored.

Estimates of kelp biomass are based on infrared aerial imagery, GIS mapping and diver-based sampling. Monthly harvest of fresh kelp is checked against the prescribed MSY as set in annual permit conditions (Table 14). Kelp beds in the two main nodes of harvesting (Gansbaai and Jacobsbaai) are monitored each year, when densities of kelps are determined during diving surveys at each of two permanent locations in each area. Every two years, the same methods are used to monitor kelp beds at Port Nolloth, Kleinzee, Hondeklip Bay and Doring Bay. Values are compared with baseline data from previous surveys. In addition, periodic inspections of selected kelp beds are made from the surface and by divers. Current research aims to improve our understanding of kelp biology in order to manage the resource better.

Table 13: Annual yields (tonnes) of commercial seaweeds in South Africa, 2008–2021, by calendar year. “Kelp beach cast” (column 3) refers to material that is collected in a semi-dry state, whereas “kelp fresh beach cast” (column 2) refers to clean wet kelp fronds that, together with “kelp fronds harvest” are supplied as abalone feed. From 2012, the commercial “season” for permits and monthly reporting of seaweed harvests was changed from a calendar year to 1 March of year 1 to end February of year 2

Year	Kelp fresh beach cast	Kelp beach cast	Kelp fronds harvest	Growth enhancer	*Gelidium*
2008	120.2	550.5	5 429.3	809.9	120.3
2009	115.5	606.7	5 109.3	1 232.8	115.5
2010	103.9	696.8	5 542.2	1 264.7	103.9
2011	102.2	435,8	6 244.8	1 618.0	102.2
2012	117.2	1 063.2	7 488.5	1 788.9	117.2
2013	106.4	564.9	5 837.9	2 127.7	106.4
2014	75.9	775.6	4 800.0	1 610.0	75.9
2015	95.2	389.2	4 223.1	1 930.7	95.2
2016	102.5	411.8	4 144.8	2 166.3	102.5
2017	102.8	482.1	3 317.8	3 001.6	102.8
2018	89.3	540.5	5 356.1	1 886.7	89.3
2019	476.0	287.2	4 209.6	1 029.7	67.4
2020	131.1	246.4	3 560.9	1 250.6	61.2
2021	50.0	297.7	3 182.4	1 645.1	58.1
Totals	1 788.2	7 348.4	68 446.7	23 362.7	1 317.9

Assessment of the gracilarioid resource is performed on an *ad hoc* basis because only beach-cast seaweed is collected and there is therefore no direct effect on the living resource.

The harvesting and biology of *Gelidium pristoides* in Area 1 of the Eastern Cape were comprehensively researched in the 1980s. Current monitoring is by annual inspections of certain harvested and non-harvested shores in that area, and annual biomass and density measurements at two permanent study sites. Catch returns are also monitored to ensure that yields do not exceed historical levels; if they did, further inspections and monitoring would be necessary. The *G. pristoides* resources in Areas 20-23 (former Transkei) have never been quantified. Although currently unexploited, they may become commercially relevant with small-scale fisheries allocations, and will require study. Other seaweed resources are assessed on an *ad hoc* basis as the need arises.

Current status

Kelps

There are 13 areas in which kelp Rights were held in 2021 and yields of dry beach-cast kelp totaled 298 t in 2021 (Table 13). A further 50 t wet weight of fresh beach-cast kelp was supplied to abalone farms, together with 3 182 t wet weight that was harvested directly as abalone feed. These yields have remained fairly steady over the past three years.

Recently, some Right Holders have requested that the MSY of their areas be reviewed because the demand for fresh kelp is increasing. However, because the Department has halted all diving operations due to staff shortages, an assessment of the resource could not be done.

Since the reassignment of four of the Rights Areas (Areas 5, 8, 15 and 16) to the small-scale fisheries sector in 2016, kelp harvesting in these areas has been done under an exception permit. This was to ensure that nearby abalone farms are not negatively impacted when the small-scale fisheries sector becomes organised.

In Areas 6 and 9, the production of plant-growth stimulant by Kelpak and Afrikelp used a combined 1 645 t of fresh kelp in 2021. The status of kelp resources varies geographically: from well/almost completely exploited in some areas to almost completely unexploited in others.

Monitoring, visual inspections and reports from Right Holders show that the kelp resource is stable and healthy.

Table 14: Maximum sustainable yield (MSY) tonnes of harvested kelp for all areas for 2023/2024 season (1 March 2023–28 February 2024). *Note: In Areas 5 and 6a only non-lethal harvesting of fronds is allowed

Area	Whole kelp	Kelp fronds
5	0*	2 625
6a*	0*	4 592
6b	174	87
7	1 421	710
8	2 048	1 024
9a	2 467	1 234
9b	2 053	1 026
10	188	94
11	3 085	1 543
12	50	25
13	113	57
14	620	310
15	2 200	1 100
16	620	310
18	2 928	1 464
19	765	383
Total	18 732	16 584

Gelidium

All harvested *Gelidium* were collected from Area 1, with *G. pristoides* now comprising almost all the harvest. The other species, which used to comprise most of the harvest in Areas 20-23, now fetch low prices on Asian markets. The 2021 harvest from Area 1 (58 t dry weight) was the lowest ever recorded, mainly because of reduced demand. Inspections and measurements done in February and September 2021 indicate very healthy *G. pristoides* populations, with density and biomass values well within normal limits.

Gracilarioids

Only sporadic wash-ups were observed in Saldanha Bay. These periodic fluctuations appear to have natural causes and have been recorded before. This resource must at present be regarded as commercially unreliable, despite such occasional wash-ups. Since 2007, no collection of *Gracialaria* has been done.

Other seaweed resources

Ulva and *Porphyra* are included in the small-scale basket of species. These seaweeds are collected in small amounts to be used in the culinary industry.

Seaweed resources in general, with the exception of the gracilarioids, are in a good state. None are over exploited, some (kelp in a few Rights Areas) are close to optimal exploitation, and some are under exploited.

Ecosystem interactions

In the case of *Gelidium pristoides* in Area 1, which makes up the bulk of the *Gelidium* harvest, considerable research has shown that harvesting, as currently practised, has negligible ecosystem effects.

Ecosystem effects of kelp harvesting have been dealt with in a few studies and are the subject of ongoing research. Results so far indicate that they are slight; harvesting never exceeds natural mortality (about 10% of biomass), recovery of beds is rapid, and previous research showed no measurable effects on plants and animals living under the kelp canopy. Current studies are examining possible climate change interactions.

Climate change

The only recorded seaweed distributional change, in South Africa, is the eastward movement of the large kelp *Ecklonia maxima* that forms extensive forests along the South African West Coast and parts of the South Coast. During the 1950s, *E. maxima* was only recorded up to Suiderstrand (130 km east of Cape Town) but can now be found 70 km further east at De Hoop Nature Reserve. The kelp bed there is now well established and fairly large. Recent research using repeat photography has shown that the abundance of *E. maxima* is also increasing within its distribution range. This range extension and increase in abundance have been ascribed to cooling of inshore sea temperatures in the region. Repeat sampling of other seaweed species has not shown any similar distributional changes.

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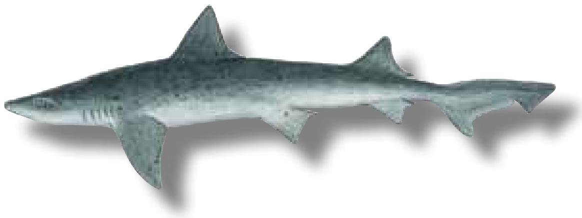
Sharks



Stock status	**Unknown** Leg skates African softnose skate Bronze whaler shark Roughbelly skate Munchkin skate Spearnose skate Leopard skate Lesser guitarshark Izak catshark Rajidae spp.	**Abundant** Slime skate Spearnose skate Biscuit skate St Joseph Whitespotted smoothhound shark Bluntnose dogshark Yellowspotted catshark	**Optimal** Smoothhound shark Blue shark	**Depleted** Yellowspotted skate Twineye skate Dusky shark Puffadder shyshark	**Heavily depleted** Soupfin shark Shortfin mako shark
Fishing pressure*	**Unknown** Leg skates African softnose skate Roughbelly skate Yellowspotted skate Munchkin skate Spearnose skate Leopard skate Lesser guitarshark Izak catshark Puffadder shyshark Rajidae spp.	**Light** Slime skate Twineye skate Dusky shark Whitespotted smoothhound shark	**Optimal**	**Heavy** Biscuit skate Spearnose skate Soupfin shark Smoothhound shark Blue Shortfin mako shark St Joseph Bronze whaler shark Rajidae spp. Bluntnose dogshark	

Status is provided only for chondrichthyans for which assessments are available. *Fishing pressure is across multiple fisheries

Introduction

The class Chondrichthyes (sharks, rays and chimaeras), hereafter referred to as "sharks", represents an ancient (420-million-year-old) lineage of fishes, present in all major marine systems. Globally, it has been estimated that more than a third of the 1 200 known species of sharks are currently threatened with extinction, mostly through direct overfishing. This has been shown in the decline by 71% in abundance of oceanic sharks and rays owing to an 18-fold increase in relative fishing pressure since 2014. For two thirds of all threatened shark species, overfishing as target and bycatch remains the sole threat to their populations. Sharks are often caught as part of the unwanted bycatch in fisheries that are managed for species that can sustain a higher fishing pressure. This unwanted bycatch is discarded at sea, and much of it is unrecorded and unregulated. Classification of sharks as an unwanted bycatch has a bifold effect on sharks; firstly it is difficult to estimate total fishing mortality per species across all fisheries, and secondly the lack of species-specific data hinders the ability to assess the species in question.

The southern African chondrichthyan fauna includes representatives from all 13 orders of cartilaginous fishes with 50 families and 105 genera, representing 20% of all known chondrichthyans. There are 111 shark, 72 batoid and 8 chimaera species, of which 13% are endemic to the region. Just over half of the 191 chondrichthyan species that occur in southern Africa are impacted by fisheries, ranging from recreational angling to industrialised fishing such as trawling and pelagic longline fishing. Of the 103 species of chondrichthyans that are impacted by South African fisheries, annual catches in excess of 11 t are reported for only 22 species (Table 15).

South Africa is a signatory of the FAO Code of Conduct for Responsible Fisheries. Under its framework an International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) was developed in 1998, which encourages mar-

Table 15: Estimated dressed catches [t] of chondrichthyans caught [in excess of 11 tonnes per annum] by South African fisheries. Current scientific name and authority follows Ebert and van Hees (2015). Fisheries abbreviations: Demersal shark longline (DSL), Pelagic longline fishery (PL), Recreational linefish (RecL), Commercial linefish (LF), Beach seine and gillnet fisheries (BG), Offshore/inshore demersal trawl fisheries (TF), *Species generally released if alive, ♦ overfished and overexploited, ♦♦ not overfished but overexploited

Scientific name	Common name	Estimated average annual catch 2010–2012 (tonnes)	Estimated average annual catch 2013–2019 (tonnes)	Fishery / fisheries catching >75%	Local trend/ stock status	IUCN Status	Global trend
Cruriraja spp.	Legskates	11–100	11–100	TF		LC	—
Bathyraja smithii	Softnose skates	11–100	11–100	TF		LC 2018	—
Callorhinchus capensis	St Joseph	400–500	300–400	TF	LC ↑	LC 2020	—
Carcharhinus brachyurus	Bronze whaler / copper shark	101–200	11–100	LF, DSL, PL, BG**	LC ↑	VU 2020	↓
Carcharhinus obscurus	Dusky shark	11–100	1–10	LF*, RecL*, DSL, BG*		EN 2018	↓
Prionace glauca	Blue shark	301–600	400–500	PL		NT 2018	↓
Isurus oxyrinchus	Shortfin mako shark	301–700	600–700	PL		EN 2018	↓
Dipturus pullopunctatus	Slime skate	11–100	11–100	TF	LC ↑	LC 2019	↑
Dipturus springeri	Roughbelly skate	11–100	11–100	TF		LC 2018	—
Leucoraja wallacei	Yellowspotted skate	11–100	11–100	TF	VU ↓	VU 2019	↓
Raja spp.	Rays and skates	11–100	11–100	TF			
Raja ocellifera	Twineye skate	11-100	11–100	TF	EN ↓	EN 2020	↓
Raja straeleni	Biscuit skate	201–300	100–200	TF	LC ↓	NT 2020	↓
Rajella caudaspinosa	Munchkin skate	11–100	11–100	TF		LC 2018	—
Rajella leoparda	Leopard skate	11–100	11–100	TF		LC 2020	—
Rostroraja alba	Spearnose skate	11–100	11–100	TF, DSL	VU ↓	EN 2006	↓
Acroteriobatus annulatus	Lesser guitarfish / wedgefish	11–100	11–100	TF, RecL*	LC ↑	VU 2019	↓
Holohalaelurus regani	Izak catshark	11–100	11–100	TF	LC ↑	LC 2019	↑
Squalus acutipinnis	Bluntnose spurdog / dogfish	11–100	11–100	TF	LC ↓	NT 2019	↓
Galeorhinus galeus	Soupfin shark / tope	101–400	101–200	TF, LF, DSL	CR♦ ↓	CR 2020	↓
Mustelus mustelus	Common smoothhound shark	101–300	11–100	DSL, LF, TF, BG**	EN♦♦ ↓	EN 2020	↓
Mustelus palumbes	Whitespotted smoothhound shark	1–100	1–100	TF, DSL, LF	LC —	LC 2020	—

itime states to develop a Shark Assessment Report (SAR) and adopt a National Plan of Action for Sharks (NPOA-Sharks).The first South African National Plan of Action for sharks (NPOA-Sharks I) was finalised in 2013 and provided baseline information on the status of chondrichthyans in South Africa and assessed research, management, monitoring, and enforcement frameworks associated with shark fishing and trade of shark products in the South African context. The NPOA-Sharks I went through an internal review and a comprehensive external review by an international panel of experts appointed by the Minister in 2020. The panel recognised South Africa's achievements, in particular in the discipline of scientific assessments, but also identified areas where improvements are still needed. Emanating from this review, after an extensive stakeholder consultation phase, the revised NPOA (NPOA-Sharks II) builds on the achievements and lessons learned from NPOA-Sharks I and closely follows the recommendations of the Shark Expert Panel.

History and management

The history of shark fishing in South Africa goes as far back as the late-1800s; however, commercial-scale exploitation only started in earnest in the late-1930s and was linked to an increased demand for natural vitamin A obtained from shark livers. This fishery was concentrated in Western Cape fishing villages, with very large catches exceeding 4 000 t focused on soupfin sharks *Galeorhinus galeus*. Although it was not until the synthesis of vitamin A in 1967 that demand for shark products decreased, catches of soupfin shark were already declining by the late 1940s, and have not returned to pre-war levels (Figure 51a). By the 1990s there was renewed interest in sharks and a shark-directed longline fishery was established. The fishery initially targeted both demersal and pelagic sharks but shifted toward pelagic sharks when further industrialisation and motorisation enabled fishers to fish farther offshore for longer periods of time. However, pelagic sharks are now caught only as bycatch in the large pelagic longline fishery.

South Africa has only one shark-directed fishery, the demersal shark longline fishery, with smoothhound *Mustelus mustelus* and soupfin shark comprising the bulk of the catch. The suite of demersal shark species caught in South Africa is caught across three fisheries: the demersal shark longline fishery, the inshore trawl fishery and the commercial linefishery (Figure 51). The demersal shark longline fishery is the only sector that consistently targets demersal sharks, with targeting in other sectors being sporadic, depending on the availability of more-valuable target species and seasonal aggregations. None of the commercial fisheries are currently limited by shark species-specific management measures such as size- or bag limits, but shark-specific regulations exist in the following commercial fisheries: demersal shark longline, large pelagic longline and beach-seine and gillnet.

Fisheries responsible for significant catches of demersal sharks

Longline permits were first issued in 1991 for targeting both demersal and pelagic sharks. This dual targeting was discontinued in 2004 with the development of the demersal shark longline sector with 11 Rights, and with those Right Holders

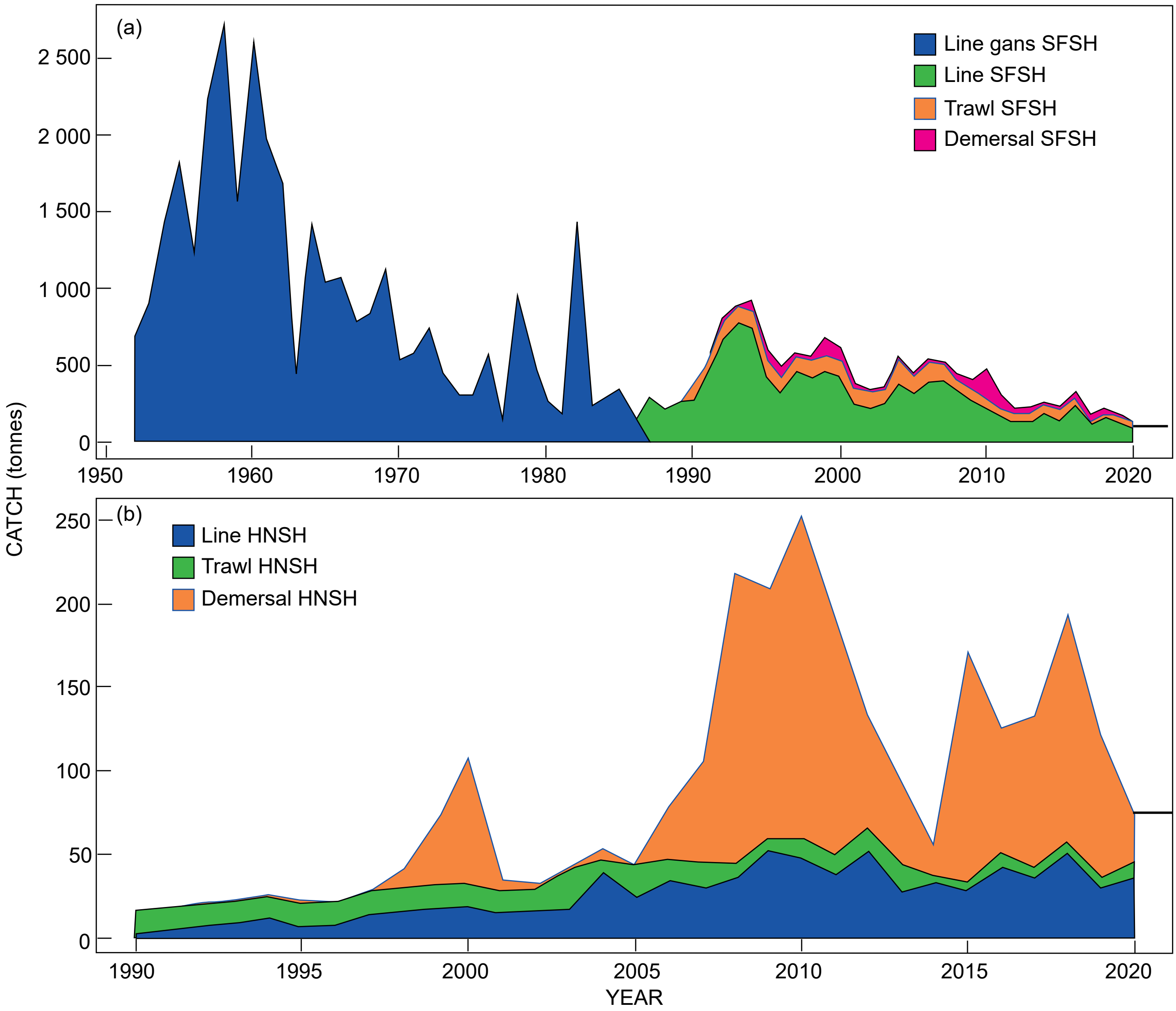


Figure 51: Total catch (tonnes) of (a) soupfin shark *Galeorhinus galeus* (SFSH) and (b) smoothhound shark *Mustelus mustelus* (HNSH) between 1950 and 2020 and 1990 and 2020, respectively, for the inshore trawl fishery, the demersal shark longline fishery, commercial linefishery and the historical commercial linefishery from Gansbaai (line gans SFSH). Catches were raised from dressed weight to total weight using the de la Cruz (2015) raising factors of 1.42 for HNSH and 1.52 for SFSH. The black line in 2020 represents the catch estimated to be sustainable at the most recent stock assessment

(RHs) focusing on pelagic-shark fishing moving to the large pelagic longline sector under an exemption. By 2006, the number of vessels in the demersal shark longline sector was reduced to six. Most RHs in this fishery hold Rights in multiple fisheries; therefore the number of active vessels fluctuates dramatically, and there have rarely been more than four vessels operating annually. From the inception of this fishery annual landings have fluctuated widely, largely because of the demand for shark trunks or "flake" internationally; however, reduced catches and effort in recent years may be directly related to declining stocks.

Rights in this sector were re-allocated during the most recent FRAP process in 2021 with only a single successful RH. It is likely that many previous RHs did not reapply for rights in the sector due to the economic constraints in the fishery. Appeals are ongoing at the time of writing and the final number of vessels within the fishery is still to be determined but will not exceed the previously recommended four RHs.

In terms of operation, the demersal shark longline fishery is permitted to operate in coastal waters from the Orange River on the West Coast to the Kei River on the East Coast but fishing rarely takes place north of Table Bay. Vessels are typically <30 m in length and use nylon monofilament Lindgren Pitman spool systems to set weighted longlines baited with up to 2 000 hooks (average = 917 hooks). The fishery operates in waters generally shallower than 100 m.

This fishery contributes >75% of the total fishing mortality for eight species; bronze whaler shark *Carcharhinus brachyurus* (classed as Vulnerable [VU] on the IUCN Red List of Threated Species, 13 t average annual dressed catch between 2010 and 2020), dusky shark *C. obscurus* (Endangered [EN], <1 t average annual reported catch between 2010 and 2020), broadnosed sevengill shark *Notorynchus cepedianus* (VU, <1 t), spearnose skate *Rostroraja alba* (EN, <1 t), smooth hammerhead *Sphyrna zygaena* (VU, <1 t), soupfin shark (Critically Endangered [CR], 29.6 t), smoothhound shark (EN, 64.2 t) and white spotted smoothhound *Mustelus palumbes* (Least Concern [LC], <1 t). A total of 27 shark species have been reported as caught in this fishery, with an increase in reporting since identification guides were included in national catch-return books. A pilot electronic monitoring (EM) program has been installed in the remaining vessel in the sector which will further assess the impact of this fishery. In addition, the effectiveness of an EM program for longline operations will be investigated from these data and from national surveys. This fishery was responsible for 7.6% of the average annual reported catch of sharks between 2010 and 2020.

The long history of the commercial linefishery can be traced back to fishing activities of European seafarers in the 1500s, with the first fishing restrictions imposed in 1652. To compensate for declining catch rates of high-value linefish species, a rapid increase was seen in shark catches between 1990 and 1993. After 2000, species-specific reporting came into effect and shark catches continued to constitute a large proportion of the livelihood of these fishers around South Africa, with the establishment of a number of dedicated shark-processing facilities. Shark catches by the commercial linefishery since the 1990s have typically fluctuated in response to the availability of higher priced linefish species and market influences. The fishery is described in detail in the Linefish section of this report, and contributes to >75% of the total fishing mortality for 22 shark species, of which 45% are listed as Vulnerable, 18% as Endangered and 5% as Critically Endangered. The average annual reported catch of sharks between 2010 and 2020 was 167.9 t with this sector responsible for 10% of the average annual reported catch of sharks in that period.

The effects of recreational angling on shark populations are largely unknown as a result of the lack of a legislated mandatory reporting system and unknown post-release mortality for most species. There is evidence from global studies that recreational catches can exceed those from commercial sectors and the collapse of certain fisheries has been attributed to recreational fishing. In South Africa, an increase in the use of unmanned aerial vehicles or drones for recreational angling focused on large elasmobranchs increased in 2016, with a high percentage of IUCN Red Listed species (69%) caught and used as bait. In 2022 a public notice was released by the Department declaring that the use of motorised equipment for recreational angling has always been illegal according to the Marine Living Resources Act of 1998. The recreational linefishery contributes >75% of the catch of 26 species of shark; of these, 39% are listed as Vulnerable, 15% as Endangered and 12% as Critically Endangered. Although most of the sharks are released, post-release mortality is unknown.

The inshore trawl fishery targets shallow-water Cape hake *Merluccius capensis* and Agulhas sole *Austroglossus pectoralis* between Cape Agulhas and the Great Kei River but takes a substantial bycatch of demersal sharks. This sector contributes >75 % of the total fishing mortality of at least 67 species (with a few generic groups), with 31% listed globally on the IUCN Red List as being under threat; with 9% as Vulnerable, 16% as Endangered and 6% as Critically Endangered (NPOA Sharks II). Only two species of shark are reported by name in the fishery: St Joseph *Callorhinchus capensis* (308.8 t average annual reported catch between 2010 and 2020) and soupfin shark (28.7 t). The remaining estimated 65 species are lumped under the following categories: dog sharks (1.5 t average annual reported catch between 2010 and 2020), hound sharks (19.9 t), skates (139.3 t), copper (or bronze whaler) shark (0.08 t), and unidentified sharks (11.4 t). The sector is described in detail in the Agulhas sole section of this report. This fishery is responsible for 30% of the average annual reported catch of sharks between 2010 and 2020. Due to a massive reduction in catches in the large pelagic sector since 2020, for this most recent aggregation of all catch data, this sector is responsible for 59% of total fishing mortality of sharks in South Africa.

A directed gillnet fishery for ploughnose chimaeras, locally referred to as the St Joseph, is confined to the South African West Coast and is managed as part of the netfishery, with strict gear and effort limitations (see Netfish section of this report). The total catch of St Joseph by the trawl fishery (308.8 t average catch between 2010 and 2020) far exceeds the catch of the directed fishery (~40 t). The legal gillnet fishery is facing increased competition from illegal gillnetting in estuaries and the sea, throughout the South African coastline. Illegal gillnetting in estuaries alone lands around 2 200 t per annum (estimated total catch of all teleosts and sharks), twice that landed by the legal gillnet fishery in the sea. Landings from illegal gillnetting in the sea, especially that directed at sharks, may now also exceed the landed mass of the legal fishery. Illicit gillnetting is highest in KwaZulu-Natal and the Western Cape but is expanding from both these provinces into the Eastern Cape. Data are limited but Northern Cape gillnet catches appear to have been dominated by the illegal fishery for at least the last three decades. Illegal gillnets are generally negatively buoyant and are often set overnight or without surface marker buoys to avoid detection, and illegal shark gillnets are increasingly being stored in weighted bags at sea. Illegal gillnetting has escalated in both in estuaries and the sea. Much of this is done using primitive craft, including large slabs of polystyrene foam, wooden frames covered with heavy-duty plastic sheeting, dugouts carved from tree trunks and even double-bed frames clad with corrugated iron, as well as using high-powered skiboats and deckboats with hidden compartments to conceal nets and catch. The more-rudimentary craft are confined to estuaries and sheltered nearshore.

Catches by illegal gillnets in estuaries are highest on the West Coast from the Orange River to just north of Table Bay (Buffels River) and in northern KZN, from Kosi Bay to Lake St Lucia. Illegal marine gillnet operations are more sophisticated, currently mostly directed at sharks with catches of 400 t to >800 t per annum estimated for the Cape South Coast. In KZN, confiscated gillnet catches reveal shark bycatch to be exceptionally high, one example being the catches of smooth hammerhead and milk shark *Rhizoprionodon acutus* in the “shark nursery” of Richards Bay. Extinction of both large-tooth *Pristis microdon* and green *P.zijsron* sawfish from South African waters are likely directly attributable to gillnet saturation and ghost-fishing in their estuarine pupping grounds and nursery areas in KZN. The nets in the Western and Eastern Cape are mostly imported from Europe whereas in northern KZN most of the nets are smuggled in from Mozambique and other countries to the north, where they are inexpensive and readily available. These nets originate from Asia and/or from previous misguided attempts by the World Bank to stimulate fisheries in the region. There is a pressing need for illegal operations to be eradicated and existing legal gillnetting to be phased out and replaced by more-selective fishing methods with lower bycatch mortalities.

Fisheries responsible for significant catches of pelagic sharks

The South African large pelagic longline fishery was commercialised in 2005. Pelagic sharks are now considered bycatch in the large pelagic longline fishery. Progressively more-stringent measures have been applied to limit the shark catch since 2013, when sharks were first designated as bycatch. Measures include a ban of wire trace, the prohibition of finning at sea (sharks to be landed with their fins attached), the implementation of a mandatory observer coverage of 20% stratified across vessels and seasons, and the restriction of targeting to less than 50% shark catch per season. Vessels that catch more than 60% sharks in any quarter are required to have 100% observer coverage thereafter.

Fishing takes place within the entire exclusive economic zone (EEZ) and beyond, targeting highly migratory pelagic species the distributions of which span multiple EEZs. Consequently, these resources are managed by Regional Fisheries Management Organizations (RFMOs); specifically, the International Commission for the Conservation of Atlantic Tunas (ICCAT); the Indian Ocean Tuna Commission (IOTC); and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). This fishery is detailed in the Tunas and Swordfish section of this report.

This sector contributes >75 % of the total fishing mortality of 15 shark species (reported by genus except for mobulids), of which 40% are listed as Vulnerable, 20% as Endangered and 13.3% as Critically Endangered. Except for shortfin mako shark *Isurus oxyrinchus* and blue shark *Prionace glauca*, the remainder of these species have been added to the prohibited list in this sector. The average annual reported catch of sharks in this sector between 2010 and 2020 was 960 tonnes. However, in response to persistent targeting of pelagic sharks, the Department introduced new permit conditions in 2016 to reduce pelagic shark catches. This resulted in a reported catch of pelagic sharks of 248.9 tonnes in 2020, an 85% reduction in just 4 years.

Significant changes in the management of sharks since NPOA-Sharks I

Since the completion of NPOA-Sharks I in 2013, there have been several substantial changes in how sharks are managed both in target and in bycatch fisheries. In the demersal shark longline fishery, no species listed in CITES Appendix II, nor broadnose sevengill sharks, may be landed. A slot limit of 70–130 cm has been implemented for all elasmobranchs in this fishery and in the commercial traditional linefishery, whereby retention of sharks outside the limit is prohibited. Strict handling and release protocols and data requirements apply to all released sharks. The oldest fishery to have historically targeted sharks, the commercial linefishery, has small segments of fishers in historical shark fishing areas that target smoothhound, soupfin and requiem shark species. The 70–130 cm slot limit has also been implemented in this fishery. The most substantial changes in shark management occurred in the large pelagic longline fishery. The shark-directed component of this fishery was merged with the tuna-directed fishery and sharks have become designated as bycatch with strict bycatch regulations in place. These include: (i) the removal of wire traces as permitted fishing gear; (ii) prohibition on retention of CITES Appendix II listed species, including look-alike species; and (iii) implementation of permit conditions requiring sharks to be landed either with fins naturally attached or partially attached but tethered.

Multi-sector shark fishing complicates management

The most-recent estimate (2020) of the dressed-weight catch of chondrichthyans across all fisheries in South Africa decreased to 902 t. Historically the large pelagic longline fishery was responsible for the highest catch of sharks (52%), followed by the trawl fishery (30%), commercial linefishery (10%) and lastly the demersal shark longline fishery (8%). After the change in permit conditions in the large pelagic longline fishery that designated sharks to be treated as bycatch, catches in this fishery decreased by 85%. In 2020, the trawl fishery was responsible for 59% of total shark mortality in South Africa, followed by the large pelagic longline fishery (28%), commercial linefishery (11%) and lastly the demersal shark longline fishery (2%). Given that the pelagic sharks of commercial interest are mainly caught by a single fishery, bringing about a decrease in targeting and a consequent decrease in catches has been a simple process. For chondrichthyans caught across multiple fisheries, reducing catches as necessitated by pessimistic stock assessment results becomes difficult to achieve.

In terms of target species, both soupfin and smoothhound sharks are being caught at unsustainable levels. These are caught across three fisheries as shown in Figure 51. Catches have been upscaled to round weight following algorithms developed by the Department's Linefish Stock Assessment Task Team. To inform discussions about future management recommendations for sharks caught in the above fisheries, it is important to understand the impact of the targeted demersal longline fishery relative to that trawl and linefish catches of the main species. Overall, the commercial linefishery takes the largest proportion of soupfin catches, with an average of 65% of catches between 2007 and 2020, followed by the trawl fishery (20%) and the demersal shark longline (15%).

Research and monitoring

There are ~200 chondrichthyan species that occur in southern Africa, with the number changing frequently due to taxonomic revisions and description of new species; since 2013, seven new species have been added. All the chondrichthyan research related to fisheries is guided by the NPOA-Sharks II of 2022, which aims to collect species-specific data needed to develop appropriate management strategies for all threatened species. All sharks impacted by fisheries in South Africa have been listed in the NPOA-Sharks II under Appendix 2. This lists: (i) the estimated dressed catch in tonnes of each species; (ii) the fisheries responsible for more than 75% of the fishing mortality for the species; (iii) the local stock status and trend; and (iv) the global IUCN stock status and trend. This list represents the first stepping-stone towards completing a prioritisation exercise with the final product to be used to guide national research initiatives at the Department during the 5-year lifespan of the document.

Life-history

To conduct a range of comprehensive assessments and risk analyses for data-poor species, the following life-history parameters are required as direct input into stock assessment models: maximum age, growth rate and size at maturity, and fecundity and generation time. In addition, the development of useful management interventions such as area and seasonal closures requires life-history information such as mating behaviour, sexual segregation, pupping location and the use of nursery grounds. From an initial gap-analysis of the ~103 sharks impacted by fisheries, it is apparent that comprehensive life-history information sufficient for stock assessment input exists for less than 15% of species, with much of this information older than a decade. Basic life-history studies have been completed for smoothhound and blue sharks, and samples have been collected opportunistically for other fisheries species where possible. The collection of these data is largely being hampered by the absence of a comprehensive observer programme as sufficient samples of certain species are difficult to obtain.

Many sharks are highly mobile, and some species exhibit large-scale movement, including transoceanic migrations. Movement studies are currently being undertaken on smoothhound, soupfin, blue and shortfin mako sharks. Research conducted by the Department on smoothhound sharks in Langebaan Lagoon has shown that these commercially valuable species spend a large proportion of their time within the confines of the local marine protected area (MPA). These sharks use the MPA for reproduction and feeding, and as a nursery ground. Occasionally they leave the protection of the MPA and then become available to fishing. The existence of eight other MPAs within the distribution of the smoothhound shark could provide considerable benefits to the fishery in the form of spill-over if nursery areas are contained within the MPAs. It is also likely that various existing MPAs also provide protection for various chondrichthyans. Data from South African fisheries have been incorporated into a shark spatial protection plan currently being developed. This plan aims to highlight additional areas where aggregations of Endangered/Threatened and Protected (ETP) species can be protected without placing excessive restrictive burdens on fisheries.

Stock delineation was investigated for the top three commercial species: smoothhound, soupfin and blue sharks, through collaborations with the Molecular Breeding and Biodiversity Group at Stellenbosch University and the Research Center for Biodiversity and Genetic Resources, Portugal. Genetic studies indicate the likely existence of two inter-oceanic populations of the smoothhound shark at the Atlantic/Indian Ocean boundary and one panmictic population of soupfin sharks. The different patterns of gene flow might be attributed to the species-specific habitat preferences and movement patterns of these species. Blue sharks, on the other hand, are much more widely distributed. Although they are currently managed by different RFMOs related to different ocean basins, it is likely that blue sharks occur in shared stocks that straddle various RFMO regions, with gene flow at a global scale. Recently a mini-barcoding multiplex assay was applied to determine the species from several confiscations and illegal operations. Several threatened species, including the CITES-listed white shark *Carcharodon carcharias*, oceanic whitetip *Carcharhinus longimanus*, shortfin mako, giant guitarfish *Rhynchobatus djiddensis* and scalloped hammerhead *Sphyrna lewini* were discovered. The findings highlight the need for improved trade monitoring and the elimination of illegal trade in shark fins, which can in part be achieved through more widespread genetic sampling of internationally traded products.

Results from pelagic-shark satellite-tagging studies indicate that blue sharks move between the Atlantic and Indian oceans, suggesting the existence of a single southern stock/global stock of the species. This strongly corroborates genetic studies. This research has also highlighted the existence of a nursery ground for blue sharks off southern Africa in the cool Benguela/warm Agulhas Current transition zone. Ongoing research is investigating the existence of a nursery area for shortfin mako sharks on the shelf-edge of the Agulhas Bank. A total of 19 juvenile sharks have been tagged in the area and the movement data are currently being analysed. South Africa is a major contributor to mako shark catch in the IOTC area, but catches fluctuate interannually as the boundary between the IOTC and ICCAT areas bisects the fishing hotspot around the apex of the Agulhas Bank and fluctuations are a function of slight shifts of the fishing area to one or the other side of the reporting boundary, regardless of stock origin.

Monitoring shark catches

As chondrichthyans are caught across multiple fisheries, an estimate of total catch can only be completed if species-specific catch data are available; if not, species-specific catch trends are calculated with the use of research data – predominantly data from the research trawl surveys. Complete, verified datasets are needed to construct catch and effort time-series to produce accurate estimations, and these can generally only be completed with a time-lag of 2 years. As such, the most-recent collated estimate of chondrichthyan catches across all South African fisheries was 902.2 t in 2020. For the two target species, smoothhound and soupfin sharks, conversion ratios have been developed to calculate total weight from dressed weight; therefore, catch reconstructions for these species include a further step where total catch can be estimated for stock assessment purposes. Data needed for the development of conversion factors are currently being collected opportunistically for other species so that total catch of these can be estimated in future. Long-term trend data from monitoring and tagging programmes from NGOs and academic institutions outside the Department are also being investigated for use in risk assessments or stock assessments, depending on the data quality. An identification toolkit for South African sharks has been developed with assistance from the Wild-Trust and WWF-Traffic to improve identification of sharks caught in South African fisheries or confiscated from illegal operations. This identification toolkit includes a simple, freely available identification guide for whole sharks, an identification guide for demersal shark trunks and an identification guide for fins of sharks listed in CITES Appendix II. The toolkit also includes several instructional videos. In collaboration with WWF-Traffic the world's first set of 3D-printed shark fins of CITES Appendix I- and II-listed species was developed and produced to aid in training and compliance exercises. Detailed scans and instructions have been uploaded online and are now being used globally.

Current status

In total, 24% of chondrichthyan species landed in SA fisheries are listed as either Endangered (EN) or Critically Endangered (CR), while a third of all chondrichthyan species impacted by fisheries are listed as least concern (LC). It should be noted that five of the species listed as Endangered are not caught in appreciable amounts in any fisheries, and therefore threats they are facing are likely related to change or deterioration of their environment. Of the 22 species caught annually in quantities exceeding 11 tonnes, nearly a third are listed as Endangered or Critically Endangered. Local risk assessments have been completed using national research surveys or the de Hoop tag and-release research programme, which is the longest fishery independent angling survey in South Africa run jointly by DFFE and CapeNature. Of all chondrichthyans with local risk assessments, nine species show lower extinction rates locally than predicted globally. Only six species of chondrichthyans have catches in excess of 100 t, and three of these are listed as Endangered or Critically Endangered, with fisheries being the sole threat to their populations. Mitigation against the threats to Endangered species is a priority action in the NPOA Sharks II. Information from the fisheries catches of sharks in excess of 100 t is detailed below.

The risk of overfishing of sharks is exacerbated by the disaggregation of catches across many fisheries and the resultant uncertainty in catch and effort time-series. The first comprehensive assessments of soupfin and smoothhound sharks were conducted in July 2019. The assessment input data included standardised abundance indices from fishery-independent demersal trawl surveys (1990–2016) and catch estimates from the demersal trawl fishery, the demersal shark longline fishery and the commercial linefishery. The Bayesian state-space surplus production model, Just Another Bayesian Biomass Assessment model (JABBA), was applied to fit the catch and abundance time-series of soupfin and smoothhound sharks (Figure 52a). All assessment scenarios indicated a >99% probability that soupfin is fished unsustainably. Biomass in 2016, the terminal year of the time-series, was estimated at 13% of carrying capacity and 25% of the biomass at maximum sustainable yield. At the most recent total catch assessment (149.8 t), the projected trajectory is stable; however for the biomass to increase to sustainable levels, catches need to be decreased to 100 t. Given these results, urgent steps are required to reduce fishing mortality for soupfin sharks. The smoothhound shark biomass, on the other hand, is still above the biomass at maximum sustainable yield (Figure 52b) and at the most recent catch construction (74.3 t) the stock is fished at sustainable levels. Projections into the future predict a sustainable level of fishing under 75.0 t. It is advisable that catch by the various sectors continues to be restricted to similar degrees, although it should be noted that the bulk of the

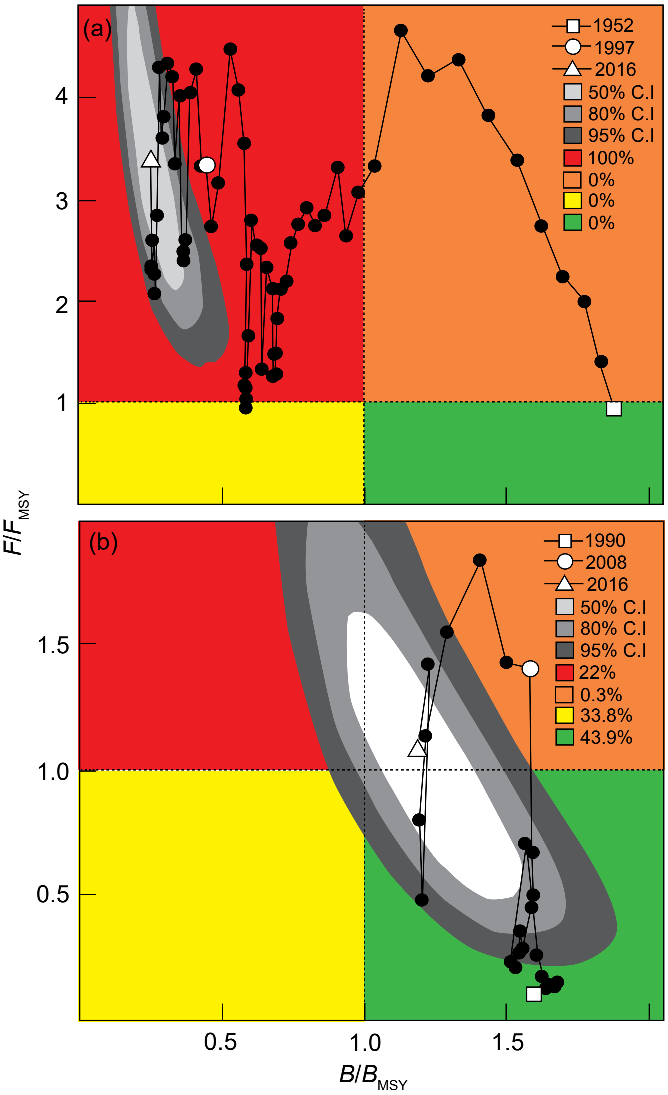


Figure 52: Kobe plot summarising the stock status estimates of fishing mortality relative to F_{MSY} and biomass relative to B_{MSY} for (a) soupfin shark *Galeorhinus galeus* and (b) smoothhound shark *Mustelus mustelus*

catch is taken by the demersal shark longline fishery. Fishing mortality needs to be kept to below 75.0 t to stem a future stock decline. It is vital for both these species that steps be taken to ensure that the small-scale fishery does not add to the fishing mortality.

In addition to the assessments of smoothhound and soupfin sharks, trend analyses for chondrichthyan species off the South and West coasts of South Africa were completed as part of a workshop hosted by the IUCN Shark Specialist Group, using the Bayesian state-space tool, Just Another Risk Assessment (JARA). Seven species were classified as threatened, with one Critically Endangered, five Endangered and one Vulnerable, whereas the remainder of the species were Least Concern. Overfishing has been identified as a concern for three of the seven threatened species, including yellowspot skate *Leucoraja wallace*i, twineye skate *Raja ocellifera* and soupfin shark, with the latter result aligning with results from comprehensive stock assessments. The negative trends in the assessments for the remaining four species are likely due to a shift in abundance, given the spatial nature of the data underpinning the JARA assessments.

Assessments of pelagic sharks are conducted at RFMO level, with input from national scientists. The most recent assessment of shortfin mako shark by the ICCAT in 2017 indicated that the stock has collapsed in the North Atlantic and that, despite the considerable uncertainty around current biomass estimates of the South Atlantic stock, fishing mortality in the South Atlantic likely exceeds sustainable levels. Partially in response to the lack of progress at the 2018 ICCAT Commission with regard to shortfin mako management, the species has now been included in CITES Appendix II, which has ramifications for the large pelagic longline fishery. The status of shortfin mako sharks in the Indian Ocean is largely unknown due to large uncertainty in reported data. For the IOTC region of competence, the absence of a stock assessment and with noticeable conflicting information, the IOTC Commission should take a precautionary approach by implementing actions to reduce fishing mortality on shortfin makos.

The most recent stock assessment for blue sharks in the ICCAT region was completed in 2015. Bayesian state-space surplus production model estimates were less optimistic than previous models and predicted that the stock could be overfished, and that overfishing could be occurring. Considering the uncertainty in stock-status results for the South Atlantic stock of blue sharks, the Committee strongly recommended that a precautionary approach be taken.

For the IOTC region of competence, the blue shark was assessed in 2021 with the assistance of national researchers. Even though the 2021 assessment indicates that Indian Ocean blue sharks are not overfished nor subject to overfishing, increasing current catches is likely to result in decreasing biomass and the stock becoming overfished and subject to overfishing in the near future. The stock should be closely monitored.

Since 2014, several species of chondrichthyans have been listed in CITES Appendix II due to their global stock status and lack of management. These include the oceanic whitetip shark *Carcharhinus longimanus*, three species of hammerhead sharks (scalloped *Sphyrna lewini*, great *S. mokarran*, and smooth *S. zygaena*), porbeagle shark *Lamna nasus*, mobulid rays, silky shark *C. falciformis* and thresher sharks *Alopias* spp. As described above, the shortfin mako shark was added to the list of species in CITES Appendix II, which has severe implications for the large pelagic longline fishery. International trade of products (i.e. fins/flesh and gillrakers) of species listed in CITES Appendix II requires an import/export permit from the Department, a CITES permit, also from the Department, and a Non-Detrimental Finding (NDF) certificate provided by an RFMO from the area of capture. The latter is available for a limited number of species and will not be issued for species such as the oceanic whitetip, rendering such species effectively CITES Appendix I-listed, whereby trade is not allowed. Prior to the listing of shortfin mako sharks, all CITES Appendix II-listed pelagic sharks were caught infrequently and were moved to the non-retention lists. Shortfin mako shark fins are the second-most-traded shark fins into and out of South Africa, and hence the risk of contravention of CITES Appendix II conditions is high. On the 26th of November 2019, South Africa issued a reservation against the listing of mako sharks on CITES. As such, until the reservation is withdrawn, South Africa will be treated as a non-party to the Convention regarding their trade.

Ecosystem interactions

Ecosystem interactions of shark fisheries are sometimes difficult to isolate, given that, in addition to being targeted in certain fisheries, chondrichthyans are caught as bycatch species in a suite of fisheries. The ecosystem effects of the different fisheries are detailed in their respective sections in this report, but are not restricted to chondrichthyans.

In terms of ecosystem interactions, the gear used in the demersal shark longline fishery is very selective and generally restricts the catches of this fishery to chondrichthyans and teleosts feeding near the bottom. Ecosystem considerations for the demersal shark longline fishery include potential incidental catches of prohibited species such as white sharks, hammerhead sharks and red steenbras *Petrus rupestris*. The weighted longline sinks too fast to incur substantial incidental bycatch of seabirds; therefore, only limited mitigation measures are in place, including permit conditions minimising the number of lights used during setting at night and the mandatory use of bird-scaring lines. No incidental catches of seabirds, mammals or turtles, and only two white sharks, have been reported in logbooks used in this fishery. An observer programme in place between 2008 and 2009 reported no significant bycatch of threatened, endangered or prohibited species. Recently mandatory observer coverage has been re-established and added into the permit conditions for this fishery. The use of electronic monitoring (EM) is being investigated for use in this fishery and one vessel has been rigged with three cameras – one on deck to observe catches, one overlooking the longline haul and a third observing the setting procedures.

Climate change and sharks

As with other marine species, sharks respond to environmental stressors associated with climate change by shifting location, depth, or a combination of these. Endemic demersal sharks and rays residing at the southern tip of the African continent may not be able to respond to changing environmental conditions by moving or changing depths given environmental and physical barriers and may be significantly affected by climate-change effects. This effect, termed ‘habitat squeeze’, could affect more-mobile species as well.

Inshore cooling and the eastward shift of kelp *Ecklonia maxima* on the Cape South Coast will likely be accompanied by distributional shifts in catsharks (Scyliorhinidae) and other kelp-associated chondrichthyans, and is likely to have occurred for other species as well. These shifts in distribution related to climate change are likely to have far-reaching consequences for sharks. For example, smoothhound sharks occurring inside the Langebaan Marine Protected Area (MPA) spend between 80 and 100% of their time inside the area closed to fishing. This is ultimately related to their thermal preferences which coincide with thermal conditions inside the MPA. Sharks inside the MPA respond to slight (<1° C) changes in temperatures by shifting location or leaving the MPA. Slight cooling or warming may shift this species outside the closed area in the MPA, negating its protective effect.

Unusual oceanographic events are likely to become more frequent. A meander of the Agulhas Current and the associated marine heat wave had a significant effect on chondrichthyans on the Wild Coast in 2021, where the difference between the warm (26° C) surface water and 11° C upwelled water caused mass strandings of tropical and sub-tropical species such as mobulid rays and bull sharks.

A recent study showed empirical evidence of distributional shifts in bottom-dwelling teleosts and chondrichthyans over the past three decades on the inshore Agulhas Bank. Several chondrichthyans have shifted southward, including biscuit skates *Raja straeleni* and slime skates *Dipturus pullopunctatus*, with the latter showing a contraction in distribution area. These shifts are likely a result of the combined effects of climate change, habitat destruction and/or fishing. The study also showed a northeastward shift in distribution for lesser sandshark *Acroteriobatus annulatus*, likely related to inshore cooling, as this species is not commercially targeted, and a distributional change across depth contours for bluntnose spiny dogfish *Squalus acutipinnis* with a southward shift in distribution to depths 30 m deeper in latter years. Long-term changes on the inshore Agulhas Bank were also investigated during a trawl survey that replicated historical gear and methods on historical sites from 1903 to 1904. Historical surveys showed larger numbers of Torpediniformes (electric rays), with an increase in abundance of *Squalus* spp., Myliobatiformes and Rajidae in recent years. Change in prey species may also have occurred as a result of the altered benthic habitat. Therefore, chondrichthyans that don't require structured habitats and are associated with soft sediments appeared to have benefitted to some degree from the altered habitat because of trawling, likely at the expense of others.

Increases in CO_2 because of climate change are thought to lead to hypercapnic conditions, especially after frequent upwelling and subsequent low-oxygen events. A recent study has shown that shysharks *Haploblepharus edwardsii* are physiologically well adapted to these events; however, denticle corrosion has been observed under hypercapnic conditions. A more detailed description of this study can be found in the Research Highlights section of this report.

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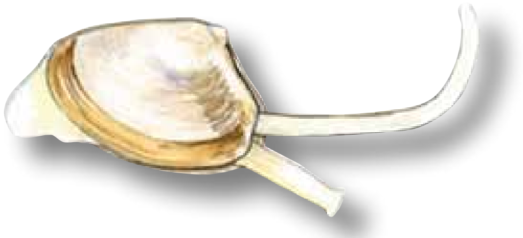
Small invertebrates and new fisheries



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
	White mussel Octopus East Coast round herring				
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
		Octopus East Coast round herring	White mussel		

White mussels

White mussels of the species *Donax serra* are found in the intertidal zone of sandy beaches. They occur from northern Namibia to the Eastern Cape of South Africa. Their abundance is highest along the West Coast because of the higher plankton production there, compared with the rest of the South African coast, which is associated with upwelling of the Benguela Current.

Routine harvesting of white mussels by humans started during the late Pleistocene around 150 000 years ago. The fishery for this species only started in the late 1960s as part of the general commercial bait fishery and was suspended in 1988 when the bait Rights were revoked. Subsequent to stock assessments conducted in 1988/1989, harvesting of white mussels was retained as a commercial fishing sector and limited to seven areas along the West Coast (Figure 53). Surveys conducted in the 1990s showed that commercial catches amounted to less than 1% of the standing biomass in the relevant areas, and the resource was considered underexploited.

Prior to 2007, each Right Holder was limited to a monthly maximum catch of 2 000 mussels. However, data from the fishery were unreliable, due to under-reporting and difficulties with catch monitoring, and hence catch limits were not considered to be an adequate regulatory tool to manage this fishery. As of October 2006, the monthly catch limit was lifted with the aim of removing constraints. Since 2007 the commercial sector has been managed by means of a total allowable effort (TAE) allocation of seven Right Holders (a Right Holder may have up to seven "pickers"), each harvesting within only one of the seven fishing areas along the West Coast. In 2013, the fishing Rights allocation process (FRAP 2013) for this fishery started and new Rights were granted in addition to those of some of the previous Right Holders. After an appeal process, 26 commercial Rights were confirmed in 2015 and those Right Holders have remained in this fishery since then. Each Right Holder was allocated a specific number of pickers. Some Right Holders are not allowed to employ pickers.

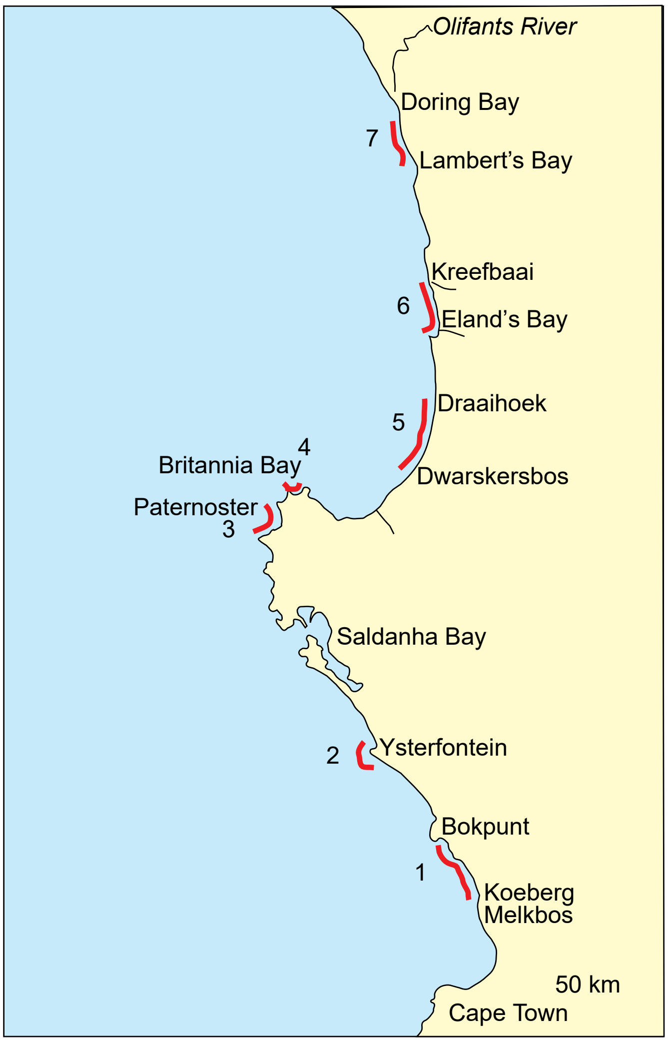


Figure 53: Areas allocated for commercial harvesting of white mussel *Donax serra* along the West Coast of South Africa

In the decades preceding the 1990s, commercial catches declined continuously (Figure 54). Increases in commercial catches after 2006 can be attributed to the lifting of the commercial upper catch limit. The result was an improvement in the reliability and quality of catch data. Therefore, CPUE data were calculated from 2006 onwards although the very high values for 2006 and 2007 likely reflect under-reporting of effort (person-hours). CPUE remained relatively stable between 2008 and 2019 at between 300 and 500 mussels per hour harvested (Figure 55). However, recently we have seen a decrease in the CPUE (2020–2021), mainly due to under-reporting. This under-reporting might be due to the harvesters still recovering from inactivity during COVID.

The Interim Relief sector was started in 2007. During the 2013/2014 season, 1 995 Interim Relief permits were issued for the Western and Northern Cape combined. This sector is subject to a limit of 50 mussels per person per day. The recreational sector is also limited by a daily bag limit of 50 mussels per person per day. For all sectors, a minimum legal size of 35 mm applies.

In the early 1990s, research on white mussels was confined to a few *ad hoc* area-specific stock assessment surveys which were carried out in response to requests for commercial permits. Fishery-independent surveys, aimed at providing information that can be used to assess the stocks, have been conducted since September 2007 and data are being collected in order to provide insights into the abundance of the white mussel resource on an area-by-area basis.

However, it is still too early for a comprehensive assessment of this resource. In addition to the fishery-independent surveys, commercial catch data are also required in setting the TAE. The lifting of the commercial upper catch limit in 2006 led to a steep increase in the number of white mussels collected by this sector over the last few years (Figure 54). In addition, the development of a bait market in Namibia in recent years has created a greater demand for the resource. It should be noted that not all the areas allocated are being harvested, and that the largest component of the overall catch of white mussels is that of the recreational sector, but these catches are not monitored. There are also information gaps regarding the level of exploitation by Interim Relief harvesters and the levels of illegal take. On account of irregularities, and despite the improvement post-2006, the catch-and-effort data are still considered to be unreliable. Recently, considerable effort and focus has been placed on assessing the standing stock of white mussels along the West Coast. The current research programme will help to gather sufficient data to allow for proper assessment of the white mussel resource in the medium term. Comprehensive fishery-independent surveys are required in each of the areas and these surveys will take at least 2–3 more years to yield sufficient information for meaningful assessment. Therefore, uncertainty remains regarding the current status of the white mussel resource.

Octopus

Octopus is commercially fished in many parts of the world, including Australia, Japan, Mauritania and several countries in Europe and South America. Markets for octopus exist in countries where this resource is considered a delicacy, for example Japan, China, Portugal, Spain and Greece. However, there is currently no commercial octopus fishery in South Africa and the local market for this product is very small. The common octopus *Octopus vulgaris* is the most sought-after octopus species internationally and has a southern African distribution from Lüderitz (Namibia) on the southern African West Coast to KwaZulu-Natal (at approximately Durban) on the East Coast. The common octopus occurs from intertidal rock pools down to depths of over 200 m, and inhabits various substrata including shell, gravel, sand and reef. Traditionally, octopus has been harvested primarily for subsistence purposes and as bait. A pilot study to investigate the potential of a commercial fishery for octopus paved the way for a 5-year experimental pot-fishery between October 2004 and September 2009. Difficulties caused by: (i) gear loss and damage from rough seas; (ii) vandalism and theft; and (iii) access to suitable vessels and equipment, resulted in this exploratory fishery yielding insufficient information to assess the feasibility of establishing a commercial fishery. Lessons learned during these attempts, however, were used in initiating and developing a further 5-year exploratory fishery, which commenced in 2012.

At the end of this second 5-year exploratory period, a proper scientific evaluation of the fishery still could not be made because of insufficient data received, due to: (i) little or no fishing; (ii) gear losses in some areas; and (iii) unfavourable environmental conditions (e.g. extended periods of red tide). The

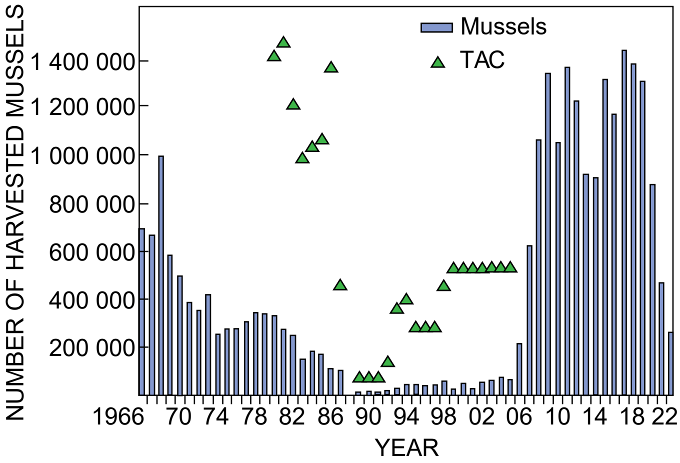


Figure 54: TAC and yield (total number) of white mussels harvested commercially per annum, 1966–2022

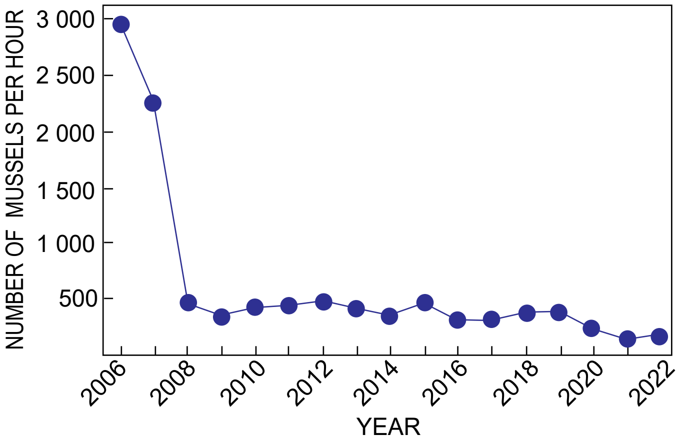


Figure 55: CPUE data calculated from catch data (see Figure 54) for mussels harvested commercially from 2006 to 2022

Department thus extended this exploratory fishery for another 3 years that commenced in 2019. However, later that year (2019) the fishery was temporarily suspended due to a public outcry over whales that became entangled in octopus fishing gear. The industry, together with the Department, held workshops to develop mitigation measures to prevent future entanglements. These measures included sub-surface buoys attached to release mechanisms, bottom lines consisting of only sinking ropes, 2 meters of PVC pipe around the top of the buoy line, and a requirement that the distance between pots must be the same or longer than the depth of the deployment site. Once Permit Holders could show that they were compliant with the new gear requirements, they were allowed to return to fishing.

The exploratory fishery for octopus aimed to improve performance by participants by introducing greater flexibility with regard to the experimental design. Sixteen fishing areas have been designated. The sampling protocol makes provision for participants to set and retrieve an average of 3–5 lines per day, with 50–100 Ivy Blue pots per line, resulting in a potential maximum of 500 pots being set per day. However, with three trigger traps per cradle and each line carrying 40 cradles, the total number of pots set per fishing day could be up to 600 if Australian trigger traps are used. Previous restrictions on pot-type have been removed, so that participants may use whichever pot design is most appropriate to their own operations. On retrieval of each line, the octopus in each pot are recorded separately, and any bycatch identified and counted.

Octopus catches have increased steadily from 17.4 t in 2014 to 74.6 t in 2022 along with increasing effort (Figure 56). Lower catches in some years (2017, 2019 and 2020) were due to lower effort, the temporary suspension of the fishery in 2019, and the Covid-19 pandemic. The steady increase in catches reflects a better understanding of the fishing environment and the improvement of fishing skills. Access to adequate financial resources remains a challenge in this fishery, however, and is the main contributor to slow progress in the current dispensation. Out of 10 successful applicants, only 5 operators were able to activate their permits and begin fishing, and of this number only 3 Permit Holders fish on a regular basis. In effect, of the 16 designated fishing areas, only three are being fished regularly, with most of the data being obtained from the False Bay area.

Octopus monthly catch per unit effort (CPUE) levels in False Bay were high (>3 kg pot^{-1}) for the first three months after initiation of the fishery, but then declined rapidly before stabilising to levels of between 0.5 and 3.0 kg pot^{-1} (Figure 57a). Monthly CPUE levels since 2015 have ranged between 0.4 and 2.0 kg pot^{-1} but show no trend through time and have an annual value of approximately 1.8 kg pot^{-1} (Figure 57a). CPUE levels in False Bay show a clear seasonal pattern, being highest in summer and autumn and lowest in winter and spring (Figure 57b). The stable annual CPUE levels observed in False Bay since initiation of this fishery suggests that these harvest levels are sustainable and economically viable. Based on these stable CPUE levels, the granting of a limited-duration (5-year) commercial fishing right in False Bay has been recommended, whilst the exploratory fishery for octopus will continue in the other 15 designated areas.

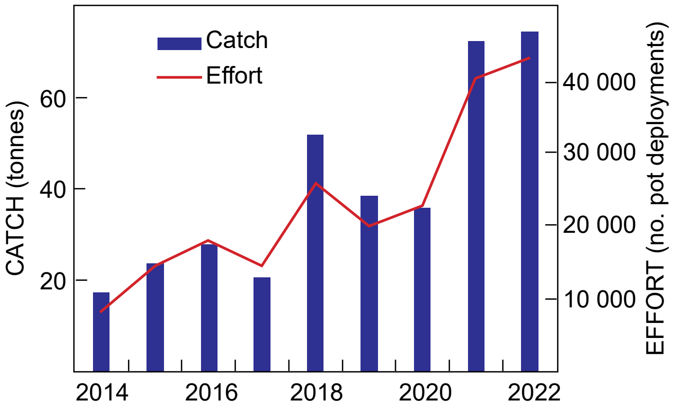


Figure 56: Total annual octopus catch (whole weight) and effort by the exploratory octopus fishery, 2014–2022

East Coast round herring (KwaZulu-Natal)

East Coast round herring *Etrumeus wongratana*i have been harvested by an exploratory fishery since 2013 with only four Exploratory Rights Holders (ERHs) active, all of whom have fished from Scottburgh on the KZN South Coast using rod-and-line or handline fishing from sea kayaks or an inflatable boat. Because of the small size of the fishing vessels used, fishing is heavily dependent on weather and sea conditions. Fishing trips typically start early in the morning and have an average duration of close to four hours, and fishing occurs throughout the week (Figure 58). East coast round herring caught range in size from 120 to 250 mm caudal length (CL) with an average of around 180 mm CL and catches show a marked seasonal pattern, peaking in winter (see Status of the South African Marine Fishery Resources Report 2020). Fish are sold immediately af-

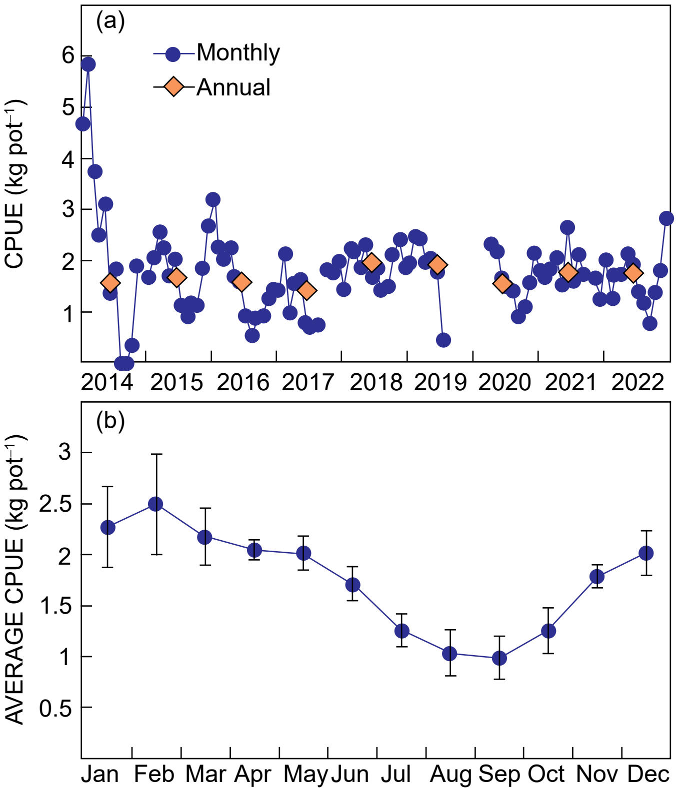


Figure 57: (a) Monthly (blue circles) and annual (orange diamonds) catch per unit effort (CPUE); and (b) average (± 1 standard error) monthly CPUE for octopus in False Bay, 2014–2022

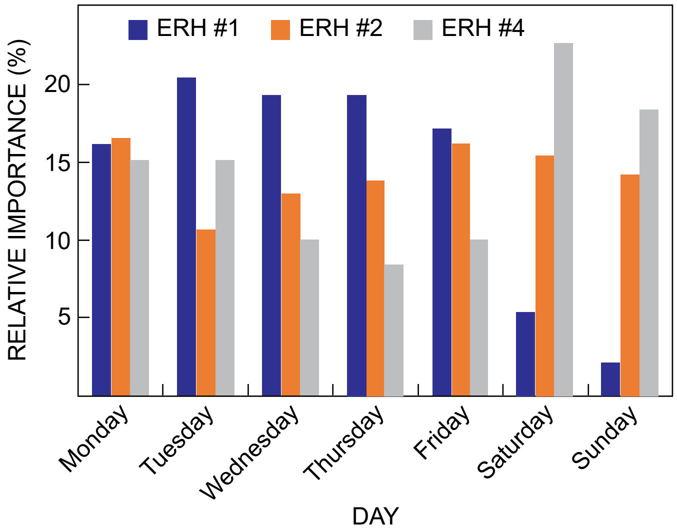


Figure 58: The relative importance (%) of each day of the week for fishing for East Coast round herring by three Exploratory Right Holders (ERHs). If fishing was spread equally throughout the week each day would have a value of 14.3%

ter landing or after freezing, are used locally as bait, and sell for a high unit (individual-fish) price of R5 to R10.

A time-line of the round herring exploratory fishery showing effort and catches by each of the ERHs is provided in Table 16, and annual catch, effort and catch per unit effort (CPUE) levels are shown in Figure 59. Significant and sustained effort was expended initially but this has declined over time, with >100 fishing trips undertaken annually for the first three years (2013–2015), around 50 trips per year for 2016 and 2017, and almost no fishing from 2018 onwards, due to administrative issues regarding the application for and issuing of exploratory permits and/or those permits not being activated, particularly during the Covid-19 global pandemic but also subsequently (Figure 59a). During the 10-year period of this exploratory fishery there have been 464 fishing trips (with a total duration of just over 1 650 hours) that have caught nearly 60 000 round herring with a combined mass of 3.2 tonnes. Catch trends have largely matched effort with higher catches in the first three years (Figure 59a), and CPUE has declined from values of 7.1 and 11.6 kg trip^{-1} (equivalent to approximately 140 and 105fish, respectively) in 2013 and 2014, respectively, to between 2.9 and 5.3 kg trip^{-1} (equivalent to approximately 57 and 230 fish, respectively) thereafter (Figure 59b).

The exploratory fishery for East Coast round herring is not a large fishery in terms of gear, the number of ERHs, spatial footprint, or catches. The information obtained to date has likely provided an accurate seasonal characterisation of catch patterns and CPUE at Scottburgh, which likely reflects fish availability there due to seasonal along- or across-shelf movements. It also indicates that the present catch levels (just over 0.6 tonnes annually, 2013–2017) represent a negligible harvest proportion, given that the single biomass estimate for *E. wongratanai* (made during a pelagic hydro-acoustic survey of the East Coast in 2005) was >10 000 tonnes. Before a decision about the viability of this fishery and its possible development into an experimental fishery can be taken, however, present ERHs should again fish intensively, the number of ERHs should be increased, and the spatial footprint of the exploratory fishery should be increased to allow for the collection of further data including from other locations along the KZN coast. An application to fish for East Coast round herring further north from

Table 16: Time-line of the exploratory fishery for East Coast round herring showing effort and catches by Exploratory Right Holders, 2013–2022. Annual totals for catch and effort, and the overall total for the 10-year period, are shown in bold font

Year	Exploratory Right Holder	Fishing effort (trips; hours)	Catch (no. ; mass)
2013	1.	30 trips; 85.6 hours	3 443 fish; 197.3 kg
	2.	88 trips; 289.6 hours	10 732 fish; 644.2 kg
	3.	Zero trips	Zero catch
		118 / 375.2	**14 175 / 841.5**
2014	1.	31 trips; 97.4 hours	8 125 fish; 562.5 kg
	2.	32 trips; 108.8 hours	4 287 fish; 193.9 kg
	3.	Zero trips	Zero catch
	4.	52 trips; 220.4 hours	12 333 fish; 576.1 kg
		115 / 426.6	**24 745 / 1 332.5**
2015	1.	23 trips; 100.8 hours	2 430 fish; 167.8 kg
	2.	60 trips; 200.7 hours	4 796 fish; 238.2 kg
	4.	36 trips; 176.5 hours	6 053 fish; 223.9 kg
		119 / 478.0	**13 279/ 630.0**
2016	1.	9 trips; 27.3 hours	673 fish; 64.7 kg
	2.	16 trips; 65.2 hours	1 334 fish; 86.3 kg
	4.	18 trips; 89.3 hours	1 918 fish; 73.8 kg
		43 / 181.7	**3 925 / 224.9**
2017	2.	43 trips; 135.6 hours	498 fish; 22.1 kg
	4.	13 trips; 54.3 hours	2 602 fish; 139.8 kg
		56 / 190.0	**3 100 / 161.9**
2018	No fishing	No data	No data
2019	No fishing	No data	No data
2020	2.	11trips; ?? hours	439 fish; 35.09 kg
		11 / ??	**439 / 35.09**
2021	No fishing	No data	No data
2022	No fishing	No data	No data
2013-2022	TOTALS	**464 / 1 651.5+**	**59 663 / 3 225.9**

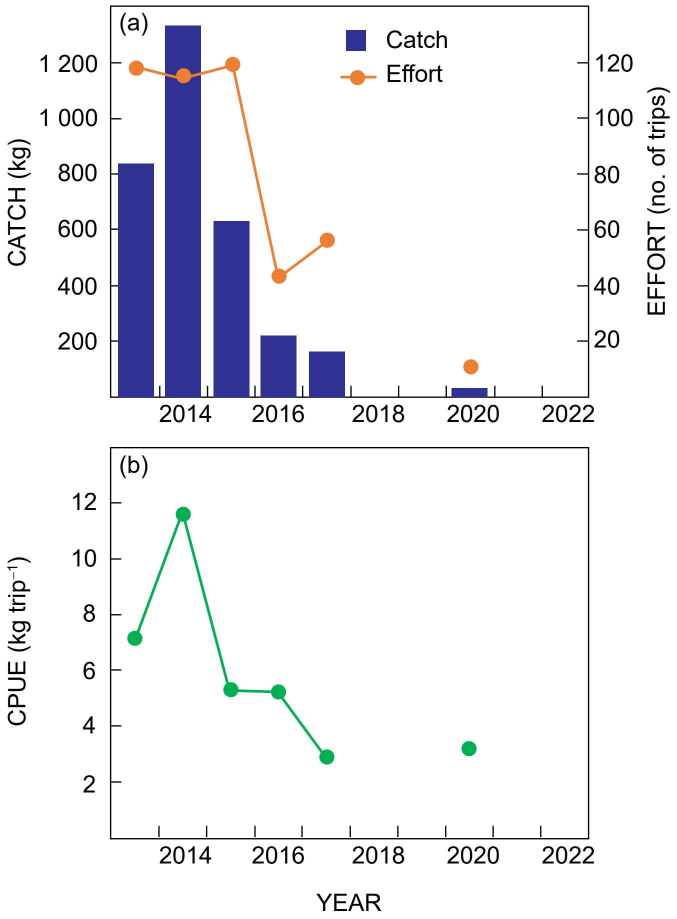


Figure 59: (a) Annual catch and effort and (b) catch per unit effort (CPUE), in the exploratory fishery for East Coast round herring, 2013 to 2022

the present exploratory fishing area and between Amanzimtoti and Umhlanga was supported for 2020 but not activated due to the Covid-19 pandemic. Additionally, the economic viability of the exploratory round herring fishery has yet to be examined and a comprehensive economic feasibility study will be needed to do this. Collecting further data and conducting an economic feasibility study to assess the possibility for development into an experimental fishery will be a medium-term project that will require 3–7 years.

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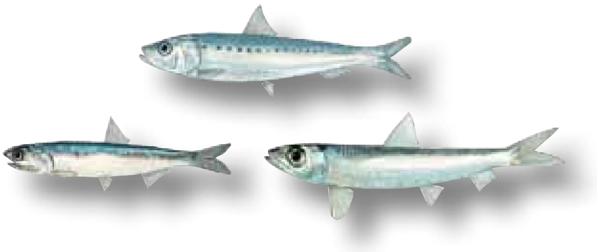
Small pelagic fish (sardine, anchovy and round herring)



Stock status	Unknown	Abundant West Coast round herring	Optimal Anchovy Sardine	Depleted Sardine	Heavily depleted
Fishing pressure	**Unknown**	**Light** West Coast round herring	**Optimal** Anchovy Sardine	**Heavy**	

Introduction

Forage fish of the order Clupeiformes occur in the South African continental shelf waters between the Orange River mouth on the West Coast and Durban on the East Coast. They generally exhibit schooling behaviour, have a small body size with rapid growth rates, have short lifespans and exhibit strong population responses to environmental variability which result in large natural fluctuations in abundance over space and time even in the complete absence of fishing. Abundant small pelagic forage fish off the coast of South Africa include anchovy *Engraulis encrasicolu*s, sardine *Sardinops sagax* and West Coast redeye round herring *Etrumeus whiteheadi*, and these three species generally account for more than 95% of the total pelagic purse-seine catch. Long-term changes in the relative abundance of anchovy and sardine, over decadal and centennial time-scales, have been observed both locally and worldwide. Changes in the abundance of the two species are generally associated with variability in their recruitment, owing to changing environmental factors that affect, amongst others, transport of eggs and larvae, and feeding conditions. These characteristics also render small pelagic fish resources susceptible to those impacts of climate change that result in changed circulation patterns, altered composition and productivity of lower trophic levels, and the distribution of marine organisms – all of which are likely to exacerbate recruitment variability.

Pelagic fish resources are important to the country for several reasons. Firstly, the purse-seine fishery in which they are caught is South Africa's largest fishery in terms of landed mass and second only to the hake fishery in terms of value. Secondly, pelagic fish are an important and high-quality source of protein. Anchovy and round herring are mostly reduced to fish meal and oil in industrial-scale factories and used as a protein supplement in agri- or aqua-feeds. Sardine is mainly canned for human and pet consumption, with a small amount packed whole for bait or as cutlets for human consumption. Thirdly, the pelagic fishery employs a large workforce in fishing and related industries. Finally, pelagic fish occupy a key position in the marine food web where they are the link that transfers energy produced by plankton to large-bodied predatory fish, seabirds, and marine mammals. In this role, forage fish species can and do have major effects on higher trophic levels as well as on lower trophic levels, and variability in forage fish abundance is likely to propagate throughout the entire ecosystem.

Because animals and humans alike depend on forage fish, it is important to manage the fishery that targets them in a manner that accounts for their high degree of variability and importance to the ecosystem. This is so because of the potentially severe risks of local depletion of forage fish for dependent species such as seabirds, particularly in years of low fish abundance in certain areas. However, an often-overlooked fact is that whereas forage fish abundance influences higher trophic levels, the predation pressure exerted by these predators also has a controlling influence on the abundance of forage fish, given that they are the main food source for many predators. Estimates of forage fish losses to predation are typically much higher on average than losses to fisheries, yet the assumption is often made that fishing is the main driver of reduced forage fish biomass.

Although it remains difficult to disentangle the impacts of fishing and natural processes at relevant time-scales in extremely complex marine ecosystems, excessive fishing is likely to disrupt important trophic interactions, particularly at low levels of forage fish abundance. Furthermore, predation pressure is likely to increase too as forage fish abundance declines, at least until a new predator-prey equilibrium is established. Fisheries management responses to such declines in forage fish abundance should therefore be precautionary to limit the risk that abundance falls below levels at which future recruitment is compromised and/or the ecosystem is markedly impacted, while at the same time having regard for the important socio-economic role of the commercial fisheries that depend on forage fish.

History and management

The first pelagic fishing operations began in South Africa in 1935, but commercial operations only started in 1943 in the St Helena Bay area in response to the increased demand for canned products during the Second World War, with purse-seiners operating between Lambert's Bay and Cape Hangklip. Sardine, horse mackerel *Trachurus capensis* and chub mackerel *Scomber japonicus* dominated pelagic catches in the early years. Annual sardine catches increased rapidly from less than 200 000 t in the 1950s to more than 400 000 t in the early 1960s, whereas annual horse mackerel catches, which had peaked at around 120 000 t by the mid-1950s, decreased to less than 30 000 t annually by the end of the 1960s. Similarly, annual chub mackerel catches that peaked at almost 130 000 t in 1967 decreased markedly by the mid-1970s. As sardine, horse mackerel and chub mackerel stocks started collapsing in the mid- to late-1960s, the fishery changed to using smaller-meshed purse-seine nets to target juvenile anchovy, which dominated catches and largely sustained the South African purse-seine fishery for the next 30 years. Anchovy catches peaked at around 600 000 t in the late 1980s then subsequently decreased to a low of 40 000 t in 1996. Catches of sardine gradually increased throughout the 1990s under a conservative management strategy and reached 374 000 t in 2004 following a rapid increase in sardine population size, particularly on the South Coast. Anchovy catches also recovered quickly during the early-2000s, resulting in total pelagic landings of more than 500 000 t per annum between 2001 and 2005. Round herring catches have been reported since the mid-1960s but have never exceeded 100 000 t or dominated the pelagic landings, despite several attempts by the pelagic industry to increase catches of this species.

A prolonged period of low sardine recruitment since 2004 resulted in a rapid decline in the size of the sardine stock with sardine catches dropping to levels in the order of 90 000 t between 2008 and 2014 and to less than 40 000 t in 2017 and 2018. The sardine catch in 2019 of only 2 100 t was the lowest recorded over the past 70 years. Sardine catches recovered to 14 800 t in 2020, 23 000 t in 2021 and 26 000 t in 2022, although more than 70% of catches in 2021 and 2022 were taken on the South Coast. The current low sardine catches are insufficient for profitable operation of the major canning facilities and the bulk of canned sardine products currently produced in South Africa contain sardine that are sourced from Morocco and elsewhere. This has enabled the industry to retain market share and to keep their workers employed, though current unfavourable exchange rates are affecting profitability and threatening the long-term viability of the canning industry, particularly if local catches remain at these low levels.

Owing to this rapid decline in sardine catches, anchovy catches again dominate the fishery, with average catches of around 220 000 t between 2000 and 2018. The 2019 anchovy catch of around 165 000 t was the lowest recorded since 2013 and although the 2020 anchovy catch of 285 000 t was the highest since 2012, catches in 2021 and 2022 were only 156 000 t and 172 000 t, respectively.

Historically, the fisheries for sardine and anchovy were managed separately in South Africa. The South African anchovy fishery has been regulated using an operational-management-procedure (OMP) approach since 1991. This adaptive management system is designed to respond rapidly to major changes in resource abundance without increasing risk. The first joint anchovy-sardine OMP was implemented in 1994, with subsequent revisions. The joint anchovy-sardine OMP is needed because sardine and anchovy school together as juveniles, resulting in the bycatch of juvenile sardine with the mainly juvenile anchovy catch during the first half of the year. This results in a trade-off between catches of anchovy (and hence juvenile sardine) and future catches of adult sardine, and the OMP aims to ensure the sustainable utilisation of both resources. Total allowable catches (TACs) for both species and a total allowable bycatch (TAB) for juvenile sardine are set at the beginning of the fishing season, based on results from the total biomass survey of the previous November. However, because the anchovy fishery is largely a recruit fishery, the TAC of anchovy and the juvenile sardine TAB are revised mid-year following completion of the recruitment survey in May/June.

The OMP formulae are selected with the objectives of maximising average directed sardine and anchovy catches in the medium term, subject to constraints on the extent to which TACs can vary from year to year in order to enhance industrial stability. Even though these formulae are also conditioned on low probabilities that the abundances of these resources drop below levels at which successful future recruitment might be compromised, now that the sardine biomass has dropped below that threshold, the primary and overriding consideration becomes assisting its speedy recovery, while still having consideration for the socio-economic implications associated with any TAC recommendation.

OMP-14, which was finalised in December 2014, was used to recommend TACs and TABs for the small pelagic fishery from 2015 to 2018. Although development of OMP-14 also included substantial analyses related to the implications of the sardine resource consisting of two components with different spatial distributions rather than a single stock, OMP-14 was still tuned using an operating model which reflected a single, homogeneously distributed sardine stock.

OMP-18, which was adopted in December 2018, was, however, developed using an operating model of the sardine resource consisting of two mixing components with differing productivity characteristics. The model of two sardine components, a western component assumed to be distributed west of Cape Agulhas and a southern component distributed east of Cape Agulhas, estimated the extent of west-to-south movement of fish of ages 1 and above each year. This assessment indicated that in terms of recruits-per-spawner, the western component is much more productive than the southern component and that future sardine population growth is mainly dependent on West Coast recruitment. OMP-18 therefore included spatial management components to limit the amount of sardine caught west of Cape Agulhas. Spatial management was formally implemented for the first time in 2019, with each sardine Right Holder constrained to take a maximum of 43% of their sardine allocation off the West Coast. This percentage varies interannually and has ranged from 33% to 46% since then.

OMP-18, as with previous OMPs, also included agreed procedures for deviating from the OMP-calculated TACs and TABs in the event of Exceptional Circumstances (ECs) when application of the TAC generated by the OMP is considered to be inappropriate. Such a deviation may occur, for example, when an observed survey biomass falls outside the range of biomass distributions simulated during the development of the OMP. ECs were first declared for sardine in 2019 and then for both sardine and anchovy in 2020 on this basis and OMP-18 was set aside. Instead, TACs for anchovy and sardine were recommended based on short-term biomass projections from updated assessments pending the development of a new OMP. These projections of spawner biomass under alternative constant catch scenarios, with testing of sensitivity to various assumptions, are evaluated in terms of the proportional increase in biomass that would be achieved in the absence of fishing. A new OMP-18rev was developed for anchovy in 2021 and used to provide TAC advice for anchovy in 2022 and 2023. This revised OMP, however, does not include a juvenile sardine bycatch vs adult sardine TAC component, given that new operating models for sardine are not yet available (see sardine population structure section below) and hence both sardine TACs and TABs continue to be based on short-term projection results, pending finalisation of a new combined anchovy and sardine OMP that incorporates advances in knowledge of sardine population structure.

Research and monitoring

Ongoing research on several issues that have an impact on the sustainable use and management of small pelagic fisheries off the coast of South Africa includes regular monitoring of pelagic fish abundance, development and revision of management procedures, and investigation into, amongst others, population structure, biology and ecology, catch patterns, distribution and behaviour of key species.

The biomass and distribution of anchovy and sardine, but also of other schooling pelagic and mesopelagic fish species such as round herring, juvenile horse mackerel and lantern- and lightfish (*Lampanyctodes hectoris* and *Maurolicus walvisensis*, respectively) are assessed biannually using hydro-acoustic surveys. These surveys, which have been conducted since 1984, comprise a summer total biomass survey and a winter recruit survey. Data for the estimation of a number of other key biological measurements needed as input into the OMP and information pertaining to the environment are also collected during these surveys. Given the fluctuating nature of the abundance of pelagic fish species, these surveys continue to provide estimates that are far more reliable than those that would have been obtained through mathematical estimation from commercial catch data only and have enabled optimal use of these resources at times of high biomass while offering protection to them at low biomass levels.

This time-series of biannual biomass estimates was unfortunately disrupted in 2018 and 2021 owing to the unavailability of the research vessel FRS *Africana* and funding delays in chartering an alternative vessel to conduct the 2018 pelagic recruit survey and 2021 pelagic total biomass survey. The loss of these surveys has had far-reaching consequences both for setting subsequent TACs and for our recent understanding of the status of the anchovy and sardine resources. Fortunately, both the 2022 recruit and adult biomass surveys were successfully conducted onboard the MFV *Compass Challenger*. The FRS *Africana* is expected to resume these surveys in late 2023 following essential replacement of power-generation units.

Data on catch statistics, including landed mass, species composition, and catch position and date, are obtained from the pelagic fishery. Samples from commercial catches are processed to obtain the length frequency distributions of harvested fish that are required as input in the species-specific population dynamics models, in addition to other data on biological characteristics such as sex and gonad maturity stage, and fish condition. The current absence of official scale-monitors at offloading factories is, however, of great concern and potentially compromises the quality of reported landing statistics. Initial investigations have suggested that bycatches of sardine in both the anchovy and round herring fisheries may have been under-reported in the absence of scale-monitors. This has serious consequences for the sustainable management of these resources and attention to this matter is urgently needed.

Sardine population structure

A substantial amount of research over the past decade has documented spatial (regional) differences in a variety of sardine traits around the South African coast. These include differences in: (i) life history strategies such as spawning and nursery areas and their environmental characteristics, and reproductive seasons; (ii) meristic characteristics such as gillraker number and vertebral number; (iii) morphometric characteristics such as gillraker length, and body and otolith shape; (iv) the prevalence and abundance of a digenean parasite biotag; and (v) otolith elemental composition and muscle metallic element composition. These results, together with observations that marine species around South Africa tend to be subdivided into regional populations associated with distinct biogeographic provinces, had suggested the existence of three sardine subpopulations (hereafter stocks) around the country, off the West, South and East coasts, respectively. The eastern stock was thought to comprise fish that mix with southern stock sardines during summer, but then separate from them during winter to travel toward their East Coast spawning grounds during the KZN sardine run. Although management of the purse-seine fishery for sardine has incorporated this hypothesised spatial structure by developing a 2-stock (western and southern) assessment model and setting region-specific catch levels in recent years, previous genetic studies did not support this multi-stock hypothesis.

Most recently, thousands of genetic markers from across the genomes of hundreds of sardines captured around the SA coast (Figure 60) were analysed to test the hypothesis that sardines participating in the KZN sardine run are genetically distinct. A suite of genetic markers with a signal of adaptation to water temperature showed regional differences within the species' temperate core range and only two stocks; one associated with South Africa's cool-temperate West Coast and the other with the warm-temperate South Coast. The strong affiliation with water temperature suggests that thermal adaptation maintains these patterns because each stock is adapted to the temperature range that it experiences in its native region.

Surprisingly, sardines participating in the run were not genetically distinct and showed a clear affiliation with the cool-temperate stock, indicating that the former were migrants that originate from the cool-temperate Atlantic. Not only are these sardines not well adapted to subtropical conditions, but they actually prefer the colder, upwelled waters of the West Coast. Off the Southeast Coast, the autumn and winter occurrence

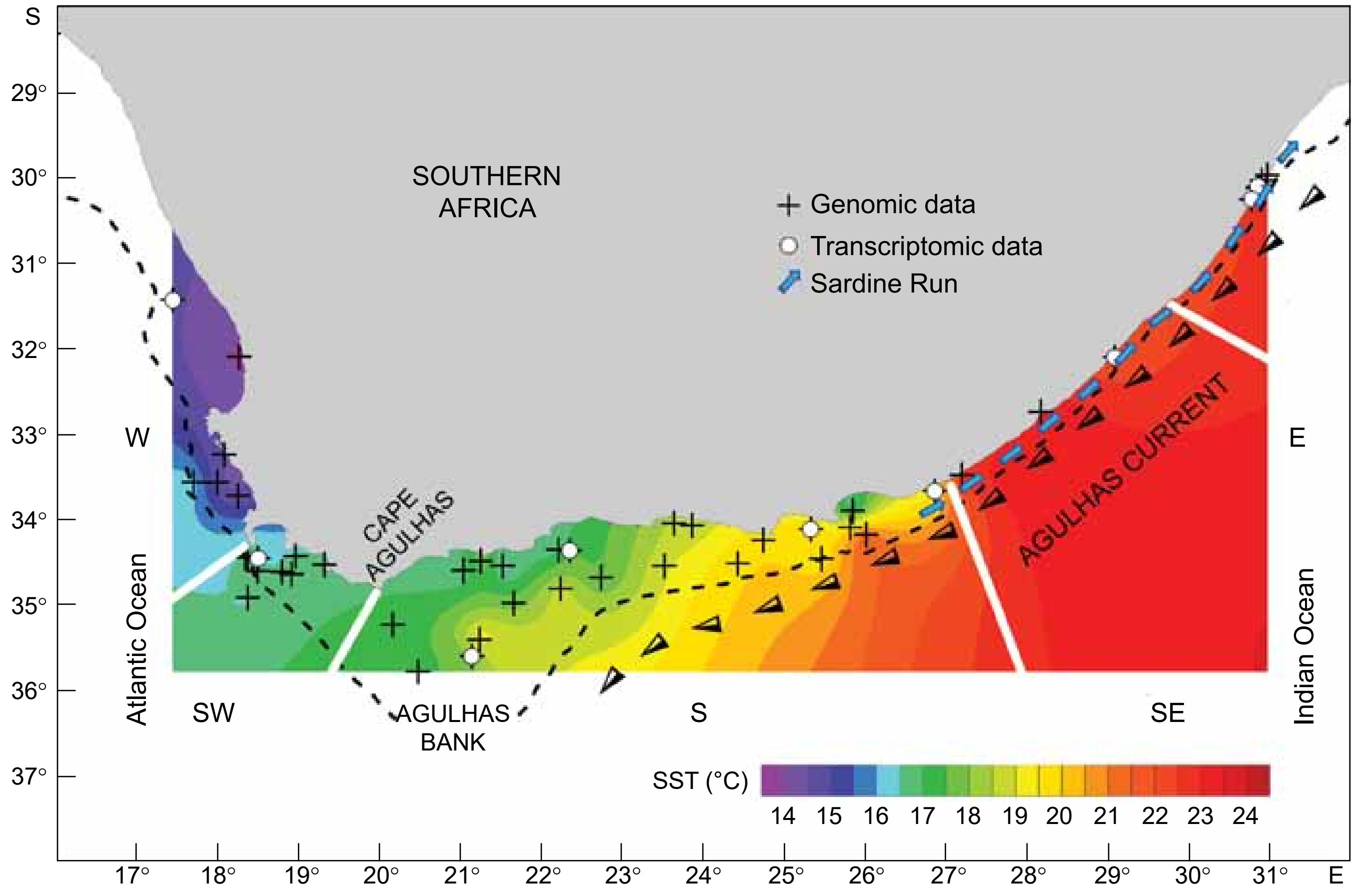


Figure 60: Map showing sites at which sardines were caught for genome and transcriptome sequencing. Colours represent mean sea surface temperatures (SSTs) with the contour plot derived from average SSTs over the previous 30 days at each location before sampling. The coastline was divided into five temperature-defined geographical regions (temperate core range: W, west; SW, southwest; S, south; SE, southeast; sardine run: E, east). Cape Agulhas indicates the approximate boundary between the Atlantic and Indian oceans; the dashed line indicates the edge of the continental shelf (200-m isobath), beyond which the sardines rarely disperse; and the black and white arrows represent the approximate path of the Agulhas Current, which transports tropical Indian Ocean water southward and confines sardines participating in the run (blue arrows) to a narrow coastal band of cooler water (not shown) (from Teske et al. 2021)

of mesoscale cyclonic eddies along the inshore edge of the Agulhas Current that transport cold water onto the shelf can result in shelf waters becoming temporarily cooler than those further west. This cooling creates conditions that favour cool-temperate sardines, triggering an aggregation of these migrants at the northeastern limit of the South Coast, and their northward movement is favoured by intermittent upwelling. Eventually, the sardines find themselves in subtropical waters that exceed their preferred thermal range and where they are subjected to intense predation, suggesting that the sardine run does not benefit South Africa's sardine population as a whole (Figure 61).

Importantly, the genomic results confirm the existence of two sardine stocks off South Africa that have adapted to different water temperatures and experience reduced fitness and lower survival when outside their preferred temperature ranges. This is supported by analyses of sardine-otolith oxygen-isotope ratios and microstructure that showed that fish from the West Coast grew significantly slower in water that was several degrees cooler than those from the South and East coasts. These results have important implications for management of the sardine fishery since, despite mixing between the two stocks, a single-stock management strategy can result in population declines if regional stocks adapted to specific temperature ranges are overexploited.

Anthropogenic pollutants in small pelagic fishes

The potential impacts on the marine environment of increasing levels of anthropogenic pollutants, such as metallic elements, persistent organic pollutants (POPs) and microplastics, are cause for concern, but information on their concentration levels and effects on marine life is limited or absent for many ecosystems, including those off South Africa. Metallic elements and POPs can attain toxic levels through bio-accumulation and can impair the functioning and survival of marine and other (e.g. human) organisms. Ingestion of microplastics can have detrimental effects, and microplastics can themselves be carriers for absorbed or adsorbed co-contaminants such as other harmful chemicals or pathogens. Studies to determine the levels of metallic elements and POPs in small numbers of South African sardine, and the occurrence and concentration of microplastics in anchovy, West Coast round herring and sardine off the South African West and South coasts, have recently been conducted. These measurements have not previously been made on small pelagic fishes in the region and hence can be used as baseline values against which data from future studies can be compared

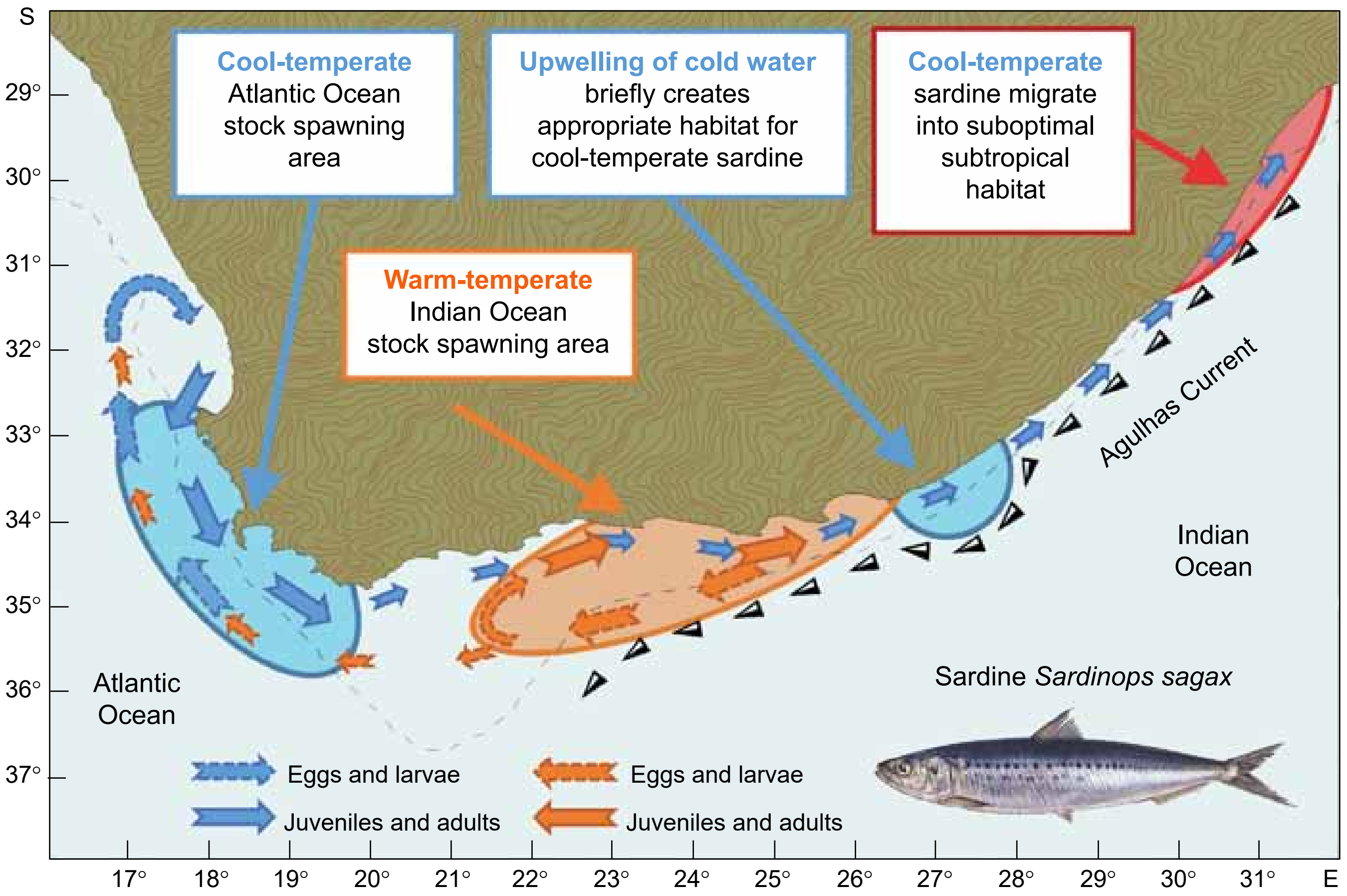


Figure 61: Stock structure of sardine in South African waters and sequence of events that result in a sardine run (from Teske et al. 2021)

as well as enabling an assessment of human consumer safety for sardine.

A total of 29 metallic elements were detected in the muscle of 30 sardine examined, with zinc (24 mg kg-dry-mass^{-1}), titanium (17 mg kg-dry-mass^{-1}) and strontium (5 mg kg-dry-mass^{-1}) having the highest concentrations. Additionally, the relative composition of metallic elements differed between sardines sampled off the West Coast compared to those from the South Coast. Based on limits set by the South African government as well as those set by the European Union, concentrations of three major toxic metals (cadmium, lead and mercury) in sardine do not pose a threat to human consumer safety. The most prominent anthropogenic POPs in sardine muscle tissue were the insecticide dichlorodiphenyltrichloroethane (DDT; now banned in South Africa for agricultural use but still used to control malaria) and polychlorinated biphenyls (PCBs) used in electrical equipment and electronic devices. Concentrations of both of these were markedly lower than concentrations of levels of naturally-occurring halogenated natural products (HNPs), and POPs were not considered to pose a human consumer safety risk. Additionally, PCB levels in South African sardine were substantially lower than those reported in sardines and sardinellas from European waters.

Small pelagic fishes feed on planktonic organisms that are of a similar size to microplastics and hence are considered useful bio-indicators of levels of this pollutant. Samples of ~200 individuals per species of anchovy, West Coast round herring and sardine collected between the Orange River mouth and Mossel Bay during the 2019 Pelagic Recruit Survey were processed to (i) apply a proposed approach for the extraction and quantification of microplastics in small pelagic fish; (ii) investigate interspecific differences in microplastic ingestion; (iii) identify the main plastic and polymer types ingested by these species; (iv) investigate spatial variations and the possible identification of "accumulation zones" of microplastics contamination; and (v) identify and propose a suitable bio-indicator species for the monitoring of microplastics in South African waters. Analyses indicated interspecific differences, with a higher concentration of microplastics in sardine (mean of 1.58 items individual^{-1}) compared to round herring (1.38 items individual^{-1}) and anchovy (1.13 items individual^{-1}), and a higher occurrence of microplastics in sardine (72% occurrence) and round herring (72%) compared to anchovy (57%). Microfibers accounted for 80% of ingested microplastics (the remainder being plastic fragments), with the main ingested polymers being poly(ethylene:propylene:diene) (33% occurrence), and polyethylene (20%), polyamide (20%), polyester (20%) and polypropylene (7%). The abundance of ingested items was not significantly correlated with fish size or body weight, and the abundance of ingested items increased from the West to the South coast. West Coast round herring was proposed as a bio-indicator for microplastics in the South African coastal environment and samples of this species have been collected for this purpose during subsequent surveys. That estimates of the occurrence of microplastics in South African anchovy and sardine are higher than those reported for these species elsewhere is concerning, but a lack of data on levels of transferral of microplastics from edible aquatic species to humans precludes predictive decisions in regard to human consumer safety

Current status

Annual TACs and landings

The total combined catch of anchovy, sardine and round herring landed by the pelagic fishery decreased by 45% from 396 000 t in 2016 to just 217 000 t in 2019, due mainly to a substantial decrease in the catch of anchovy from 262 000 t in 2016 to only 165 000 t in 2019. The catch of anchovy subsequently rebounded in 2020, reaching 285 000 t and pushing the total combined catch of small pelagic fish above the long-term average. Catches of anchovy were again at low levels in 2021 and 2022, despite high TACs being set for these years. The average combined catch over the last five years of 288 000 t is about 45 000 t lower than the long-term (1949–2022) average annual catch of 333 000 t (Figure 62). The utilisation of the anchovy TAC allocated for most years since 2000 remains low, with only 56% of the TAC being caught on average since 2000 (Figure 63a).

The directed sardine catch fell rapidly from 63 000 t in 2016 t to an all-time low of 2 100 t in 2019 (Figure 63b) as a result of drastically reduced TACs given the declaration of ECs for sardine at the end of 2018 and in subsequent years. In 2019, the directed sardine TAC was only 12 000 t, but has since been increased to around 33 300 t because of a slight recovery of the resource in 2022. The landings of sardine in 2021 and 2022 averaged around 30 000 t, with most of these catches having been taken on the South Coast. The sardine resource, however, remains in a stressed state, following poor recruitment in most years since 2004.

Sardine bycatch, which includes juvenile sardine caught with anchovy, adult sardine, and round herring as well as adult sardine caught with round herring, decreased from 17 000 t in 2016 to around 3 000 t in 2018 and 2019 (Figure 63c) but has subsequently ranged from 7 000 to 9 500 t during the past 3 years. The levels of sardine bycatch are well below that allowed in most recent years – mainly because the industry has tried to avoid areas with high bycatches of sardine to improve the chances of a recovery in the size of the adult sardine population.

The catch of West Coast round herring has remained relatively stable, averaging at 55 000 t over the last 5 years, and a relatively large catch of 66 000 t in 2022 (Figure 63d). These recent catches, however, are only half of the 100 000 t precautionary upper catch limit (PUCL) recommended for this resource and reflects the difficulty of catching this species with purse-seine nets. Increased utilisation of the West Coast round herring resource is encouraged but attempts to improve catch rates using midwater trawling have not been successful to date. Bycatches of juvenile horse mackerel have also been well below the three-year PUCL of 12 000 t, averaging only 3 600 t in the most-recent 3 years. This PUCL has now been increased to 15 000 t to make provision for those years where a high bycatch of horse mackerel is unavoidable (Figure 63e).

An annual PUCL for mesopelagic fish of 50 000 t was introduced in 2012, following increased catches of lantern- and lightfish by the experimental pelagic trawl fishery in 2011, when just over 8 000 t of these species were landed. A resumption of the trawl experiment in 2018 resulted in mesopelagic catches of 5 800 t and 3 500 t in 2018 and 2019, respectively. The relatively high costs associated with this experiment, coupled with the recent downturn in the anchovy and sardine fishery, has led to the applicant not pursuing this any further. The PUCL

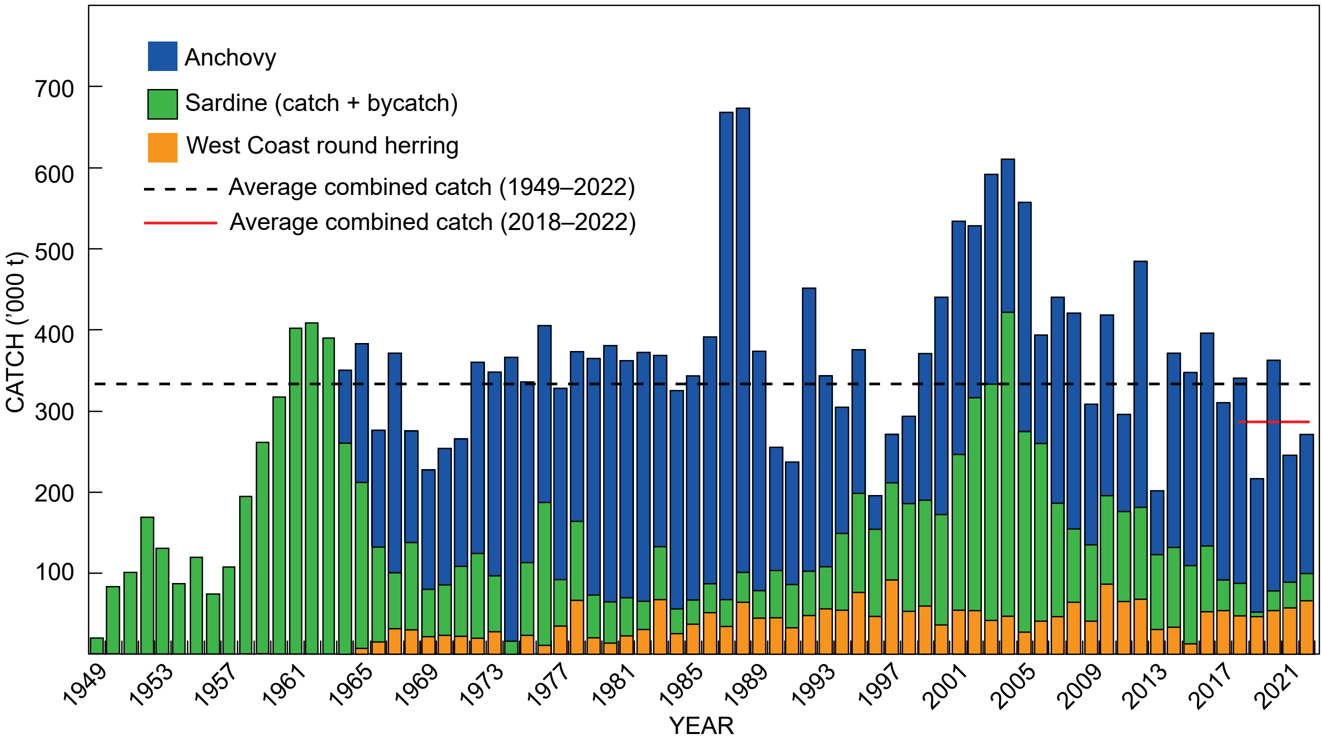


Figure 62: The annual combined catches of anchovy, sardine and round herring by the small pelagic fishery, 1949–2022. Also shown is the long-term average combined annual catch (black dashed line) and for the past five years (2018–2022; red solid line)

has subsequently been reduced to 25 000 t. The Department remains desirous of continuing this experimental fishery as well as the exploratory trawl fishery for anchovy and West Coast round herring aimed at improving utilisation of these resources off the South Coast, especially given the current depleted state of the sardine resource.

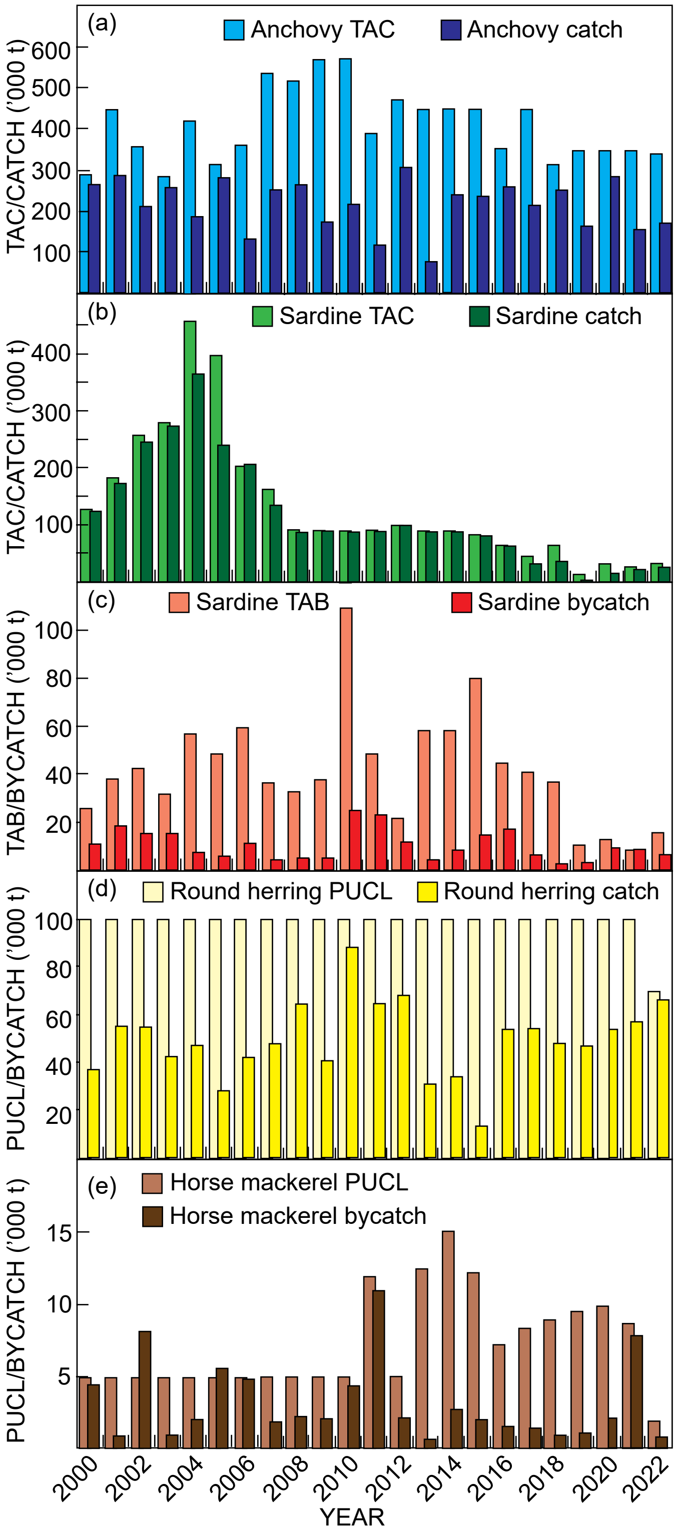


Figure 63: Total allowable catches (TACs), total allowable bycatch (TAB) and precautionary upper catch limits (PUCLs), and subsequent landings of each by the South African pelagic fishery for (a) anchovy, (b) directed sardine, (c) sardine bycatch, (d) round herring and (e) horse mackerel, 2000–2022

Recruitment strength and adult biomass

Anchovy recruitment measured in 2016 was considerably lower than the long-term average and almost half that measured in 2015. This was followed by a record high anchovy recruit estimate of 830 billion fish in 2017 (Figure 64a). Fish sampled during that survey on average weighed about 1.4 g less than those sampled during the preceding two years and not many of them appeared to have survived subsequent to the survey, with the adult anchovy biomass in 2017 and 2018 remaining relatively stable at around 1.5 million t. The decrease of close to 50% in the adult anchovy biomass from 1.5 million t in 2018 to only 0.84 million t in 2019 was followed by above average anchovy recruitment in 2020 giving rise to a 3-fold increase in adult biomass in that year. Recruitment of anchovy in 2021 and 2022 was again below average with a subsequent below average adult biomass of only 1 million t measured at the end of 2022*.*

Sardine recruitment has remained very low. The lowest recruit estimate in 30 years of <1 billion fish in 2016 was followed by an estimate of 7 billion fish in 2017 and 4 billion fish in 2019

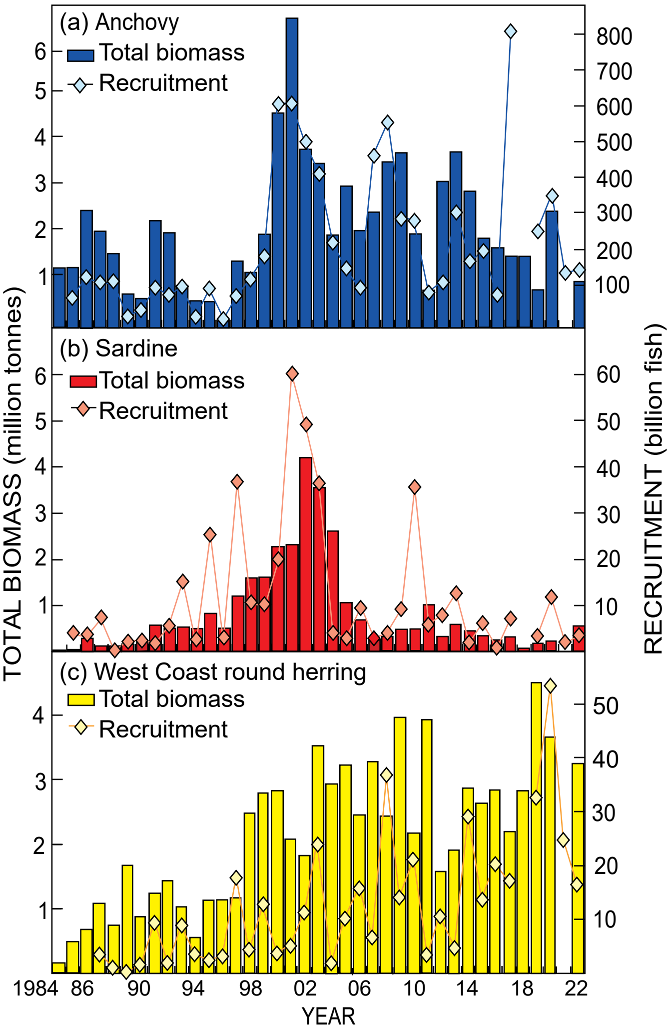


Figure 64: Time-series of acoustically estimated recruitment strength and total biomass of (a) anchovy, (b) sardine and (c) round herring, 1984–2022

(Figure 64b). Despite a slight increase in sardine recruitment in 2020, half of the recruitment estimates in the past 10 years have been lower than 5 billion fish. Given this sustained below-average recruitment, the adult sardine biomass decreased further to only 91 000 t in 2018. A slight increase to 190 000 t in 2019 and to 250 000 t in 2020, although encouraging, did not provide sufficient motivation to set aside low-biomass ECs provisions for this species. By 2022, the biomass had, however, increased to over 560 000 t. Despite this recent increase, the 2022 biomass estimate is still lower than the long-term average of 844 000 t, hence the categorisation of sardine status as being between depleted and optimal and the setting of a precautionary TAC for 2023. The 2019 West Coast round herring recruit estimate was the third highest on record (Figure 64c) and resulted in a 60% increase in the biomass of adult West Coast round herring from 1.4 million t in 2018 to 2.3 million t in 2019, the highest yet recorded. Recruitment dropped substantially in 2021 and 2022 but remained above the long-term average recruitment of 13 billion fish and the adult biomass by the end of 2022 remained relatively high at over 3 million t.

Shifts in the distribution both of anchovy and sardine adults that have previously been reported on (see previous issues of Status of the South African Marine Fishery Resources Report, since 2012) continue to be monitored. The abrupt eastward shift of anchovy that occurred in 1996 persists in most years, with an average of 38% of the adult anchovy biomass observed in the area to the west of Cape Agulhas since 1996 compared to 64% on average in the years preceding the shift (Figure 65a). Given the recent decline in the size of the anchovy population, the biomass of anchovy in this western area has declined to <500 000 t, a level far below that observed from 2012 to 2016. The percentage of the sardine biomass found in the area to the west of Cape Agulhas remains highly variable but has decreased considerably in recent years. Around 71% (180 000 t) of the sardine biomass was found in the area to the west of Cape Agulhas in 2016 (Figure 65b), but this percentage decreased to 32% in 2017 and subsequently to only 23% (44 000 t) in 2019 and 21% (52 000 t) in 2020. Despite a large increase in the biomass of sardine in both regions in 2022, the percentage located to the west of Cape Agulhas remains relatively low (39%). This decrease in the biomass of sardine to the west of Cape Agulhas is likely to compromise future recruitment, given the relatively low transport of eggs and larvae to the West Coast nursery area from sardine spawning on the South and East coasts.

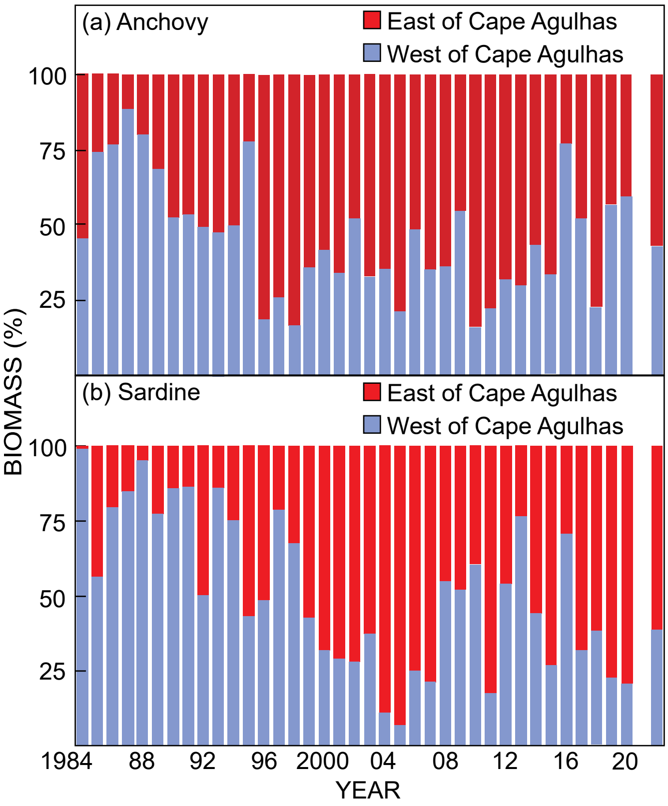


Figure 65: Percentage of the total (a) anchovy and (b) sardine biomass found to the west and east of Cape Agulhas, 1984–2022

Ecosystem interactions

The primary approach that has been used to limit catches of forage fish is Rights-based management with specific annual TACs. The incorporation of ecosystem considerations and the development of ecosystem-based management is typically carried out through OMP simulation testing to ensure certain probabilities that sardine and anchovy abundances would not drop below specified thresholds when harvested. Recent OMPs were also tested using parameters denoting risk to the African penguin *Spheniscus demersus* population. Penguins were chosen as a key predator species for consideration because they feed predominantly on sardine and anchovy and because of their conservation status, which is of concern due to appreciable reductions in their numbers at the major breeding colonies over recent years and their listing as Endangered by the IUCN. As part of the implementation of an ecosystems approach to fisheries (EAF) in South Africa's fishery for small pelagic fish, a model of penguin dynamics was developed for use in conjunction with the small-pelagic-fish OMP so that the impact on penguins of predicted future pelagic fish trajectories under alternative harvest strategies could be evaluated. So far results have suggested that fishing is likely to have a relatively small impact on penguins, especially when compared with uncertainties that arise from the variable spatial distribution of the sardine population. For example, OMP-18 performance statistics indicated that even with zero sardine catch, penguin numbers were expected to decline only about 1.4 % slower than if there was fishing. However, these results are now dated and both the OMP and the penguin population model need updating. Additionally, central to the development of any future OMP will be the consideration of harvest strategies that include spatial management of sardine, given the existence of two local stocks of this resource as described above. Such spatial management, which has already been formally implemented to avoid high local exploitation levels, also has the associated benefit of preventing local forage fish depletion and heightened competition between dependent predators and the fishing industry.

Penguins are potentially also sensitive to changes in pelagic fish abundance and distribution because of their land-based breeding sites and their limited foraging range (< about 20 km) during breeding. An experiment that involved alternating periods of fishing and closure to fishing around some important penguin breeding colonies (the Island Closure Experiment) was conducted between 2008 and 2020 to assess the impact of localised fishing on the breeding success of these birds.

Results from this study indicated that although certain island closures may help reduce the rate of decline of the penguins (by between 0.25% and 1%), they would do little to halt the decline, which is as much as 10% per annum at some colonies. Furthermore, these fishery closures have cost implications for the small pelagic fishing industry and, as such, any benefit of fishery closures should be weighed up against their costs.

Following increased media attention and calls from the conservation sector to intensify fishing restrictions, an internal Governance Forum comprising senior managers of the Department was established to advise the Minister on this matter. Under this forum, the Department sought to develop a compromise proposal for future fishing restrictions that would decrease the cost of closures to industry, but still maintain reasonable levels of protection of those areas where penguins prefer to forage. Further discussion of this proposal with the fishing industry and conservation sector resulted in an impasse. The Consultative Advisory Forum for Marine Living Resources (CAFMLR) established by the Minister to advance the discussion took a “middle of the road” approach between having no closures around colonies (advanced by the fishing industry based on the marginal benefits to penguins as quantified during the experiment) and full closure of core penguin foraging areas or marine important bird areas (MIBAs) around the largest six remaining colonies (as advanced by the conservation sector). The CAF recommendations, which essentially advocated closure of a total of 50% of the 6 MIBAs (i.e. 300% instead of the 600% recommended by the conservation sector) were rejected by both the fishing industry and the conservation sector. A further recommendation of the CAF, however, was to convene an international panel of experts to assist in decision-making.

The Minister has subsequently appointed such a panel to review the interpretation of the results from the experiment, explore the value of fishing closure around penguin colonies in providing meaningful benefits to penguins, review the processes and outcomes completed through the Governance Forum and CAFMLR, and make recommendations on the future implementation of fishing closures. This process is currently underway. In the meantime, and pending the outcome of the review, the Minister approved interim closures in September 2022 around the six breeding colonies of Dassen and Robben Islands on the West Coast, Stony Point and Dyer Island off the Southwestern Cape coast and St Croix and Bird Islands in Algoa Bay (Figure 66).

Climate change implications

Small pelagic fishes have been characterised as excellent bio-indicators of climate-driven changes in marine systems because of their responsiveness to environmental forcing. Predicted effects of climate change include changed species distributions, and these are frequently the first effect to be observed and are driven primarily by changed temperatures. The relative distributions of both anchovy and sardine have shifted eastwards over the past few decades, with these shifts significantly correlated with the cross-shelf SST gradient off the South Coast. Spatial catch patterns of both species have also changed, and whereas for sardine recent catch patterns will have been affected by explicit spatial management measures, a higher proportion of annual anchovy catches (which are not spatially restricted) have been taken on the western Agulhas Bank (between Cape Point and Cape Agulhas) than previously.

Improving predictive capacity in terms of the likely responses to climate change of exploited fish has been identified as a critically needed adaptation for South African fisheries management, including the need to develop models to better understand the potential impacts of climate change on species, food webs and fisheries. Given that small pelagic fish distri-

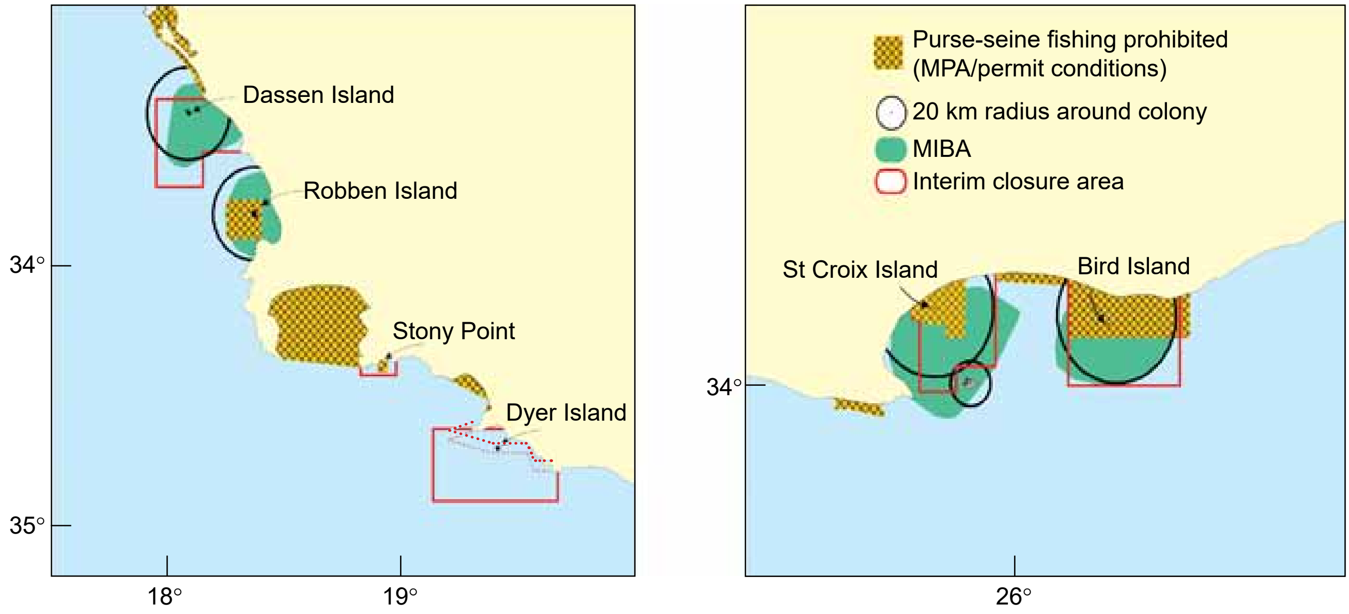


Figure 66: The locations of marine important bird areas (MIBAs; core foraging areas of African penguins), the 20-km-radius closed areas implemented during the Island Closure Experiment (note that an area of 5 km-radius around Riy Banks, to the southeast of St Croix Island, was also closed when St Croix Island was closed to fishing), and the interim closures that are presently in place. Also shown are the locations of marine protected areas (MPAs) and other restricted areas where pelagic fishing is not allowed. The dotted line within the interim closure area around Dyer Island demarcates an inshore area where no pelagic fishing is allowed and an offshore area where only small vessels are allowed to fish

butions are changing, a first step in developing models to improve predictive capacity is to better understand the effects of different environmental parameters on their distributions. Such bioclimatic-envelope models use associations between environmental variables and a species' occurrence to define sets of conditions under which that species is more likely to be found, and once envelopes are estimated they can be applied to forecast the effects of climate change on species' distributions.

A recent study used generalised additive models (GAMs) to assess the influence of several environmental variables on the distributions of eggs, recruits, and adults of anchovy, round herring and sardine in the Southern Benguela ecosystem. Abundance and distribution data of these different stages and species were collected during routine Pelagic Recruit (recruits) and Total Biomass (adults and eggs) surveys conducted between 2000 and 2011. Selected environmental variables were those expected to respond to climate change and that can be remotely sensed, and included sea surface temperature (SST), sea surface height (SSH), sea surface chlorophyll (Chl *a*), Ekman upwelling (Ek-Up) and eddy kinetic energy (EKE). Environmental data for the regions and periods matching the Pelagic Recruit and Total Biomass surveys of each year were collected from online sources (mostly the National Oceanic and Atmospheric Administration – NOAA) and were then mapped to the species- and stage-specific abundance and distribution maps for GAM analyses. The relative importance of these variables in influencing fish distribution patterns was also estimated.

Whereas almost all of the GAMs had good predictive performance, those for sardine had relatively higher explanatory capabilities compared to those for round herring and anchovy, and hence had a better capability for modelling sardine habitat suitability. This suggests that sardine distributions respond more strongly to environmental variables than do those of round herring and anchovy. Sea surface temperature had the highest relative importance of predictor variables for eight of the nine life stage / species combinations, sometimes by a substantial margin (Figure 67). The only exception was for

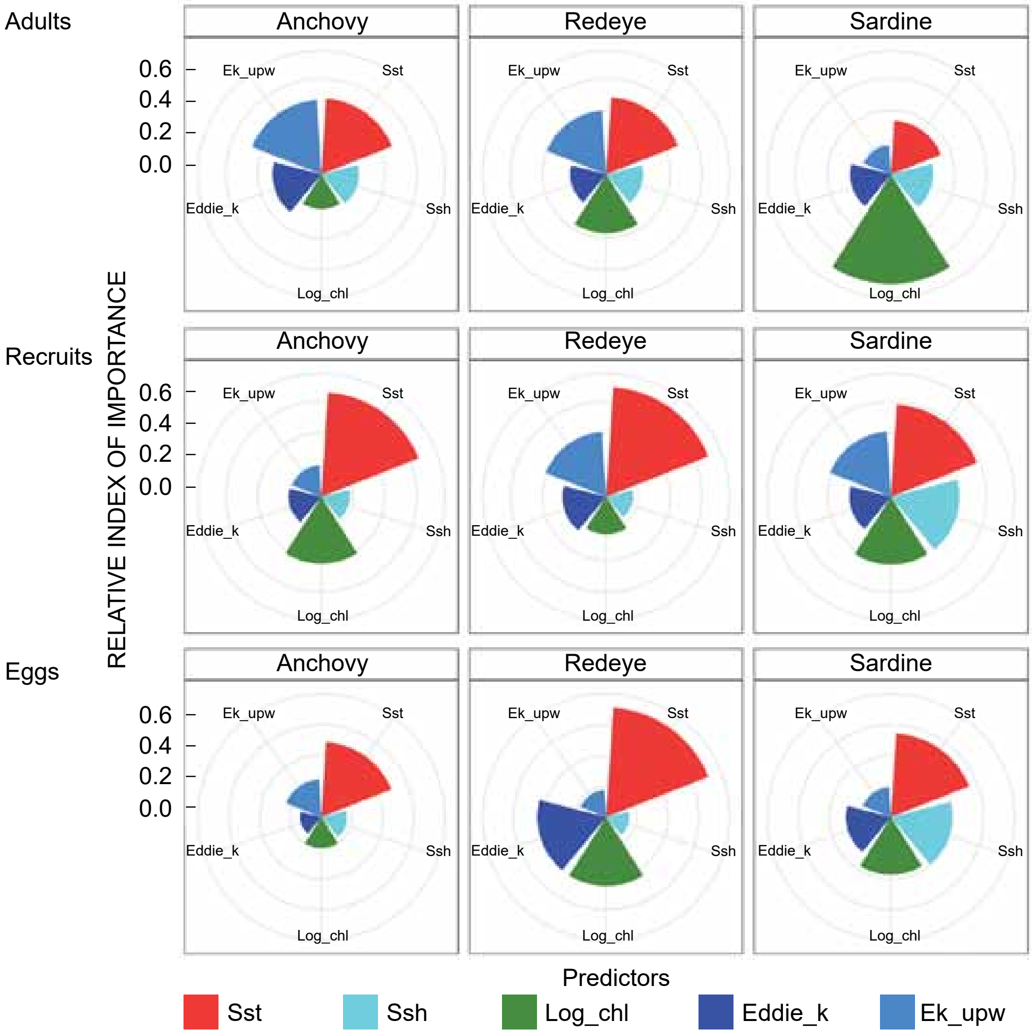


Figure 67: Pie diagrams illustrating the relative importance of the top five environmental variables in generalised additive models relating to the distributions of adults (top row), recruits (middle row) and eggs (bottom row) of anchovy (left column), West Coast round herring (redeye; middle column) and sardine (right column). The sizes of environmental predictor pies are proportional to their relative importance in predicting the distribution of that life stage of that species, and range from 0.14 for EKE (Eddie_k) on anchovy eggs to 0.71 for SST on round herring (redeye) eggs Sst = sea surface temperature; Ssh = sea surface height; Log_chl = log of surface chlorophyll *a* concentration; Eddie_k = eddy kinetic energy; Ek_upw = Ekman upwelling

adult sardine where SST had the second-highest relative importance, substantially lower than that for Chl *a*. This latter predictor was also important for anchovy recruits, and round herring eggs and adults. Sea surface height and eddy kinetic energy typically had lower values of relative importance. Other interspecific and intraspecific (i.e. between life history stages of the same species) differences in the relative importance of environmental variables were apparent (Figure 67).

These analyses have improved understanding of how present distribution patterns of small pelagic fish are related to environmental variables and are a necessary first step to investigating how changing oceanographic conditions might affect their future distributions. The interspecific differences in the relative importance of environmental variables in affecting the distributions of small pelagic fishes off South Africa suggest that species will be impacted differently by, and respond differently to, climate change. Importantly, the intraspecific differences observed suggest that different life history stages will also be impacted differently by climate change. These models can be coupled with models that predict future ocean state around South Africa to indicate where, and when, particular areas/regions may become less or more favourable to small pelagic fishes. This is important for the development of appropriate management strategies and the long-term sustainable exploitation of these valuable marine resources.

Adaptation to climate change measures that should be considered for the small pelagic fishery include, *inter alia*, (i) rebuilding the sardine population; (ii) developing anchovy products for human consumption and developing local markets for such; (iii) determining sustainable harvesting levels for West Coast round herring and lanternfish, with consideration for ecosystem needs, and increasing their exploitation levels if warranted; and (iv) developing an integrated, concerted and multi-disciplinary national research response to climate change impacts on South African marine fisheries. The analysis described above forms part of the last adaptation measure and could usefully be applied to other important marine resources.

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Useful statistics

Pelagic fish catches and TACs/TAB/PUCLs, 2000–2022 (x 1000 tonnes).

Year	Anchovy catch	Sardine catch	Directed sardine	Sardine bycatch	Horse mackerel bycatch	Chub mackerel bycatch	Round herring catch	Meso-pelagic catch	TOTAL	Anchovy TAC	Sardine TAC	Sardine TAB	Round herring PUCL	Horse mackerel PUCL	Meso-pelagic PUCL
2000	267.29	135.20	123.57	11.63	4.50	0.04	37.28	0.18	444.31	291.00	126.00	26.20	100.00	5.00	
2001	287.51	191.53	172.64	18.90	0.92	0.12	55.33	0.08	535.41	451.00	182.00	38.40	100.00	5.00	
2002	213.45	260.88	244.74	16.14	8.15	0.08	54.80	0.03	537.36	359.72	257.97	42.47	100.00	5.00	
2003	258.88	289.99	274.15	15.85	1.01	0.25	42.53	0.06	592.66	285.00	280.00	32.31	100.00	5.00	
2004	190.09	373.83	365.79	8.03	2.05	0.48	47.23	0.47	613.68	423.00	457.00	57.15	100.00	5.00	
2005	282.73	246.71	240.29	6.42	5.63	0.4	28.39	0.00	563.81	315.89	397.00	48.45	100.00	5.00	
2006	134.18	217.28	205.87	11.42	4.82	0.10	41.89	0.00	398.28	362.25	204.00	59.30	100.00	5.00	
2007	253.09	139.50	134.62	4.88	1.90	0.40	47.93	0.00	442.83	536.94	162.44	36.50	100.00	5.00	
2008	265.82	90.92	85.74	5.17	2.28	0.87	64.23	0.00	424.13	517.50	90.78	32.85	100.00	5.00	
2009	174.47	94.33	89.20	5.12	2.09	0.62	40.49	0.01	311.99	569.44	90.00	37.73	100.00	5.00	
2010	217.06	112.41	87.70	24.71	4.39	0.64	88.49	0.33	422.99	573.18	90.00	109.51	100.00	5.00	
2011	119.88	112.14	89.05	23.09	10.99	0.24	64.64	8.03	307.89	390.29	90.00	48.54	100.00	12.00	
2012	307.30	109.44	97.91	11.53	2.20	0.07	68.30	0.02	487.31	472.72	100.60	21.95	100.00	5.00	
2013	78.80	91.94	87.84	4.10	0.60	0.02	31.30	0.00	202.67	450.00	90.00	58.87	100.00	12.47	
2014	240.50	97.03	88.41	8.62	2.76	0.84	34.38	0.01	375.51	450.00	90.00	58.78	100.00	15.19	
2015	237.90	96.14	80.94	15.20	2.04	0.93	13.42	0.00	350.43	450.00	83.47	80.22	100.00	12.23	50.00
2016	261.51	80.25	62.99	17.26	1.60	3.90	53.95	0.17	401.21	354.33	64.93	45.01	100.00	7.27	50.00
2017	216.56	37.41	30.99	6.42	1.41	2.13	54.27	0.33	311.78	450.00	45.56	41.16	100.00	8.37	50.00
2018	253.37	39.26	36.51	2.75	0.95	2.07	48.29	5.83	343.94	315.24	65.00	37.28	100.00	8.95	50.00
2019	164.80	5.21	2.048	3.16	1.08	3.76	47.14	3.48	222.00	350.00	12.25	10.75	100.00	9.57	50.00
2020	285.18	24.56	15.01	9.55	2.17	2.83	53.75	0.00	368.51	350.00	32.00	13.05	100.00	9.99	50.00
2021	156.24	31.84	22.52	9.32	7.86	1.53	57.30	0.02	254.79	350.00	26.80	9.17	100.00	8.76	50.00
2022	172.19	33.00	25.94	7.07	0.82	0.83	66.42	0.01	273.28	341.00	33.35	16.15	70.00	1.91	25.00

South Coast rock lobster

Stock status	Unknown	Abundant	[✓ Optimal]	[✓ Depleted]	Heavily depleted
Fishing pressure	Unknown	[✓ Light]	[✓ Optimal]	Heavy	

Introduction

South Coast rock lobsters *Palinurus gilchristi* are endemic to the southern coast of South Africa, where they occur on rocky substrata at depths of 50–200 m. The fishery operates between East London and Cape Point and up to 250 km offshore along the outer edge of the Agulhas Bank, and fishing gear is restricted to longlines with traps. It is now the largest rock lobster fishery in South Africa by total mass and is capital-intensive, requiring specialised equipment and large, ocean-going vessels.

Products (frozen tails, whole or live lobster) are exported to the USA, Europe and the Far East. Sales are affected by seasonal overseas market trends and competition from other lobster-producing countries. High prices on international markets and the increase of the Rand to Dollar exchange rate make the sector lucrative. Prices for commodities fluctuate and the sales prices in the USA are currently the equivalent of about R1 000 per kg tail mass.

Longline trap-fishing is labour intensive and as such each boat requires approximately 30 officers and crew. The total sea-going complement of the fleet is about 300 individuals, nearly all previously disadvantaged. In addition to sea-going personnel, the sector employs approximately 100 land-based factory (processing) and administrative personnel, also mostly previously disadvantaged people. The total export value in 2021 was approximately R353 million.

History and management

The South Coast rock lobster was first described in 1900 and was recorded occasionally in trawler catches for sole at a depth of about 70 m. The commercial fishery commenced in 1974, after the discovery of concentrations of rock lobsters on rocky ground at a depth of around 110 m off Gqeberha (formerly Port Elizabeth). Numerous local and foreign fishing vessels converged on the fishing grounds, giving rise to the expansion of the fishery. However, foreign fishing vessels were withdrawn from the fishery in 1976, when South Coast rock lobster was recognised as a species occurring wholly within South African waters. From 1977 onwards, the sector operated solely as a local commercial fishery.

The fishery has a management history stretching back to 1974. The fishery was regulated initially by limiting the number of traps permitted per vessel. Catches and catch rates declined significantly between 1977 and 1979 (Figures 68 and 69). The introduction of management measures such as reduction of ef-

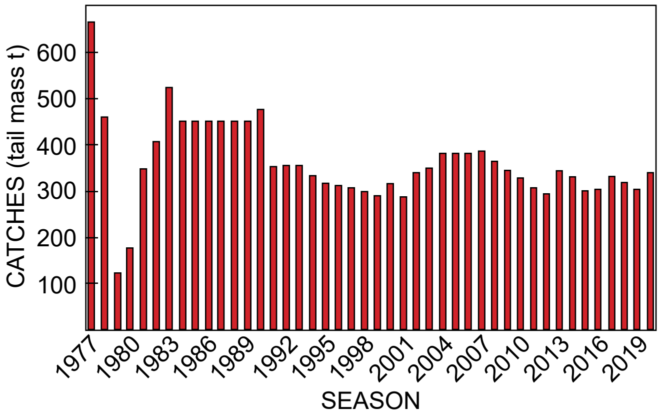

Figure 68: Annual catches of South Coast rock lobster from 1977 to 2020. Note that 1977 refers to the 1977/78 season, etc

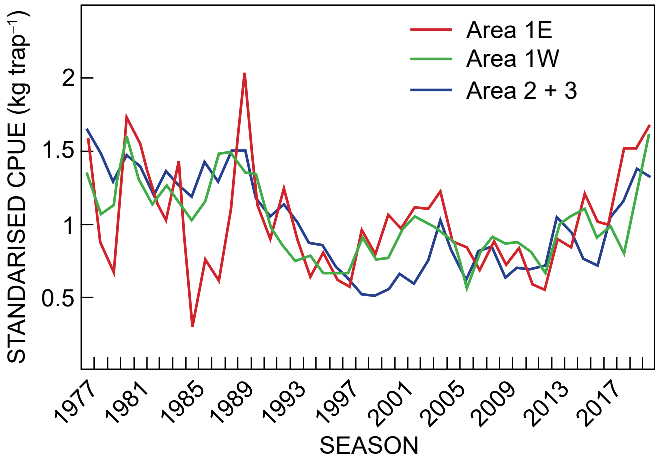

Figure 69: South Coast rock lobster catch per unit effort (CPUE) by area from 1977 to 2020. Note that 1977 refers to the 1977/78 season, etc

Table 17: South Coast rock lobster historical records of TAC, TAE, catch and standardised CPUE by area

Season	TAC (tonnes tail mass)	TAE (allocated seadays)	Standardised CPUE (kg trap^{-1})		
			Area 1E	Area 1W	Area 2 & 3
1977/1978			1.59	1.34	1.65
1978/1979			0.88	1.06	1.49
1979/1980			0.66	1.14	1.30
1980/1981			1.73	1.59	1.48
1981/1982			1.54	1.27	1.41
1982/1983			1.21	1.13	1.19
1983/1984			1.03	1.27	1.37
1984/1985	450		1.43	1.16	1.27
1985/1986	450		0.28	1.03	1.18
1986/1987	450		0.77	1.15	1.43
1987/1988	452		0.61	1.48	1.29
1988/1989	452		1.11	1.50	1.50
1989/1990	452		2.04	1.37	1.50
1990/1991	477		1.16	1.34	1.17
1991/1992	477		0.91	0.99	1.05
1992/1993	477		1.23	0.84	1.14
1993/1994	477		0.91	0.75	1.02
1994/1995	452		0.64	0.79	0.87
1995/1996	427		0.81	0.67	0.86
1996/1997	415		0.63	0.67	0.71
1997/1998	402		0.58	0.66	0.63
1998/1999	402		0.97	0.93	0.52
1999/2000	377		0.79	0.76	0.51
2000/2001	365	2 339	1.07	0.77	0.55
2001/2002	340	1 922	0.96	0.96	0.66
2002/2003	340	2 146	1.12	1.06	0.59
2003/2004	350	2 038	1.10	1.01	0.74
2004/2005	382	2 089	1.24	0.95	1.03
2005/2006	382	2 089	0.87	0.89	0.78
2006/2007	382	2 089	0.84	0.57	0.62
2007/2008	382	2 089	0.68	0.79	0.82
2008/2009	363	2 675	0.89	0.92	0.85
2009/2010	345	2 882	0.73	0.86	0.63
2010/2011	328	2 550	0.85	0.88	0.70
2011/2012	323	2 443	0.60	0.80	0.70
2012/2013	326	2 250	0.56	0.66	0.72
2013/2014	342	2 536	0.89	0.97	1.05
2014/2015	359	2 805	0.84	1.06	0.95
2015/2016	341	2 858	1.22	1.10	0.76
2016/2017	332	2 029	1.02	0.91	0.71
2017/2018	338	2 042	0.99	0.99	1.04
2018/2019	321	2 148	1.51	0.78	1.17
2019/2020	337	2 220	1.53	1.21	1.37

fort and catches during the early 1980s resulted in some resource recovery (Figures 68 and 69). An annual total allowable catch (TAC) was introduced in 1984, based on the performance of the fishery in the previous years. The TAC and limited entry stabilised the sector until the 1993/94 season (Figure 68), and a more rigorous procedure for stock assessment was developed in 1994.

The fishing season for South Coast rock lobster is year-round, extending from 1 October to 30 September of the following year. The management strategy is a combination of TAC and total allowable effort (TAE). The TAC limits the total catch and is based on an annual resource assessment, whereas the TAE is measured in fishing days allocated to each vessel. A vessel may fish until its fishing days expire or its quota is filled, whichever occurs first. The number of days spent at sea by each vessel is monitored. Catches may be offloaded only in the presence of fishery control officers and are weighed at designated offloading points. Skippers must, at the conclusion

of each trip, provide the Department with accurate daily catch statistics.

The scientific recommendations for catch limits are based on an operational management procedure (OMP) which was introduced in 2008 and modified ("re-tuned") in 2010. A full review of the OMP was completed in 2014 (designated OMP-2014) and was used to provide the scientific recommendations for the 2015/16 to 2018/19 seasons.

A full OMP review was completed in 2019 (OMP-2019). This was used to determine the TAC and TAE for the 2019/20–2022/2023 fishing seasons. The objective of this OMP is to increase the spawning biomass of the resource by 30% over the 20-year period from 2006 until 2025, while restricting inter-annual TAC fluctuations to a maximum of 5%.

Research and monitoring

The stock assessment model used for South Coast rock lobster (an age-structured production model [ASPM]) is based, *inter alia*, on size and age composition of the catch, somatic growth rates, and population size estimates. A tagging programme supplies the critical growth- and population-size estimates, as well as estimates of migration.

Scientific observers are deployed aboard commercial South Coast rock lobster fishing vessels. These observers primarily collect data relating to catch composition, take biological measurements (length, sex and reproductive state), estimate catch and effort, report on gear used, observe fishing practices such as discarding, dumping and bycatch, and also record the areas where fishing takes place. The data are utilised in the annual stock assessment to determine the TAC. Observers also tag lobsters during commercial fishing operations, and information from recaptured tagged lobsters is returned by commercial fishers, with details of the date and location of recapture. Tagging covers as wide an area and range of size classes as possible.

Commercial CPUE data are captured from landing slips. These provide input data (CPUE and landings) for TAC and TAE management.

New research planned for this resource aims to use baited "video fishing" techniques to offer a standardised, non-extractive methodology for estimating relative abundance and observing the behaviour of South Coast rock lobster. Precise and accurate length and biomass estimates will also be recorded by paired stereo-cameras. The baited underwater video camera traps will be used to monitor the effect that bycatch species have on catch rates, the fate of bait and other bycatch and discards, and to help measure metabolic rates, swimming speed and foraging behaviour of South Coast rock lobsters.

The feasibility of introducing a fisheries independent survey to track status indicators for this resource is being investigated.

The effect of benthic environmental factors on daily catches of South Coast rock lobster have not been investigated to date. However, new research is directed at elucidating these relationships.

Current status

In 1977–1979/80, fishing effort and catches increased above sustainable levels (Figures 68 and 69), and thereafter the catches declined rapidly to 122 tonnes tail mass (Figure 68). The decline in catches was partly as a result of the withdrawal of the foreign vessels from South African waters in 1976, and also overfishing. By the end of the 1970s, several of the remaining local fishing vessels were forced out of the fishery by low catch rates. Gradual recoveries of catches between 1980 and 1984 and stable catch rates during that time were accompanied by a resurgence of interest in the fishery by fishers who had previously withdrawn. In response to the possibility of overfishing, a TAC was introduced into the fishery in 1984, and quotas were allocated to companies that were active in the fishery. This measure effectively limited the number of participants in the fishery.

The TAC initially restricted total catches to 450 t tail mass (970 tonnes whole mass) per year (Table 17); fluctuations in the TAC up to 1994 included the addition of 2 t (tail mass) for research purposes in the 1988/89 fishing season, and the addition of 25 t in 1990/91. The latter increase was justified by the inclusion of a previously unfished area off the Eastern Cape coast after 1990. The TAC remained stable at 477 t up to the 1993/94 fishing season.

Resource assessments introduced in 1993–1994 indicated that an annual catch of 477 t could not be sustained. Consequently, a programme of annual TAC reductions was initiated in 1994–1995, reducing the TAC in steps of 25 t per year. The 2001 assessment of the resource indicated that the reductions had, however, failed to impact significantly on the trend of declining abundance. However, since then, the resource has remained relatively stable and seems to be growing in the most recent years. The exploitable biomass, assessed in 2022, has recovered and was approximately 47% – and spawner biomass about 41% – of pre-fished levels.

Ecosystem interactions

There are some concerns around the levels of whale entanglements in this fishery. The Right Holder Association has taken proactive steps to implement guidelines regarding gear management measures to reduce the chance of encountering marine mammals and have designed and implemented a digital reporting system. Experiments into gear changes, such as sinking groundlines and ropeless traps, are currently being conducted in this fishery. There are no other major ecosystem issues in this fishery at present. Furthermore, the spatial and temporal distribution of berried females should be investigated to allay concerns regarding the vulnerability of these females under current fishing practices.

There are currently no indications of an impact of aspects of climate change on this fisheries resource. It is likely, however, that this species has the physiological capability to adjust to temperature changes and acidification in a similar way as the closely related and well researched West Coast rock lobster (see Research highlights section).

Further reading

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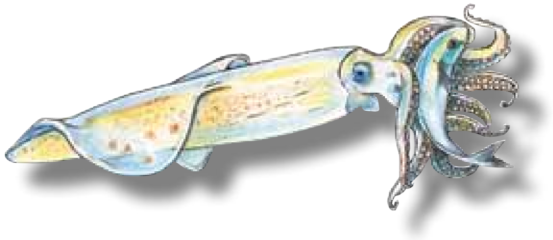
Squid



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
Fishing pressure	Unknown	Light	Optimal	Heavy	

Introduction

The Cape Hope squid *Loligo reynaudii* d'Orbigny, 1845, locally known as 'chokka', is a ubiquitous loligonid squid that occurs around the southern African coast from Namibia to the Wild Coast region of the Eastern Cape (Figure 70). A separate stock targeted by some artisanal fisheries occurs farther north off southern Angola, but scant information is available from that region. Chokka is fast-growing, reaching reproductive size in approximately one year or less with a potential fecundity of about 18 000 eggs. Age after hatching in males ranges from 164 to 484 days with a mean of 323 days, and in females from 125 to 478 days with a mean of 316 days, and its total lifespan is less than two years. The size composition in terms of the length-frequency and length-weight relationship of chokka squid assessed over a period of 22 years shows no significant long-term temporal trends in the mean lengths, and the maximum observed mantle lengths are 48 cm for males and 28 cm

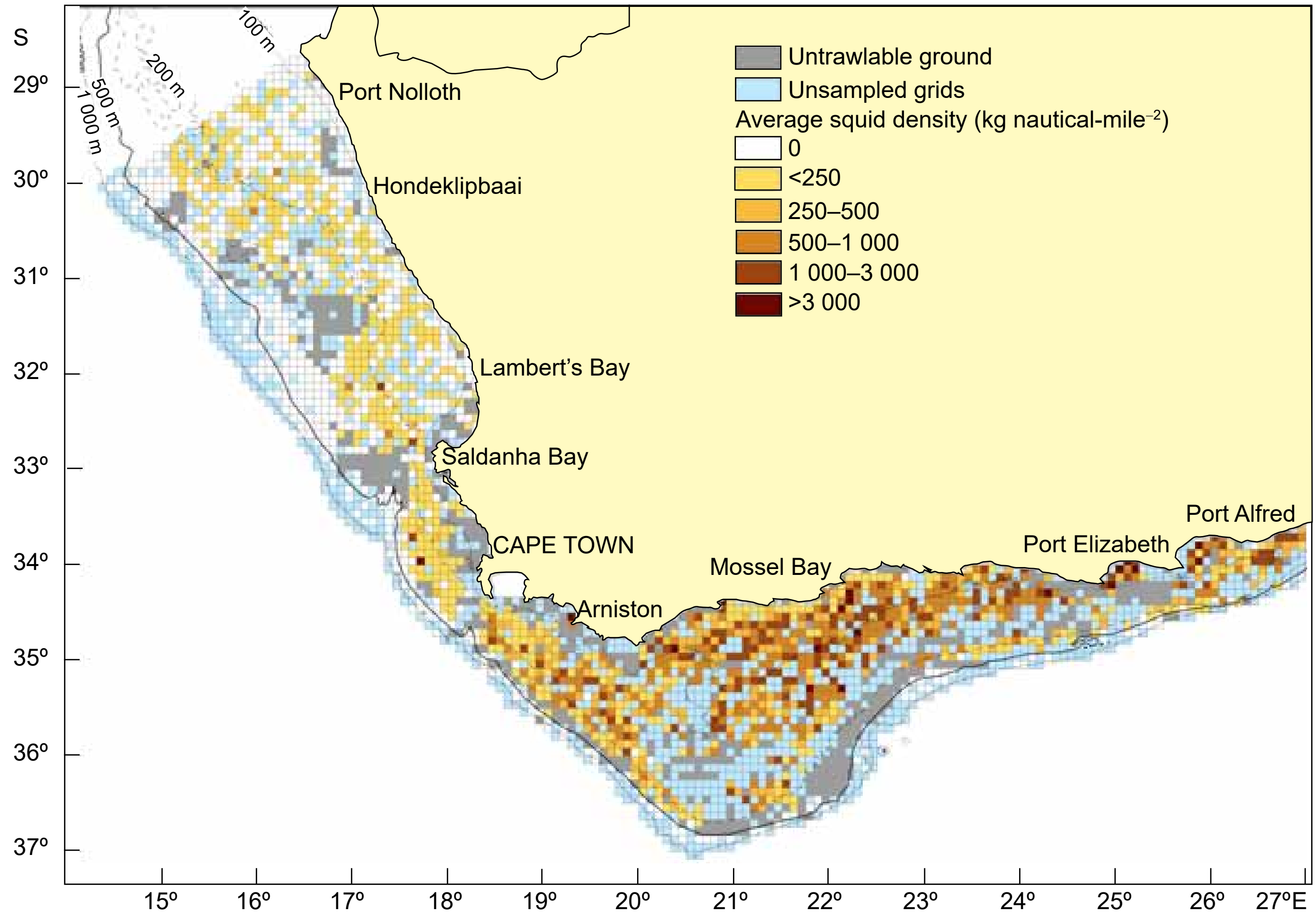


Figure 70: Distribution of chokka squid *Loligo reynaudii* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations within each survey grid block over the period 1985–2023 (note there was no survey in 2018)

for females. However, a significant drop in mean lengths, especially in females, was noted from 2014 to 2017. Chokka spawn throughout the year with a peak in summer and their spawning behaviour is particularly complex. Females mate with multiple males over short time-periods and therefore females have access to sperm from different males and multiple paternity within offspring of individual females is common. Spawning distribution is governed largely by environmental conditions and spawning occurs mostly inshore in the relatively sheltered embayments off the Southeast Coast, in less than 60-m depth, and occasionally in deeper waters. The chief prey items of chokka are fish and crustaceans, but they also sometimes feed on other cephalopods, and cannibalism is fairly frequent. The abundance of squid fluctuates widely, mainly due to biological factors such as spawning distribution and survival rates of hatchlings and juveniles, and to environmental factors such as temperature, currents, turbidity and macro-scale events such as *El Niños*.

Chokka squid are the target of a dedicated jig fishery that operates between the Cape of Good Hope and Port Alfred. The squid fishery is relatively stable and provides employment for approximately 3 000 people locally. The fishery is believed to generate in excess of R480 million in a good year and is South Africa's third-largest fishery in monetary terms. Chokka are mostly frozen at sea in small blocks. They are landed mainly between Plettenberg Bay and Port Alfred and exported whole to European countries, most notably Italy. Squid are also used as bait by linefishers. Apart from the directed fishery, squid are also caught as bycatch in the hake-directed demersal trawl fishery.

History and management

In the 1960s and 1970s, the squid resource was heavily exploited by foreign fleets, predominantly from the Far East. Foreign fishing activity was gradually phased out in the late 1970s and early 1980s following South Africa's declaration of an EFZ in 1977. Since then, squid and other cephalopods have continued to be caught by South African trawlers as bycatch. Over the last decade, the squid bycatch in the demersal trawl fishery has fluctuated between 200 and 800 t annually (Figure 71).

A commercial jig fishery for squid was formally established in 1984. Hand-held jigs are used to catch squid, making this a particularly labour-intensive fishery. Between 1986 and 1988 a licensing system was introduced with a view to limiting the number of boats participating in the fishery. The chokka squid fishery has a high variability in both biomass and catches, with annual catches varying from 2 000 to over 13 000 tonnes. Catches in the 1990s ranged between 1 900 and 7 400 t, and in the 2000s between 2 600 and 13 900 t. In 2004 the jig fishery registered its highest catch of just below 14 000 t (Figure 71). Catch data indicate an increase in jig catches over the period 2001 to 2004, followed by catches stabilising at approximately 9 000 t between 2005 and 2008, and then increasing again to just over 10 000 t in 2009 and 2010 (Figure 71). Annual catches in both the jig and trawl fisheries declined after 2010, reaching levels in 2013, and more recently in 2021, that are almost the lowest since the inception of the commercial jig fishery.

The fishery is effort-controlled and was historically capped at a maximum of 2 422 crew with the number of vessels commensurate with the number of persons permitted to fish. The current recommended total allowable effort (TAE) is 295 000 person-days. After the recently concluded fishing Rights allocation process (FRAP 2021/22), the global TAE is currently apportioned as follows: commercial – 250 750 person-days (2 077 crew); and small scale – 44 250 person-days (366 crew). A mandatory 5-week closed season (October–November each year) has been implemented since 1988, with the intention of minimising the disturbance to spawning squid and improving recruitment the following year. Furthermore, an additional closed season (in the range of three to five months' duration) has been implemented since 2014 to guard against the TAE being exceeded.

The current management objective for the squid fishery is to cap effort at a level which secures the greatest catch, on average, in the longer term without exposing the resource to the

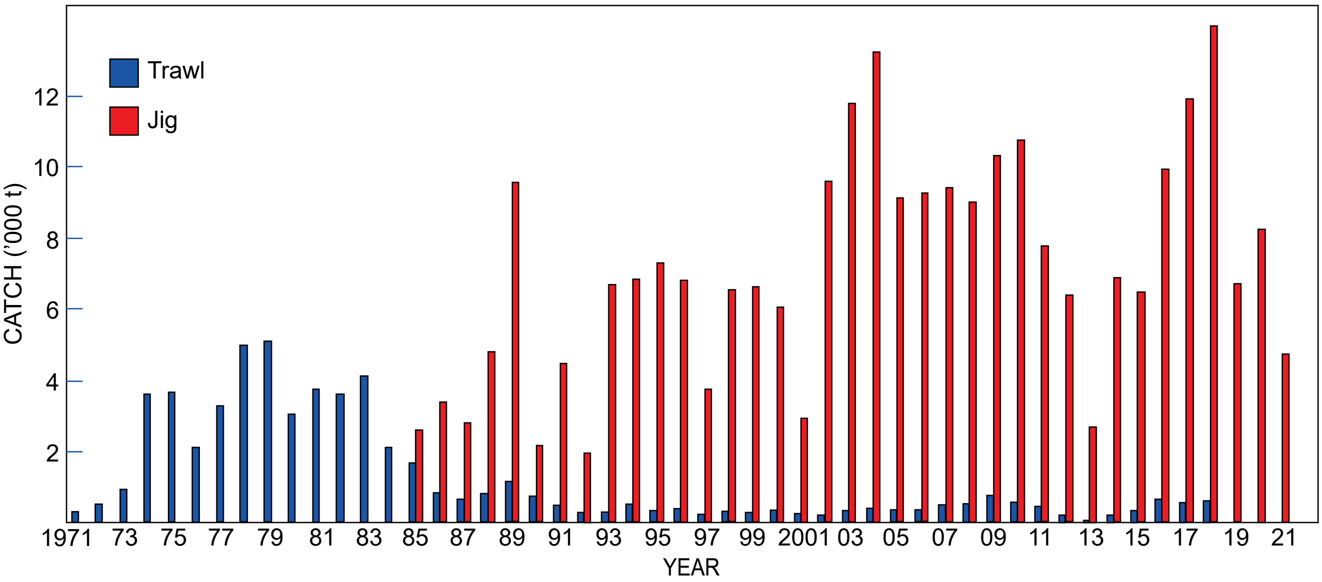


Figure 71: Annual catch (tonnes; trawl- and jig-caught) of squid off South Africa, 1971–2021. Trawl data are from external data 1971–1982, and from the DFFE demersal database 1983–2021. Commercial jig catch data are from the South African Bureau of Standards (SABS) as provided by Industry for the period 1985–2006, and the National Regulator for Compulsory Standards (NRCS) for the period 2007–2021

threat of reduction to levels at which future recruitment success might be impaired or catch rates might drop below economically viable levels.

Research and monitoring

Biomass estimates of chokka squid (as well as accompanying size structure and biological information) are derived from data collected on demersal swept-area research surveys conducted on the West Coast in summer each year and on the South Coast in autumn each year, as well as in spring in some years. Interpretation of the trends in the time-series of abundance estimates (Figure 72) is complicated by the changes in the gear and vessels employed during the surveys (see the section on Cape hakes for details). The data obtained from surveys conducted with different gear and vessels are not directly comparable, and any apparent trends in the time-series should be viewed with caution pending the development of reliable calibration factors for the various vessel-gear combinations. Although data from both the autumn and spring surveys are used in assessments of the resource, the spring surveys provide the most useful indication of spawning stock abundance, given that these surveys are conducted just prior to peak spawning season. Unfortunately, in the last 10 years, only one spring South Coast demersal survey has taken place.

Currently, the Department is developing an independent direct method of estimating the biomass of spawning concentrations of squid using hydroacoustics. Two surveys carried using DFFE's RV *Ellen Khuzwayo* show potential for developing the first absolute acoustic estimate of chokka squid abundance over the survey area.

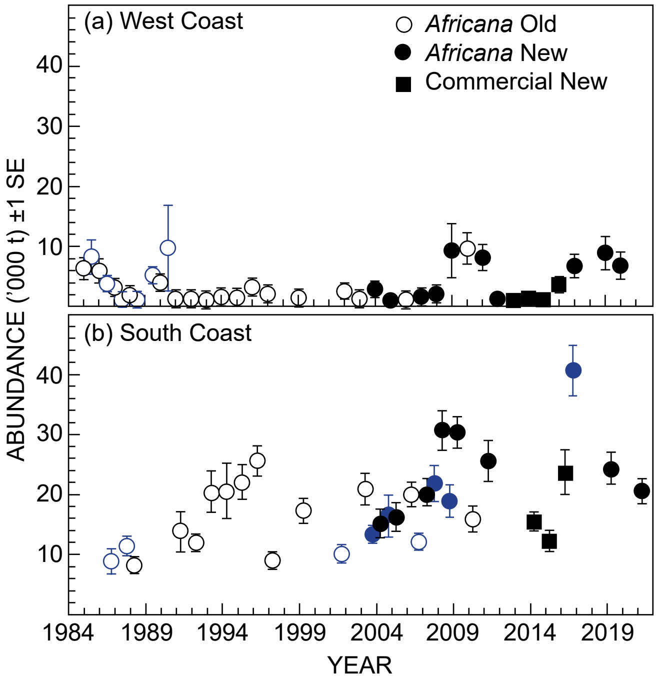


Figure 72: Chokka squid abundance estimates (tonnes ± 1 SE) derived from fishery-independent swept area demersal surveys 1984–2021. Estimates are illustrated by coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West Coast) and spring (South Coast) surveys are indicated with blue symbols. Note that surveys that only extended to the 200-m isobath have been excluded from the figures and that estimates across the vessel-gear combinations cannot be directly compared due to differences in catchability [*Africana* = research vessel RS *Africana*, Commercial = commercial fishing vessel]

Catch-and-effort data are collected on a regular basis from the commercial jig fishery and additional landings data were available from the National Regulator for Compulsory Specifications (NRCS) – formerly the South African Bureau of Standards (SABS) (Figure 71). In the past, squid data were recorded along with catches of linefish, and stored in the National Marine Linefish System. In 2006, a new logbook was introduced specifically for the squid fishery, allowing for the recording of more-detailed catch-and-effort information, and the data are now stored in a dedicated database.

Chokka squid is one of the best-researched squid species in the world and aspects of its early life history and adult ecology are relatively well known. However, capacity constraints within the Department have considerably slowed research efforts. Current research is conducted on the age and growth of squid, possible changes in biological characteristics of squid over time, genetics of adults (stock identity), environmental influences on stocks, acoustic mapping of inshore spawning grounds, and the use of acoustics as a method of surveying squid egg beds and investigating the potential damage of different anchor systems on squid spawning grounds and squid egg beds. Following the marked decline of the squid resource in 2013, the Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in the Western Indian Ocean (SOLSTICE-WIO) initiative was launched. SOLSTICE was a 4-year collaborative Global Challenge Research Fund project that sought to address key environmental and anthropogenic factors controlling the ecosystem dynamics of the Agulhas Bank. Results from the study were published in a special issue of a reputable scientific journal in 2022 and information therein should assist in enhancing the management of this resource.

In 2013, exploratory fisheries for a number of other squid species were initiated. These include three ommastrephid species (*Todarodes angolensis*, *Todaropsis eblanae* and *Ommastrephes bartramii*), one loligonid squid (*Uroteuthis duvauceli*) and one thysanoteuthid (*Thysanoteuthis rhombus*), though the fisheries are yet to be fully implemented.

Current status

A biomass-based stock assessment model is applied to assess the status of the squid resource. The most recent assessment was conducted in 2019 and indicated a more positive outlook regarding resource status than did the 2016 assessment. As a result the Department's Squid Scientific Working Group recommended that the TAE could be increased from 270 000 person-days to 295 000 person-days for the 2019 fishing season. Above-average recruitment had been observed over the period 2002–2009, but then declined to below-average levels over the period 2010–2013, before showing an improvement in 2014 (Figure 73). The assessment indicated a period of declining abundance over the period 2009–2014, after which biomass showed an increasing trend (Figure 74), and the stock was estimated to be at about 41% of pre-exploitation levels in 2015. The 2010–2013 decline in recruitment may be related to possible environmental anomalies over the 2012–2014 period, given that other species on the South Coast

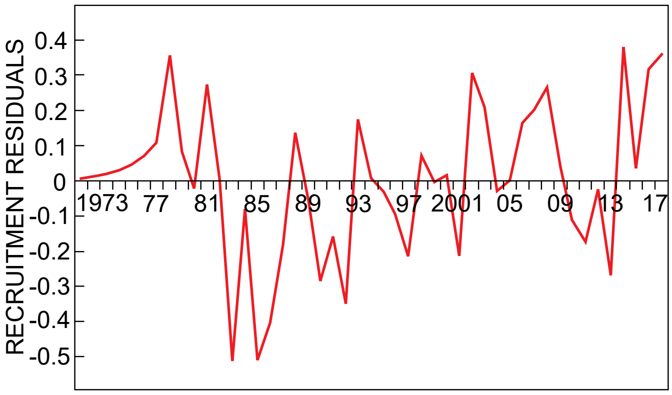


Figure 73: Recruitment residuals from 1971 to 2017. (N.B. derived from 14 vessels and restricted to records where 3<=crew<=26. Note this is to be updated on development of the new squid assessment model)

have shown similar declines in catch rates during this period. It is important to note that efforts are being directed at improving the current squid assessment model, as well as the data inputs.

Ecosystem interactions

The South African chokka squid fishery employs hand-held jigs, mainly targeting aggregations of spawning adult squid. This method selectively targets the desired species. There is little to no bycatch in this fishery and jigs have little impact on the environment. Some damage to the seabed and squid eggs may occur during deployment, adjustment and retrieval of anchors. A study to evaluate the impact of different anchoring systems on squid eggs and the seabed is currently being planned. Chokka squid is currently listed as 'green' (most sustainable choice from the healthiest and most well-managed fish populations) under WWF's SASSI (South African Sustainable Seafood Initiative) assessment.

Further reading

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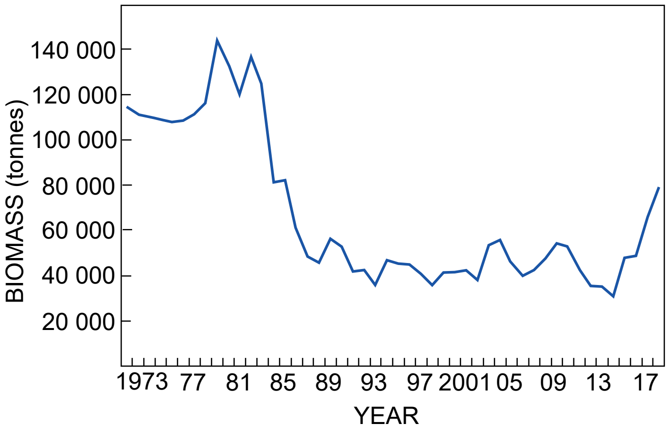

Figure 74: Estimated begin-year biomass in tonnes from 1971 to 2018. (N.B. derived from 14 vessels and restricted to records where 3<=crew<=26. Note this is to be updated on development of the new squid assessment model)

Useful statistics

Total squid catches (tonnes) from commercial jig and as bycatch from trawl, as well as squid total allowable effort (TAE) (2003–2021). Note that trawl bycatch data differ from those previously reported due to ongoing validation and correction of historical data.

Year	Squid commercial jig catches	Squid landings as bycatch from hake trawl	Squid TAE
2003	11 820	340	2 423 unrestricted crew* 41 restricted crew*
2004	13 261	391	2 423 unrestricted crew* 41 restricted crew*
2005	9 147	373	2 423 unrestricted crew* 22 restricted crew*
2006	9 291	358	2 423 crew or 138 vessels, whichever occurred first
2007	9 438	496	2 422 crew or 136 vessels, whichever occurred first
2008	9 021	528	2 422 crew or 136 vessels, whichever occurred first
2009	10 341	759	2 422 crew or 136 vessels, whichever occurred first
2010	10 777	574	2 422 crew or 136 vessels, whichever occurred first
2011	7 796	460	2 422 crew or 136 vessels, whichever occurred first
2012	6 392	227	2 422 crew or 136 vessels, whichever occurred first
2013	2 664	61	2 422 crew or 136 vessels whichever occurred first
2014	6 907	213	TAE of 250 000 person days
2015	6 479	333	TAE of 250 000 person days
2016	9 952	642	TAE of 250 000 person days
2017	11 919	558	TAE of 270 000 person days
2018	13 444	630	TAE of 270 000 person days
2019	6 730	534	TAE of 295 000 person days
2020	8 253	731	TAE of 295 000 person days
2021	4 741	–	TAE of 295 000 person days

*NB Unrestricted permits applied to Right Holders who were not restricted to fishing in any particular area, whereas restricted permits applied to Right Holders who were only allowed to fish off the former Ciskei (in the Eastern Cape Province). Restricted permits were eventually phased out of the fishery from 2006

Tunas and swordfish

Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
			Albacore (Ind. and Atl.) Yellowfin (Atl.) Bigeye (Ind.) Swordfish (Ind.)	Swordfish (Atl.) Bigeye (Atl.)	Southern bluefin (Ind. and Atl.) Yellowfin (Ind.)
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
		Albacore (Atl.)	Yellowfin (Atl.) Bigeye (Atl.) Swordfish (Ind. and Atl.) Southern bluefin (Ind. and Atl.)	Albacore (Ind.) Yellowfin (Ind.) Bigeye (Ind.)	

Introduction

Large pelagic fish resources in the waters around South Africa comprise several species in quantities that can sustain commercial exploitation. The common commercial species include four tuna species: albacore *Thunnus alalunga*, yellowfin *Thunnus albacares*, bigeye *Thunnus obesus* and southern bluefin *Thunnus maccoyii*, as well as swordfish *Xiphias gladius*. In addition, blue shark *Prionace glauca* and shortfin mako shark *Isurus oxyrinchus* are abundant in South African waters. All these species are highly migratory and their distributions span across all oceans, except southern bluefin tuna, which is confined to the Southern Hemisphere.

Given their wide-ranging distribution across multiple exclusive economic zones (EEZs), fisheries for large pelagic fish and their management are international, and participation is regulated through the tuna Regional Fisheries Management Organizations (tRFMOs). For management purposes, a single southern bluefin tuna stock, straddling all oceans in the southern hemisphere, is considered. Single stocks of yellowfin tuna and bigeye tuna are also assumed for the entire Atlantic Ocean, and likewise the Indian Ocean is considered to have one stock each of yellowfin, bigeye, albacore tuna and swordfish. Two different stocks, i.e. a North stock and a South stock, separated at 5° N, are recognised in the Atlantic Ocean for albacore tuna, swordfish, and blue and shortfin mako shark. A management boundary separates the Indian and Atlantic oceans at 20° E, though there is scientific evidence that questions the biogeographical validity of this boundary for tuna and the extent to which tuna, billfishes and pelagic shark populations straddle this boundary.

South Africa has two commercial fishing sectors that target tuna and tuna-like species in the Atlantic and Indian oceans. These sectors are the tuna pole-line (TPL) or “baitboat” and the large pelagic longline (LPL) fisheries. Additionally, the boat-based commercial linefishery catches tuna opportunistically and the boat-based recreational anglers undertake game fishing for tuna and billfishes. Longline fishing takes place throughout the entire EEZ and beyond. Southern bluefin tuna, bigeye tuna, yellowfin tuna, albacore tuna and swordfish are the main target species in the LPL fishery, with blue- and shortfin mako sharks being the main bycatch species. This fishery also incidentally catches a number of other pelagic and epipelagic species, including billfishes, oilfish and escolar, as well as several pelagic shark species. In contrast, the TPL fleet traditionally targets albacore tuna using poles and trolling lines. This fishery operates in waters up to 1 000 km off the South- and West coasts of South Africa and off Namibia, generally from October to May. When available in the inshore regions, yellowfin tuna, predominantly caught with rod and reel, is the second-most important species targeted by this sector. The TPL fishery also catches bigeye tuna, southern bluefin tuna and skipjack tuna

Katsuwonus pelamis in smaller volumes. The use of two gears in this fishery – pole to catch albacore and rod and reel to catch yellowfin tuna – was recognised and incorporated into the naming of this fishery as the TPL fishery. This fishery may not retain any incidentally caught swordfish, billfishes or sharks.

History and management

Large pelagic longline fishing for tuna dates back to the early-1960s, when South African longline vessels targeted southern bluefin and albacore tuna off the Western Cape Coast. Poor market conditions, however, led to a rapid decline in this fishery during the mid-1960s. Foreign vessels, mainly from Japan and Taiwan, continued to fish in South African waters from the 1970s until 2002 under a series of bilateral agreements. Thirty experimental LPL permits were issued to South Africans in 1997 to revive the local tuna fishery. Catches were, however, dominated by swordfish during this experimental phase.

The South African LPL fishery was commercialised in 2005, with the issuing of 18 swordfish-directed and 26 tuna-directed fishing Rights valid for a period of 10 years. At the same time, nine vessels were exempted, in terms of section 81 of the Marine Living Resources Act (MLRA; Act No. 18 of 1998), to exclusively fish for pelagic sharks until March 2011. In 2011, this pelagic shark fishery was incorporated into the tuna/swordfish longline fishery. In 2015, a decision was taken to no longer refer to the fleet as having two different fishing strategies (i.e. tuna-directed and swordfish-directed, respectively) since the fishing behaviour of the local fleet had been shifting from exclusive swordfish targeting to include tunas and sharks. Subsequently, the fishery has been referred to as the large pelagic longline fishery and includes vessels that target tunas and swordfish and take sharks as bycatch. In 2017, 60 new fishing Rights were allocated in the LPL fishery for a period of 15 years.

Although the fishing grounds just outside South Africa's EEZ are hotspots for international tuna longline fleets, the South African LPL fleet continues to fish locally. This is attributed to small vessels and this fleet remains under-capitalised when compared to international tuna longline fleets.

The primary target species are southern bluefin tuna, yellowfin tuna, bigeye tuna and swordfish. This fishery may no longer target sharks, a practice further discouraged in 2017 with the banning of the use of wire traces. Until very recently, however, a small component of the fleet continued to target sharks, with blue- and shortfin mako sharks accounting for more than 95% of the total landings of some vessels. To restrict directed fishing of sharks further, the proportion of sharks in the catch of each vessel has been limited to a maximum of 60% per quarter and less than 50% per annum since 2019. The fishery has slowly changed its profile with less foreign vessel participation, less bycatch and more-effective tuna targeting (Table 18).

The South African TPL fishery started in the late 1970s and initially targeted yellowfin tuna, but switched back to its traditional albacore tuna target species when yellowfin tuna moved out of Cape waters in 1980. Since then, albacore tuna has made up the bulk of the catch, with annual catches varying between 2 000 and 4 500 t in recent years (Table 19). South Africa's TPL fishery is one of four major fisheries in the South Atlantic that contribute to the region's albacore tuna catches; the remaining three fisheries that target this species include Namibia's bait-boat fleet and the longline fleets of Brazil and Chinese Taipei. Although tuna generally occur in mixed-species shoals, bigeye tuna and skipjack tuna are typically caught only in low volumes. During occasional "good years", higher-value yellowfin tuna becomes available to the fishery, with catches in the order of 1 000 t substantially increasing the profit margin of this fishery.

Initially managed under the linefishery, the TPL fishery has been recognised as a separate sector since 2003. In 2005, the Department allocated 191 commercial TPL fishing Rights, thereby authorising 198 vessels (greater than 10 m in length) and more than 2 600 crew to target tuna using the pole

Table 18: Total catch (tonnes; figures for sharks denote dressed weight) and number of domestic and foreign-flagged vessels in the large pelagic longline sector for 2005 to 2021

Year	Bigeye tuna	Yellowfin tuna	Albacore tuna	Southern bluefin tuna	Swordfish	Shortfin mako shark	Blue shark	Number of active vessels	
								Domestic (*)	Foreign-flagged
2005	1 077.2	1 603.0	188.6	27.1	408.1	700.1	224.6	13 (4)	12
2006	137.6	337.3	122.9	9.5	323.1	457.1	120.7	19 (4)	0
2007	676.7	1 086.0	220.2	48.2	445.2	594.3	258.5	22 (5)	12
2008	640.3	630.3	340.0	43.4	397.5	471.0	282.9	15 (4)	13
2009	765.0	1 096.0	309.1	30.0	377.5	511.3	285.9	19 (4)	9
2010	940.1	1 262.4	164.6	34.2	527.8	590.5	311.6	19 (5)	9
2011	906.8	1 181.7	338.7	48.6	584.4	645.2	541.6	16 (6)	15
2012	822.0	606.7	244.6	78.8	445.3	313.8	332.6	16	11
2013	881.8	1 090.7	291.1	50.9	471.0	481.5	349.0	15	9
2014	543.8	485.8	113.8	31.2	223.1	609.6	573.4	16	4
2015	426.9	601.0	153.0	42.1	408.2	768.2	523.7	22	4
2016	328.9	478.1	84.6	43.9	310.0	869.5	526.6	20	3
2017	493.6	408.0	172.7	113.4	258.2	750.6	558.0	22	3
2018	462.1	464.7	239.1	209.5	318.9	613.8	592.7	26	3
2019	646.2	655.4	356.8	173.5	565.8	200.8	223.7	20	3
2020	394.0	384.9	260.5	102.9	317.2	184.9	63.8	20	-
2021	515.3	490.0	375.7	132.3	457.6	84.2	81.6	19	-

*Pelagic shark vessels, included in total method, for a period of 10 years. On average, 130 vessels were active over the period 2005–2013. During the 2013 fishing rights allocation process (FRAP 2013), 163 fishing Rights and 165 vessels gained access for a period of 10 years. The most recent Rights allocation process (FRAP 2021/22) resulted in a similar quantum of Rights being allocated. Appeals are still ongoing at the time of writing and the final number of vessels within the fishery is to be determined. Catches of the fishery have been stable for a number of years, but the fleet has been consolidated to the most effective vessels (Table 19).

Due to the seasonality of the TPL fishery, fishers also have access to snoek *Thyrsites atun* and yellowtail *Seriola lalandi*. However, the traditional linefish sector also relies on these species for the majority of their catch. An assessment of yellowtail conducted in 2017 suggests that the stock is currently not being subjected to overfishing, but trajectories indicate rapid stock declines can be expected if annual catches exceed 850 t. Consequently, TPL access to yellowtail is currently managed by means of a bag limit of 10 fish per person per trip and all non-tuna species have been designated as bycatch during the latest fishing rights allocation.

South Africa's tuna resources straddle international boundaries. Consequently these resources are managed by three tuna-directed Regional Fisheries Management Organizations (tRFMOs) of which South Africa is a full member: (i) the International Commission for the Conservation of Atlantic Tunas (ICCAT), (ii) the Indian Ocean Tuna Commission (IOTC), and (iii) the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). The CCSBT has the sole mandate for the management of southern bluefin tuna. South Africa is obliged to adhere to the Conservation and Management Measures (CMMs) of the tRFMOs to ensure sustainability of target and bycatch species and protection of Endangered/Threatened and Protected (ETP) species; i.e. turtles, seabirds, marine mammals and sharks. Providing tRFMOs with accurate and complete data is extremely important for regional stock assessments conducted by the tRFMOs. These assessments ultimately inform total allowable effort (TAE) and total allowable catch (TAC) allocations. The permit conditions relating to bycatch of ETP species must satisfy international best practices and require strict enforcement. It is essential for South Africa to demonstrate that it is actively implementing all requirements necessary to reduce impacts of the fishery on threatened and endangered species. Except for southern bluefin tuna, managed by the CCSBT, all catches of tuna and tuna-like species to the west of longitude 20° E fall under ICCAT jurisdiction whereas catches to the east fall under the IOTC. This leads to the peculiar situation where, for example, yellowfin tuna caught in the Atlantic is considered optimally exploited but determined to be overfished if caught just a few kilometres further to the east.

TAC quotas are allocated by ICCAT to South Africa for albacore tuna (4 400 t) and swordfish (1 001 t) in the Atlantic. Currently, South Africa almost reaches its quota of albacore tuna but is far from attaining its swordfish quota. The IOTC does not yet manage the Indian Ocean stocks by way of TAC quota allocations. Instead, South Africa has an effort limitation (TAE) of 50 vessels above 24 m "length overall" (LOA) in the IOTC's Area of Competence. South Africa became a full member of the CCSBT in February 2015. This resulted in a sequentially increased TAC of southern bluefin tuna quota for South Africa from a mere 40 t to 160 t in 2016 and to 450 t for 2017–2022. The opportunity to catch larger quantities of this extremely valuable tuna, combined with the current underutilisation of effort allocation and catch quotas for other important target species, emphasises the substantial development potential of South Africa's large pelagic fisheries sector, perhaps the most promising in terms of landed value.

Research and monitoring

Fisheries and observer data

Being a full member of the three tRFMOs obligates South Africa to submit a wide range of fisheries statistics and reports to ICCAT, IOTC and CCSBT annually. The two key sources of mandatory information are catch statistics in the form of logbooks from the LPL and TPL sectors, and the LPL observer data. Right Holders in the LPL fishery have been required to complete daily logs of catches since 1997. The following information is recorded in the logbooks: the catch locations, number of hooks, time of setting and hauling, bait used, number

Table 19: Total catch (tonnes) and number of active vessels in the tuna pole-line sector for 2005 to 2021

Year	Albacore	Yellowfin tuna	Snoek	Yellowtail	Skipjack tuna	Bigeye tuna	Number of active vessels
2005	3 149.4	975	193.4	13.8	0.9	1.7	111
2006	2 526.6	978.9	118.0	1.4	0.0	1.0	116
2007	3 681.0	945.2	79.5	19.2	0.2	20.5	12
2008	2 189.9	347.8	313.7	13.0	3.6	22.9	109
2009	4 795.3	223.8	186.2	33.4	4.0	37.9	118
2010	4 272.8	177.2	476.8	41.2	1.6	12.6	108
2011	3 346.8	629.5	163.8	26.9	5.4	35.5	111
2012	3 619.6	165.6	180.1	27.5	8.0	13.2	119
2013	3 488.8	374.5	620.5	18.2	2.6	125.8	106
2014	3 526.4	1 308.2	266.9	11.1	4.6	43.3	94
2015	3 969.3	790.0	332.6	199.4	2.2	50.7	93
2016	2 029.7	543.0	219.3	12.0	1.6	9.3	99
2017	1 791.5	212.4	453.7	21.3	0.7	21.4	95
2018	2 498.5	232.9	774.6	10.0	1.5	20.2	94
2019	4 243.4	457.3	859.5	16.3	2.7	98.4	91
2020	3 912.4	537.6	1 363.5	35.6	0.6	76.0	97
2021	3 503.2	214.2	503.2	874	1.0	122.1	74

and estimated weight of retained species, and data on bycatch incidents (seabirds, turtles and sharks). Identification guides detailing tunas, common bycatch species such as escolar and oilfish, sharks, billfish, seabirds and turtles are issued to all active vessels to facilitate reporting.

Recognising the importance of the observer programme in ensuring that vessels comply with bycatch (sharks, seabirds and turtles) mitigation measures, as well as catch and size limits for target and bycatch species, South Africa has implemented an on-board observer programme for the LPL fishery since 1998. Although the government-funded programme came to an end in March 2011, industry-funded observer coverage has continued to comply with tRFMO requirements. The foreign-flagged vessels, which fish under joint-venture charter agreements, are required to carry an observer all of the time. Observer coverage of local LPL vessels has been included in the permit conditions and has been steadily increasing. To improve the spatiotemporal observer coverage further, South Africa is aiming to increase its overall observer coverage to 20% per quarter. To achieve this, the current LPL permit conditions now require permit holders to carry one or more scientific observers on board their vessels on a minimum of one fishing trip per quarter to ensure monitoring of 20% of all fishing days in each quarter. Vessels that exceed a 60% shark bycatch limit per quarter will also have to carry an observer on board for the remainder of the fishing season.

The small size of the South African TPL bait-boat vessels (average 16 m LOA) precludes the accommodation of an on-board observer. As the majority of the vessels offload their catch at night, there is limited capacity within the permanent Departmental monitoring and compliance staff to monitor every discharge as required, limiting the collection of size frequencies and the verification of logbook information for a subset of the effort. The Department's shore-based observer programme that monitored vessel offloads in port ended in March 2011. Although the programme has not yet been fully re-established, a pilot programme started in 2022. Specifications developed for the new programme include comprehensive monitoring of all the large pelagic fisheries operating around South Africa. In addition, the Department is engaging with tRFMOs to develop and trial electronic monitoring systems (EMS) that would negate the use of on-board observers. The EMS are camera-based, whereby footage of fishing operations can be stored and reviewed, and data retrieved, when necessary.

Abundance indices and stock assessment

Catch per unit effort (CPUE) indices are commonly used to track the abundance of large pelagic species in the absence of fisheries independent surveys, which are not possible for these wide-ranging species. Over the past four years, South Africa has made significant progress in developing models to standardise tuna pole and longline catch and effort data that account for targeting (as opposed to bycatch), individual vessel characteristics and spatial effects. For the ICCAT region, South Africa has presented standardised CPUE indices for albacore and yellowfin tuna from the tuna pole fleet, as well as swordfish, shortfin mako and bigeye tuna from the longline fleet. For the IOTC region, standardised CPUE indices were provided for swordfish, based on domestic vessel catch and effort, and for the two tropical tuna species, bigeye and yellowfin tuna, based on catch and effort data from joint-venture vessels. South Africa continues to improve the standardisation of CPUE indices of both the tuna pole and the tuna/swordfish longline fleet as South African indices provide vital information for many international stock assessments of tunas, swordfish and sharks.

South Africa has been actively participating in the regional stock assessments of several large pelagic species since 2017. South African government scientists have been leading the development and implementation of the open-source modelling framework JABBA (Just Another Bayesian Biomass Assessment), which has been widely applied in stock assessments of highly migratory species (sharks, tuna, and billfishes) around the world (Table 20). Furthermore, South Africa holds several positions within the tRFMOs, including but not limited to, Chair of the ICCAT Panel 3, vice-Chair of the IOTC Commission and vice-Chair of the IOTC Scientific Committee. South Africa's contribution to the sustainable management of global large pelagic fish stocks is disproportionally large given the size of its fleet or magnitude of catch, especially when compared to fleets such as that from the European Union.

Bycatch and its mitigation

Scientists from the Department, together with other national scientists from countries operating pelagic fleets south of 25° S, participated in the First Regional Bycatch Pre-assessment Workshop held in early 2017. This workshop was part of a collaborative process to bring national scientists together, and where appropriate and requested, to help build capacity of national scientists to undertake a global bycatch analysis. In 2018 and 2019, scientists from DFFE and NOAA (US National Oceanic and Atmospheric Administration) participated in the Seabird Bycatch Small Working Group Meeting hosted by BirdLife SA under the Common Oceans project to explore alternative techniques for estimating bird encounters and overall captures from observer and effort data. Delegates collaborated by sharing observer data on seabird bycatch and applied spatial models, including the Spatially Explicit Fisheries Risk Assessment (SEFRA), to estimate seabird bycatch by pelagic longline fisheries operating south of 25° S. In addition, a multinational group from Atlantic coastal states, including Brazil, Uruguay, South Africa and Portugal, investigated the effect of seabird bycatch mitigation methods using the largest multinational observer dataset pertaining to seabird bycatch collated to date. In 2021, the Department reviewed the National Plan of Action for Sharks (NPOA-Sharks) and presented an updated NPOA-Sharks to numerous stakeholders. The NPOA-Sharks was well-received and was subsequently adopted by the DFFE Minister in 2022. Finally, the Department's scientists partici-

Table 20: Assessments of large pelagic stocks that South African scientists have produced at RFMOs since 2017. RFMO = Regional Fisheries Management Organization; ICCAT = International Commission for the Conservation of Atlantic Tunas; IOTC = Indian Ocean Tuna Commission

RFMO	Year	Stock assessment
ICCAT	2017	South Atlantic shortfin mako shark
		North Atlantic shortfin mako shark
		South Atlantic swordfish
	2018	Bigeye tuna
		Blue marlin
	2019	South Atlantic shortfin mako shark
		White marlin
	2020	South Atlantic albacore
	2022	South Atlantic swordfish
IOTC	2017	Blue shark
		Swordfish
	2018	Black marlin
		Striped marlin
	2019	Blue marlin
	2020	Swordfish
	2021	Blue shark
		Black marlin
		Striped marlin
	2022	Blue marlin

pated in a multi-national research project to assess the extent of turtle-bycatch by longline fisheries in the Atlantic, which has not been concluded at the time of this report's publication.

Current status

Stock assessments and country allocations for the Atlantic and Indian Ocean stocks of tuna and tuna-like species are the responsibility of ICCAT and the IOTC, whereas CCSBT conducts the stock assessments for southern bluefin tuna only. South Africa contributes significantly to these assessments, both in providing data (i.e. abundance indices/standardised CPUE) as well as scientific expertise.

Yellowfin tuna

The most recent stock assessment for yellowfin tuna, conducted by ICCAT in 2019, indicated that the spawning stock biomass (SB) in the Atlantic Ocean was just above that which would produce a maximum sustainable yield (MSY; Figure 75) and estimates suggested that maintaining catch levels at the current TAC of 110 000 t were sustainable. However, the 2018 catch was estimated to be four times higher at 423 815 t and at these catch levels the stock will be driven into an overfished state. Increased harvests on smaller yellowfin tuna have negative consequences for the long-term sustainability of the stock.

A stock assessment carried out in 2021 for yellowfin tuna in the IOTC area of competence estimated the spawning stock biomass in 2020 to be 31% of the unfished levels. In terms of this assessment, the spawning stock biomass in 2020 was below the level that would produce MSY (SB_{2020}/SB_{MSY} = 0.87) and the fishing mortality was 32% higher than that required to reach MSY (F_{2020}/F_{MSY} at 1.32; Figure 75). Catches in recent years have substantially increased the pressure on the Indian Ocean stock, resulting in fishing mortality exceeding the MSY-related levels.

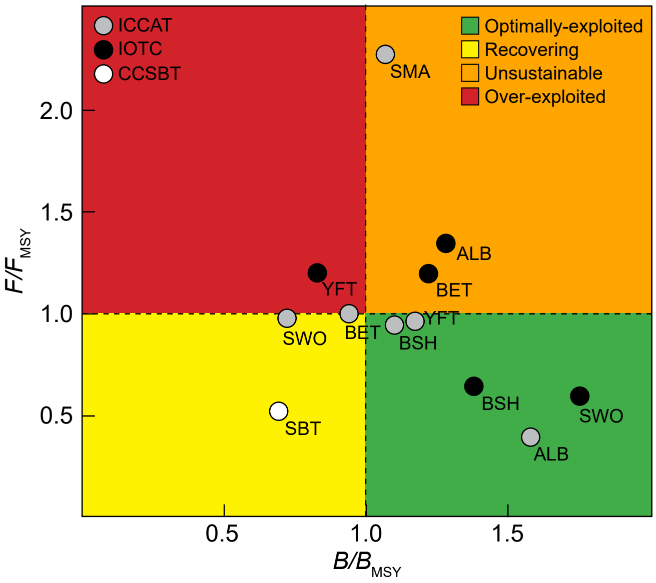

Figure 75: Kobe plot summarising the most-recent stock status estimates of fishing mortality relative to F_{MSY} and biomass relative to B_{MSY} for large pelagic species targeted by the South African longline and tuna pole-line fishery. Only results from formal stock assessments conducted by ICCAT (Atlantic Ocean), IOTC (Indian Ocean) or CCSBT (Southern Ocean) are included. ALB: albacore tuna; YFT: yellowfin tuna; BET: bigeye tuna; SBT: southern bluefin tuna; SWO: swordfish; BSH: blue shark; SMA: shortfin mako shark. Note that "Biomass" (*B*) in the plot can reflect exploitable biomass, spawning biomass, total reproductive output or pupping stock fecundity, depending on the type of model used to estimate stock status

Albacore tuna

ICCAT conducted a full southern Atlantic albacore stock assessment in 2020, using a broad range of methods and including data up to 2018. The assessment results suggest that biomass increased since fishing mortality started to decrease in the early 2000s, and currently there is a 99.4% probability that the South Atlantic albacore stock is neither overfished nor subject to overfishing, with only 0.6% probability for the stock to be overfished (Figure 75). Projections at a level consistent with the estimated MSY level (27 000 t) will maintain biomass levels above B_{MSY} and fishing mortality below F_{MSY} with a high probability of 90% over the projection horizon through 2033.

Swordfish

Swordfish stock assessments conducted by ICCAT in 2022, from two separate models using data up to 2020, produced consistent results indicating that there is a 56% probability that South Atlantic swordfish stock is currently overfished and that overfishing is occurring (B/B_{MSY} = 0.77; F/F_{MSY} = 1.03) and only a 9% chance that it is sustainably exploited and in terms of current biomass and fishing pressure. Catches at, or below, 10 000 t are required to rebuild the population to biomass levels that can produce MSY by 2033.

The most recent stock assessment conducted by IOTC in 2020 (with fisheries data up to 2018) determined that this swordfish stock was not overfished nor subject to overfishing (figure 75). Spawning biomass in 2018 was estimated to be 40–83% of the unfished levels. Most recent catches of 33 590 t in 2019 are approximately at the MSY level (33 000 t).

The assessment indicated that there is recurring evidence for localised depletion in the southern regions, particularly in the Southwest.

Bigeye tuna

In the Atlantic Ocean, the bigeye tuna stock has been exploited by three major gear-types (longline, bait boat and industrial purse-seine fisheries) and by many countries throughout its distributional range. Catches peaked in 1994 at about 135 000 t but have since been gradually declining. In 2021 a stock assessment was conducted using data until 2019. The results indicate that in 2019 the Atlantic bigeye tuna stock was overfished ($SSB_{2019}/SSB_{MSY} = 0.94$) but was not undergoing overfishing ($F_{2019}/F_{MSY} = 1.00$; Figure 75). The MSY was estimated as 86 833 t. Future constant catches of 61 500 t, equal to the TAC established in the ICCAT Recommendation Rec. 19-02, are expected to continue to prevent overfishing ($F<F_{MSY}$) with greater than 90% probability and to prevent the stock from becoming overfished with greater than 80% probability by 2034 (a period of 2 generations).

In 2019 a new stock assessment was carried out for bigeye tuna in the IOTC area which estimated the 2018 spawning stock biomass to be 31% of the unfished levels and 22% (18–81%) higher than that required to achieve MSY. Based on the pessimistic outlook, South Africa led the negotiations during the 2019 ICCAT commission and managed to get consensus on a wide range of measures to stop overfishing of bigeye tuna. These include a reduction of total catch and a reduction of effort related to fish aggregating devices (FADs), including a closed season for fishing on FADs and a restriction in FAD numbers.

Southern bluefin tuna

The most recent stock assessment of the southern bluefin stock was conducted in 2020 at the Extended Scientific Committee (ESC) of CCSBT. The stock, as indicated by relative total reproductive output (TRO), is estimated to be 20% of the unfished levels. There has been improvement since previous stock assessments conducted in 2017 which indicated that relative TRO was at 13%. The stock remains below the level estimated to produce maximum sustainable yield (MSY; Figure 75). However, the fishing mortality rate is below the level associated with MSY and the stock has been rebuilding by approximately 5% per year since the low point in 2009. The Extended Scientific Committee recommended that the global TAC in 2022 should remain unchanged at 17 647 t.

Ecosystem considerations

South Africa's large pelagic fishing grounds are in the proximity of large seabird breeding colonies in the Southern Ocean and at the boundary of two large marine ecosystems. This area is home to a rich and diverse megafauna and, consequently, increased potential for fishery-related impacts on these. Interactions between fishing vessels and seabirds, turtles, sharks and mammals are relatively common and do not necessarily reflect high fishing pressure, but rather fishing within a global pelagic biodiversity hotspot.

Extensive research and subsequent management advice have contributed to mitigating the bycatch of seabirds, turtles and marine mammals in the pelagic longline fishery. The most frequently caught seabird bycatch species, all of which are either Near Threatened, Vulnerable or Endangered on the IUCN Red List of Threatened Species, are the white-chinned petrel *Procellaria aequinoctialis* and albatrosses, the most common being the shy-type (mostly white-capped *Thalassarche steadi*, black-browed *T. melanophrys* and Indian yellow-nosed *T. carteri*). Leatherback turtles *Dermochelys coriacea* and loggerhead turtles *Caretta caretta* are the most common turtle species caught as bycatch.

South Africa is regarded as a leader amongst developing states in bycatch mitigation for longline fisheries and has, in the last few years, consistently been among a handful of countries that are compliant with all bycatch-related conservation measures imposed by the tuna RFMOs. South African longline observer coverage is amongst the highest of all longline fleets in the world and the resulting data are used to refine bycatch mitigation measures and to investigate their impact.

Climate change

Although there has not been any specific research in South Africa to investigate the effects of climate change on tuna and other large pelagic species, considerable changes in distribution and abundance of several species are to be expected, as South Africa is located at several oceanographic, climatic and ecosystem transition zones that are expected to shift as a result of the warming ocean. One predicted impact of climate change on tuna populations is the change in the spawning habitat and subsequent larval recruitment in equatorial ocean regions.

On ocean basin levels, shifts of tuna abundance in all three spatial axes, i.e. latitudinal, longitudinal and vertical within the water column, have been suggested, based on modelling scenarios. These shifts, if the predictions hold true, will have implications for fisheries, but dedicated research is needed to understand these potential impacts for large pelagic fisheries in South Africa.

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APPENDIX 1: Detailed status of large pelagic resources and allocations by RFMOs

(a) Tuna and tuna-like species

	Albacore tuna		Yellowfin tuna		Bigeye tuna		Swordfish		Southern bluefin tuna
	Atlantic Ocean	Indian Ocean	Atlantic Ocean	Indian Ocean	Atlantic Ocean	Indian Ocean	Atlantic Ocean	Indian Ocean	Atlantic and Indian
Stock assessment	2020	2019	2019	2021	2021	2019	2022	2020	2020
MSY	27 264 t (23 734-31 567)	35 700 t (27 300–44 400)	121 298 t (90 428–267 350)	349 000 t (286 000–412 000)	86 833 t (72 210–106 440)	87 000 t (75 000–108 000)	11 481 t (9 793–13 265)	33 000 t (27 000–40 000)	–
Total yield for stock	15 640 t (2019)	38 082 t (2020)	423 815 t (2018)	430 956 t (2020)	57 486 t (2020)	83 498 t (2020)	9 020 t (2020)	26 005 t (2020)	16 441 t (2020)
RFMO TAC	24 000 t	–	110 000 t	–	61 500 t	1.20 t (0.70–2.05) 1.22 t (0.82–1.81)	TBC	–	17 647 t (2021–2023)
Quota allocation to South Africa	4 400 t (+1 100 t underage)	–	–	–	–	–	1 001 t	–	455 t
Relative biomass	B_{2019}/ B_{MSY} = 1.58 (1.14–2.05)	$\mathrm{SSB}_{2017}/\mathrm{SSB}_{MSY}$ = 1.28 (0.57–2.07)	B_{2018}/B_{MSY} = 1.17 (0.75–1.62)	$\mathrm{SSB}_{2020}/\mathrm{SSB}_{MSY}$ = 0.87 (0.63–1.10)	$\mathrm{SSB}_{2019}/ \mathrm{SSB}_{MSY}$ = 0.94 (0.71–1.37)	$\mathrm{SSB}_{2018}/\mathrm{SSB}_{MSY}$ = 1.22 (0.82–1.82)	B_{2020}/B_{MSY} = 0.77 (0.53 –1.11)	$\mathrm{SSB}_{2020}/ \mathrm{SSB}_{MSY}$ = 1.75 (1.28–2.35)	$\mathrm{TRO}_{2020}/\mathrm{TRO}_{MSY}$ = 0.69 (0.49–1.03)
Relative fishing mortality	F_{2019}/F_{MSY} = 0.40 (0.28–0.59)	F_{2017}/F_{MSY} = 1.35 (0.59–2.17)	F_{2018}/F_{MSY} = 0.96 (0.56–1.5)	F_{2020}/F_{MSY} = 1.32 (0.68–1.95)	F_{2019}/F_{MSY} = 1.00 (0.63–1.35)	F_{2018}/F_{MSY} = 1.20 (0.70–2.05)	F_{2020}/F_{MSY} = 1.03 (0.67–1.51)	F_{2018}/F_{MSY} = 0.60 (0.40–0.83)	F_{2019}/F_{MSY} = 0.52 (0.37–0.73)

(b) Large pelagic shark species

	Blue shark		Shortfin mako shark	
	Atlantic Ocean	Indian Ocean	Atlantic Ocean	Indian Ocean
Stock Assessment	2015	2021	2017 (2019)	2017 (2019)
MSY	Unknown	36 000 t (33 500-36.600)	Unknown	Unknown
Total yield for stock	34 309 t (2018)	Estimated catch 43 240 t (2019) Reported catch 21 344 t (2020)	3 158 t (2018)	1 613 t (average 2016–2020)
RFMO TAC	-	-	-	-
Quota allocation	-	-	-	-
Relative biomass	B_{2013}/ B_{MSY} = 1.15 (0.78–1.29)*	SSB_{2015}/SSB_{MSY} = 1.39 (1.27–1.49)	B_{2015}/B_{MSY} = 1.07 (0.65–1.75)	Unknown
Relative fishing mortality	F_{2013}/F_{MSY} = 0.94 (0.54–1.18)*	F_{2015}/F_{MSY} = 0.64 (0.53–0.75)	F_{2015}/F_{MSY} = 2.27 (0.86–3.67)	Unknown
RFMO summary and recommendations	Estimates obtained with the Bayesian state-space surplus production model formulation should be considered more reliable than other Bayesian production models. These were less optimistic, predicting that the stock could be overfished and overfishing could be occurring. Considering the uncertainty in stock status results for the South Atlantic stock of blue sharks, the Committee strongly recommends that the Commission considers a precautionary approach for this stock. If the Commission chose to use the same approach taken for the North Atlantic stock, the average catch of the final five years used in the assessment model (28 923 t for 2009–2013) could be used as a limit.	Even though the 2021 assessment indicates that Indian Ocean blue shark are not overfished nor subject to overfishing, increasing current catches is likely to result in decreasing biomass and the stock becoming overfished and subject to overfishing in the near future. If the catches are increased by over 20%, the probability of maintaining spawning biomass above MSY reference levels ($SSB>SSB_{MSY}$) over the next 10 years will be decreased. The stock should be closely monitored. While mechanisms exist for encouraging CPCs to comply with their recording and reporting requirements (Resolution 16/06), these need to be further implemented by the Commission, to better inform scientific advice in the future.	For the South Atlantic stock of shortfin mako sharks, the estimates of unsustainable harvest rates appear to be fairly robust at this stage whereas the biomass depletion and B/B_{MSY} estimates must be treated with extreme caution. Given the uncertainty in stock status, the large fluctuations in catch, the high intrinsic vulnerability of this species, and the depleted status for the North Atlantic stock, the Committee recommends that until this uncertainty is reduced, catch levels should not exceed the minimum catch in the last five years of the assessment (2011–2015; 2 001 t).	In the absence of a stock assessment and noting conflicting information, the Commission should take a cautious approach by implementing management actions that reduce fishing mortality on shortfin mako sharks. While mechanisms exist for encouraging CPCs to comply with their recording and reporting requirements (Resolution 18/07), these need to be further implemented by the Commission to better inform scientific advice.

West Coast rock lobster

Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
Fishing pressure	Unknown	Light	Optimal	Heavy	

Introduction

The West Coast rock lobster (*Jasus lalandii*) fishery is one of the most important fisheries in South Africa due to its high market value (more than R500 million per annum) and its importance in providing direct and indirect employment (~4 300 sea- and land-based jobs), especially for impoverished communities along the West Coast. The West Coast rock lobster is a cold-water, temperate, spiny lobster species occurring from Walvis Bay in Namibia to East London in South Africa. In South Africa, the commercial fishery operates between the Orange River mouth and Danger Point in waters up to 150 m in depth. This slow-growing species inhabits rocky areas and exhibits a seasonal inshore–offshore migration governed by its biology and environmental factors. Currently the resource is harvested by hoop nets from “bakkies” (small wooden rowing boats) in the nearshore region up to one nautical mile offshore and by offshore trap vessels operating in water depths greater than 100 m. The resource in the nearshore region is also harvested by recreational fishers and small-scale or subsistence fishers operating exclusively in the nearshore region during the summer months.

The invasion of West Coast rock lobsters into the traditional abalone fishing zones east of Cape Hangklip marked the onset of an eastward shift in lobster distribution. Commercially viable quantities of lobster in this area resulted in the opening of three new lobster fishing areas (areas 12–14; Figure 76). As a result, the fishery on the West Coast, which historically landed the bulk (60%) of the lobster catch, now lands only 40% of the total catch annually. This decline in catch has had a devastating effect on coastal communities, with economic hardships experienced by most fishers on the West Coast. In the face of resource decline, an operational management procedure (OMP) was developed which aims to rebuild the stock to sustainable levels.

History and management

The commercial harvesting of West Coast rock lobster commenced in the late 1800s and peaked in the early 1950s, yielding an annual catch of 18 000 t. Lobsters were predominantly caught with hoop nets prior to the 1960s and from 1965 more-efficient traps and motorised deck boats were also used. Average catches declined by almost half to 10 000 t during the 1960s and continued to decline sharply to around 2 000–3 400 t in the first decade of this century. From about 2014, there was a continuous decline in legal catches, reaching 720 t in 2021 (see ‘Useful statistics’). The decline in catches is believed to be due to a combination of changes in fishing methods and efficiency, changes in management measures, overfishing, environmental changes, and reduced growth rates.

A number of management measures have been put in place during the history of the fishery. A minimum size limit was introduced in 1933 (89 mm carapace length), which protected a large proportion of the slower-growing female component of the population, and a tail-mass production quota was imposed in 1946. However, catches declined sharply during the 1950s, particularly in the northern areas, in response to overfishing. A minimum legal size limit of 76 mm carapace length was implemented in 1959, after which the average catch increased to around 10 000 t until the mid-1960s. However, catches declined again from 1966 and continued to decline during the 1970s, when a minimum legal size limit of 89 mm carapace length was implemented. In 1979, the tail-mass production quota was replaced by a whole-lobster quota, which led to the introduction of the total allowable catch (TAC) management system in the early 1980s.

Under the TAC management system, annual catch limits were subdivided for the 10 traditional West Coast fishing areas (Figure 76, zones A–D). A new fishing ground in False Bay (zone E) was opened in 1987, and zone F was opened in 1999 following the eastward shift in distribution of lobster towards the area east of Cape Hangklip. Currently the stock is managed on a per zone (super-area) basis. The resource in zones A, E and F are exclusively harvested by fishers operating with hoop nets in the nearshore region.

Other management controls applied included protection of females with eggs (berried females) and soft-shelled lobsters, a closed winter season, and a daily bag limit for recreational fishers. Average annual catches stabilised at around 3 500 to 4 000 t until 1989 when the resource started to decline further. This continued decline in the resource during the 1990s and

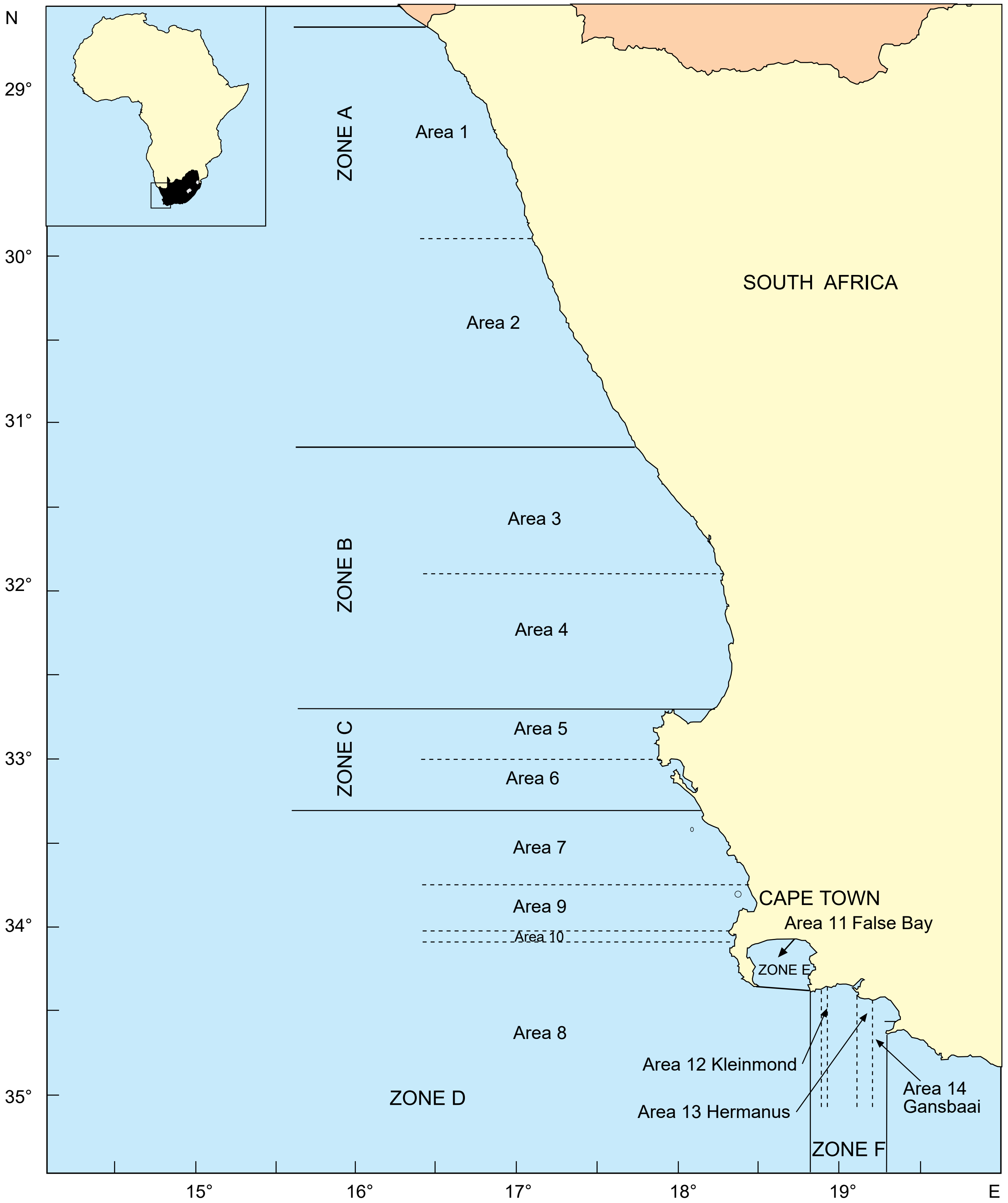

Figure 76: West Coast rock lobster fishing zones and areas. The five super-areas are: areas 1–2, corresponding to zone A; areas 3–4, to zone B; areas 5–6, to zone C; area 7, being the northernmost area within zone D; and area 8+, comprising area 8 of zone D as well as zones E and F

early 2000s was attributed to mass strandings of lobster and reduced growth caused by low oxygen events along the West Coast. During this period the size limit was decreased from 89 to 75 mm carapace length to reduce mortalities resulting from discards of undersized lobsters. By 1996 catches had declined to their lowest levels of 1 500 t and showed no marked signs of recovery.

In the face of decreases in growth rates, catch rates and biomass, an OMP was implemented in 1997 in an attempt to rebuild the resource to sustainable levels (defined as pre-1990). Since then, scientific recommendations for TACs for the West Coast rock lobster resource have been based on OMPs. Recommendations each year are calculated in a manner that incorporates updated information from resource-monitoring data according to formulae pre-agreed by scientists, managers and stakeholders, and then adopted by the Branch: Fisheries Management in the Department as the accepted management basis for the fishery concerned. These data provide for annual recommendations of a global TAC and a TAC for each Zone (Figure 76). Each OMP is based on biomass recovery targets for the resource within a defined period. The OMP for West Coast rock lobster is revised in 3–4-year intervals, the last time in 2015. The OMP also provides for “Exceptional Circumstances” when the resource progresses outside the range of the scenarios for which this OMP had been tested. These circumstances permit TAC recommendations to be based instead on “best estimate” projections. Due to worse-than-expected resource performance, “Exceptional Circumstances” were agreed to apply for super-area 7 in 2013 and for the whole resource in 2016. Also in 2016, the recovery target of 35% above the 2006 level by 2021, which had been set for OMP-2011, was found to be unachievable, even in the absence of any legal catches, and was replaced by a 7% target. The 7% figure was a trade-off between achieving at least some resource recovery, while maintaining some fishing activities for socio-economic reasons. It is noteworthy that in many years, for example for the 2019/20 and 2020/21 fishing seasons, the TAC was set substantially higher than recommended by scientists.

In 2017, an effort-reduction strategy based on reducing the fishing season length to three months was implemented to assist in reducing the unacceptably high levels of poaching. This was extended to four months in 2018. As a result of the COVID-19 outbreak, the Minister granted an extension to the 2019/20 season to allow ample time for the full TAC to be landed; furthermore, in 2022, the season was extended by two weeks in the offshore part of super-area 8+.

Further catch reductions have been necessary during the last five years due to resource decline in most areas. In most of these years, a phased-reduction approach was recommended to reduce socio-economic disruption.

Most recently, during the 2020/21 season, all relevant data, except for the fishery-independent monitoring survey (FIMS) data for super-area 8+ (due to administrative problems), were collected and analysed. For socio-economic reasons, a phased reduction of the TAC over a period of two seasons was recommended (600 t in the first year, and 400 t in the second and thereafter). However, a subsequent Consultative Advisory Forum for Marine Living Resources (CAFULR) process recommended a three-year scenario (700, 550 and 400 t), which had been investigated, but less favoured, by the scientific working group due to its lower likelihood of resource rebuilding by 2025. Subsequently, a 700 t TAC was set for the 2021/22 season.

Research and monitoring

Research and monitoring of West Coast rock lobster continues to provide and improve essential data inputs for assessing the sustainability of the stock, its management and setting annual catch limits for the fishery. Indices of abundance such as catch per unit effort (CPUE) derived from the FIMS and commercial catch statistics (Figures 77 and 78), annual assessments of somatic growth rate (Figure 79), and estimates of recreational and interim relief catch, are used as input data to the OMP assessment model.

Catch monitors record fishing effort and catch landed by commercial nearshore and offshore Right Holders and interim relief fishers on landing slips after each fishing trip. Recreational catch was estimated from catch and fishing effort statistics reported during an annual recreational telephonic survey. However, the last survey was conducted during the 2018/19 season and the survey was abandoned in the following years. The reason was the huge reduction in the recreational season which made this survey less meaningful.

Growth of West Coast rock lobsters is monitored by tagging pre-moult male lobsters (>75 mm carapace length) along the West Coast from July to November. Growth increment and release-recapture times are incorporated into a “moult probability growth model” to estimate the growth per moult cycle.

Information on sex, reproductive state, size frequency and bycatch are also recorded during FIMS and ship-based observer monitoring surveys on board commercial vessels. These statistics are used to derive abundance indices of subadult and legal-sized male and female (>75 mm carapace length) lobsters which are used as inputs into the size-structured assessment model. This information, together with environmental data, is also used in providing ongoing scientific advice for management of the resource. Historical FIMS data and analysis methods have recently been re-checked, and changes in weather conditions, most notably wind, have been identified as a source of variation in CPUE. The associated effects of changes in bottom-oxygen levels, temperature and current speed on catch rates is also currently being investigated.

The OMP assessment model provides projections of future biomass under the assumption that future recruitment and growth will follow trends similar to those observed in the past. New research projects are being developed to provide improved indices of future recruitment, growth and catch to refine OMP projections of future biomass. Studies on the recruitment of post-larval and juvenile lobster have been initiated in the past to establish a long-term index of pre-recruit abundance that could potentially be used in predicting future recruitment and catch (6–7 years in advance). The function of internal energy sources in regulating growth and reproduc-

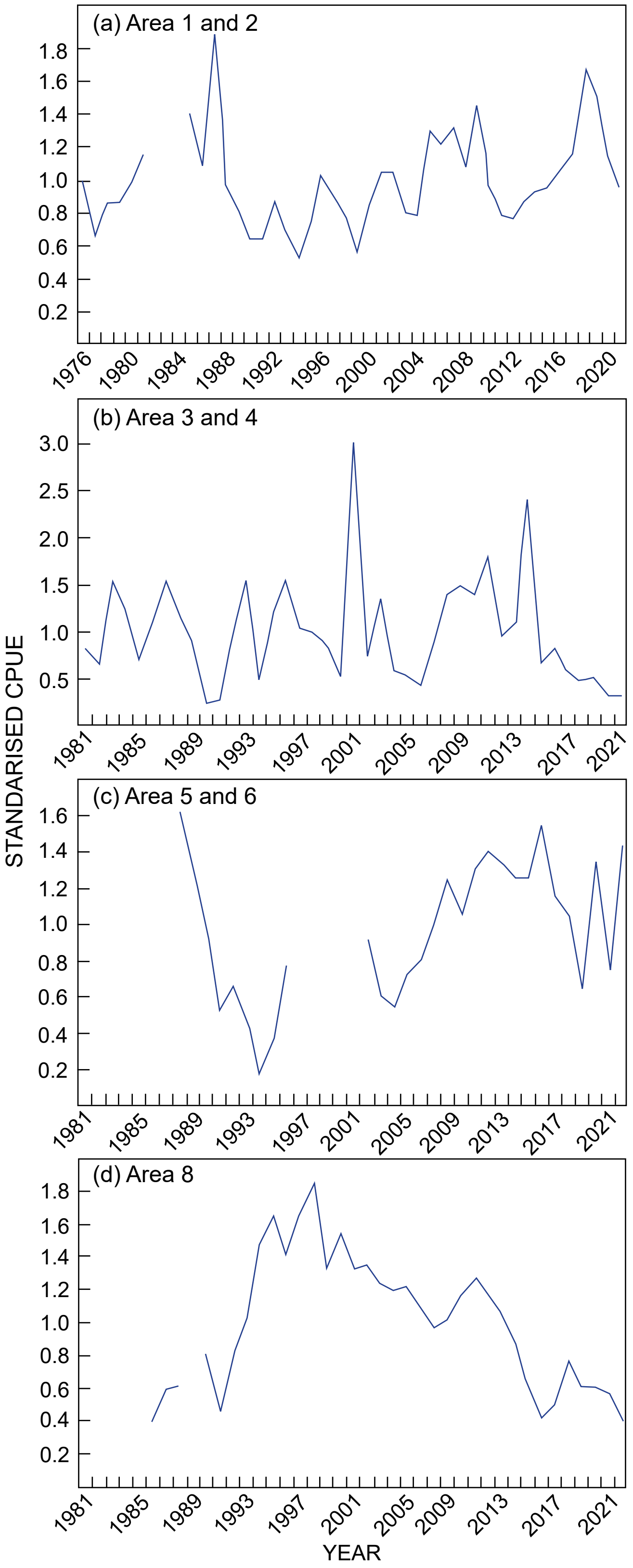

Figure 77: Standardised hoopnet CPUE indices per area (each index has been standardised to its mean)

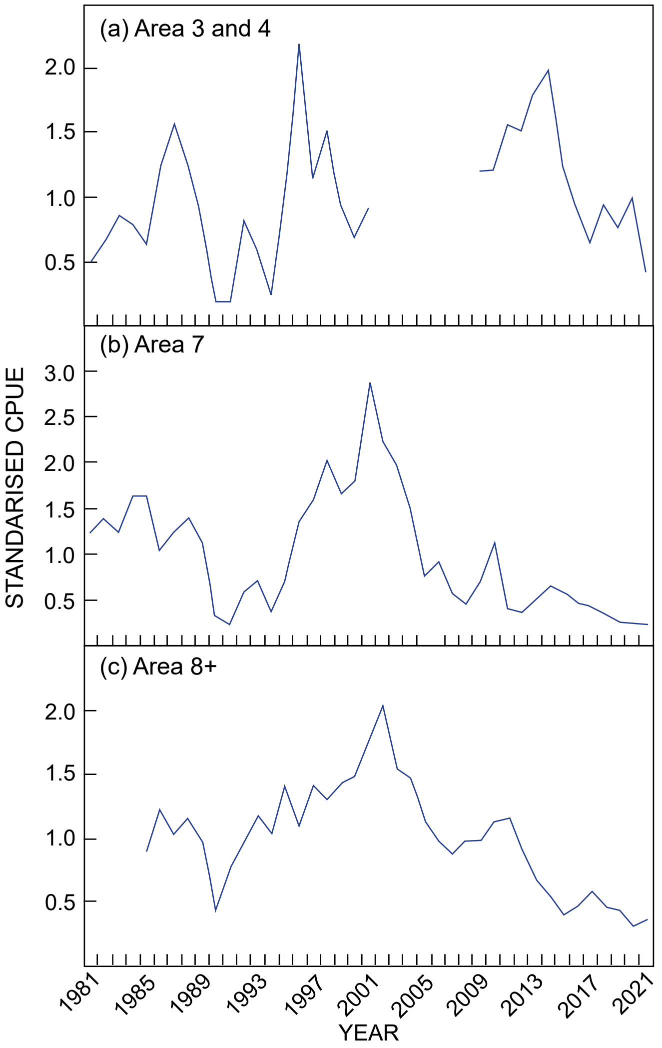

Figure 78: Standardised trap CPUE indices per area (each index has been normalised to its mean)

tion in females is also under investigation, to formulate energy-growth-reproduction conversion factors for predicting future trends in growth and reproductive potential.

Current status

The West Coast rock lobster resource is heavily depleted and legal and illegal fishing pressure remains high. The decline of the resource has continued since the turn of the century despite reductions in TAC and introduction of effort control. The most recent assessment in 2022 revealed that the resource is appreciably more depleted than estimated in the previous assessments for which the full input datasets were not available. The current male biomass above 75 mm carapace length is now estimated to be 13 350 t, or only some 1.4% of the corresponding pristine (1910) level. The spawner biomass is 24 020 t, 5.3% of pristine levels. It is noteworthy that, in the

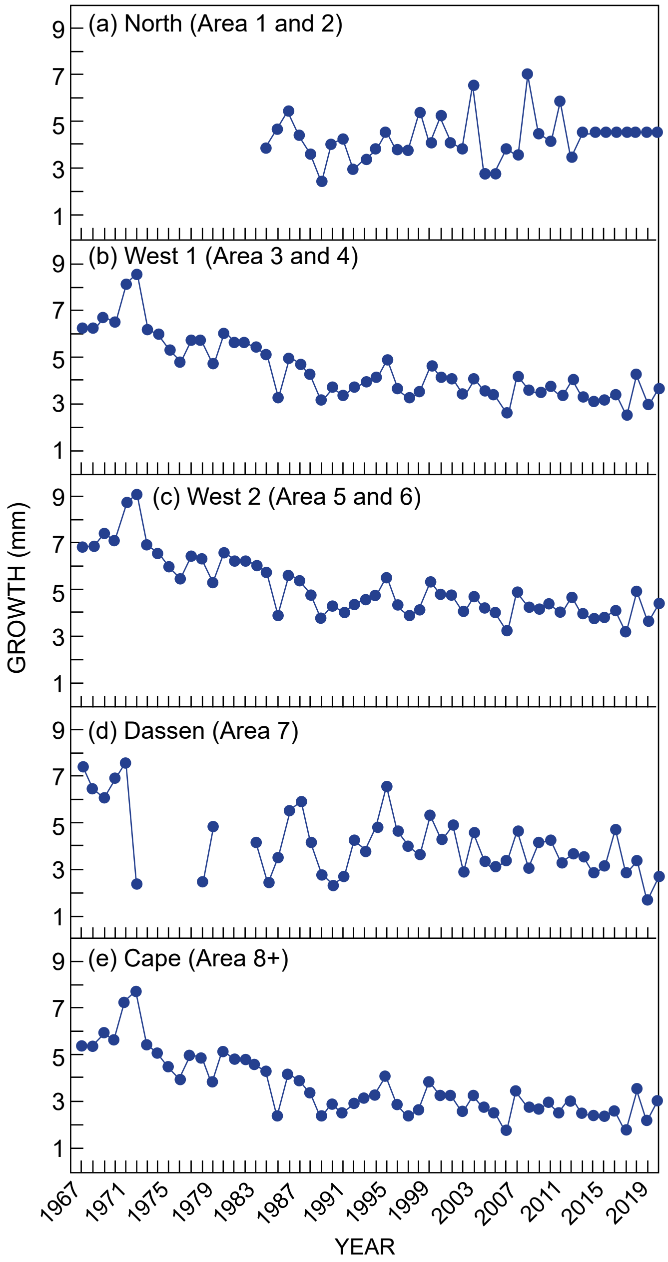

Figure 79: Annual somatic growth trends (estimated for a 70 mm lobster) per area

most recent years, the allocated TAC was higher than that recommended by the Scientific Working Group. However, in the last eight years, the allocated TAC was not caught (see 'Useful statistics').

Ecosystem interactions

Bycatch is not an issue of concern in this fishery. However, whale entanglements have become a challenge. Currently, the WCRL sector accounts for the highest number of entanglements of all fisheries (about 50%) in South Africa. Entanglements are seasonal and are more prevalent towards the end of the fishing season. This is somewhat mitigated by the current effort control that ends the fishing season by the latest at the end of July. Before effort control was implemented in 2017, the season only concluded at the end of September, with a concomitant higher risk of whale entanglements. In addition, an awareness programme has been implemented that is directed at encouraging lobster-trap fishers not to leave excess trap rope untied during fishing operations.

Three major events, which are possibly linked to climate change, have impacted the West Coast rock lobster fishery in recent decades: (i) a sharp decline in lobster somatic growth; (ii) a major increase in the number and severity of lobster "walkouts" in the Elands Bay region; and (iii) a large-scale change in the spatial distribution of lobsters. This includes an influx of lobsters into areas east of Cape Hangklip that were previously not associated with high lobster abundance. As a knock-on effect, the endangered bank cormorant *Phalacrocorax neglectus* population, which relies on lobsters as a major food source, has been negatively impacted. These events have also led to social and economic hardships. Fisheries management responded to these resource changes with changes in minimum size limits for the commercial fishery, reduced overall TACs, reduction in lobster landings in the northern fishing areas and the opening of new lobster fishing grounds in the area east of Cape Hangklip. The widespread nature of the growth reduction was indicative of a large-scale environmental perturbation (such as productivity changes). In future, further habitat areas suitable to West Coast rock lobster to the east could open up. This is currently under investigation.

Future climate-change scenarios anticipate increasing upwelling intensity and duration accompanied by an expected cooling and increased acidification of nearshore waters along the West Coast. Recent research by DFFE has revealed that juvenile and adult *J. lalandii* are physiologically well-adapted to the highly dynamic nature of the Benguela Current upwelling system and are therefore resilient to many aspects of predicted climate change scenarios. Adult lobsters can rapidly and fully compensate for the extracellular acidosis caused by sudden hypercapnia (high pCO_2, causing lowered pH) such as experienced during severe upwelling events. This adjustment, which is reversible, is achieved by a sharp increase in the bicarbonate levels in the haemolymph (the lobsters' blood). This protects the pH-sensitive oxygen carrying capacity of haemocyanin (the lobsters' respiratory pigment) under hypercapnic conditions that occur fairly frequently in its habitat. Juvenile *J. lalandii* can maintain this bicarbonate buffering of their haemolymph for several months of hypercapnia, which provides optimum pH conditions for respiratory gas exchange. In addition, the oxygen affinity of haemocyanin was improved by an intrinsic modification of its molecular structure. Another investigation has revealed that the immune system, too, is resilient to acidification and warming. Despite chronic exposure to combinations of reduced seawater pH and high temperature, captive juveniles still had normal haemocyte levels and were capable of rapid clearance of injected bacteria. Furthermore, acidification does not affect embryonic development in eggs attached to berried females, other than a slight delay. Moreover, electron-microscope observation showed that calcification of the exoskeleton of the females was not affected. Despite this general resilience of West Coast rock lobsters, some uncertainty exists regarding future growth rates. It is possible that expected cooling and/or possible metabolic costs associated with adaptations to lower pH could further reduce the growth rate of juveniles and adults. This would have serious resource- and socio-economic consequences.

The larval period of West Coast rock lobsters is assumed to be the part of the life cycle that is most vulnerable to climate change. Despite this, little is known regarding the potential impact of climate change on larvae. The long larval phase makes them particularly vulnerable to climate variability and hence climate-change impacts. Our limited understanding of *J. lalandii* larval biology, ecology and behaviour complicates speculation on the possible impacts on this phase of the life cycle.

Further reading

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Useful statistics

Total allowable catch, fishing sector landings and total landings for West Coast rock lobster.

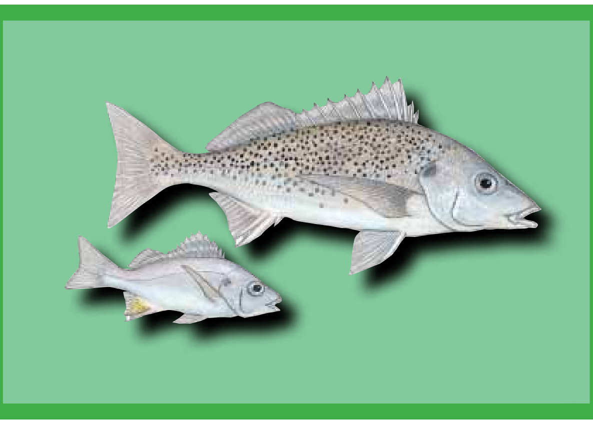
	TAC (t)						
Season	Global TAC	Commercial offshore allocation	Interim relief/ small-scale offshore	Commercial nearshore allocation	Interim relief/ small-scale nearshore	Recreational	Total catch[3]
1998/1999	2 300	1 780				258	2 051
1999/2000	2 156	1 720			145	291	2 152
2000/2001	2 018	1 614			230	174	2 154
2001/2002	2 353	2 151			[1]	202	2 410
2002/2003	2 957	2 713			[1]	244	2 706
2003/2004	3 336	2 422		594	[1]	320	3 258
2004/2005	3 527	2 614		593	[1]	320	3 222
2005/2006	3 174	2 294		560	[1]	320	2 291
2006/2007	2 857	1 997		560	[2]	300	3 366
2007/2008	2 571	1 754		560	[2]	257	2 298
2008/2009	2 340	1 632		451	[2]	257	2 483
2009/2010	2 393	1 632		451	180	129	2 519
2010/2011	2 286	1 528		451	200	107	2 208
2011/2012	2 426	1 541		451	251	183	2 275
2012/2013	2 276	1 391		451	251	183	2 308
2013/2014	2 167	1 356		451	276	83.5	1 891
2014/2015	1 800.85	1 120.25		376.1	235.3	69.2	1 688
2015/2016	1 924.08	1 243.48		376.1	235.3	69.2	1 524.4
2016/2017	1 924.08	1 204.48		376.1	274.3[4]	69.2	1 564.3
2017/2018	1 924.08	994.784	248.7	305.7	305.7[4]	69.2	1 355.7
2018/2019	1 084	563.91	140.83	170.25	170.25[4]	38.76	908
2019/2020	1 084	563.91	140.83	170.25	170.25[4]	38.76	898
2020/2021	837	435.9	108.97	131	131	30.1	719
2021/2022	700	351.6	87.9	119.5	119.5	21.6	532

[1] No Interim Relief allocated

[2] Interim Relief accommodated under Recreational allocation

[3] Total catch by all sectors

[4] Allocations to small-scale cooperatives in the Northern Cape only


RESEARCH HIGHLIGHTS



Grunting in murky waters: Investigating fish sounds to identify subpopulations of spotted grunter *Pomadasys commersonnii* from different estuaries

Background

The spotted grunter *Pomadasys commersonnii* ranges throughout the tropical and warm-temperate western Indian Ocean from India to False Bay (Heemstra and Heemstra 2004) and is one of the most important linefish species for estuarine and shore-based subsistence and recreational fishers on South Africa's South and East coasts (Kerwath et al. 2005). Concerns over commercial crustacean-trawl and beach-seine bycatch led to spotted grunter being "decommercialised" and listed as a no-sale species in 1992. Catching and keeping grunter is only permitted for own consumption by small-scale and recreational fishers. Despite this, heavy fishing pressure and targeting of spotted grunter by these fisheries have seen it become overexploited.

Spotted grunter spawn at sea in the nearshore and are estuarine-dependent for at least their first year of life. Both juveniles and adults display a high degree of residency in individual estuaries. Historically, their core South African distribution was the warm-temperate and subtropical East Coast. Over the last four decades, spotted grunter have gone from being a rare occurrence to a dominant component of estuarine fishers' catches on the Cape South Coast. Until the early 2000s, spotted grunter in South African waters were regarded as a single population due to little evidence of genetic differentiation or observations of reproductively active fish or spawning outside of KwaZulu-Natal waters (Klopper 2005). Over the last 20 years, the proportion of reproductively active adults has increased on the Cape South Coast (Næsje et al. 2007). These fish appear to be residential and spawning in this warm-temperate transition zone occurs during autumn as opposed to spring in the eastern subtropical and tropical bioregions. Consequently, it is hypothesised that we are witnessing a stock separation in progress and the genesis of discrete, non-migratory, regional estuarine subpopulations along the South Coast. In particular, the Breede Estuary subpopulation has become residential and derived from a recent migratory parent stock. Key to our understanding is to determine connectivity among estuaries and to identify subpopulations with significantly different traits. Because spotted grunter are sound-producing (soniferous) fish, one of the traits investigated was vocalisation and communication.

Acoustic communication

Acoustic communication is found in a range of habitats; however, sounds generated in water have a rapid distribution and a slow attenuation rate (Kasumyan 2008). Therefore, aquatic and marine environments are well-suited for acoustic communication as signals have a better chance of reaching the receiver. Spotted grunter belong to the best-known soniferous fish family, the Haemulidae. These fish produce sound through stridulation of their pharyngeal teeth (Ladich 2004). Members of the Haemulidae, commonly known as grunts, are well known among fishers for the loud sounds that they produce when captured and it is thought grunting occurs under distress, in competitive feeding and territorial behaviour, and during courtship and spawning (Bertucci et al. 2014; Millot et al. 2021). Spotted grunter have a wide distribution that spans over many different environmental conditions and different modalities of communication will have specific costs and benefits associated with differing environments. Over time, different environmental conditions may select for divergent dialects, increased isolation, and ultimately distinct subpopulations.

An important environmental factor which has been shown to affect communication modalities is turbidity (van der Sluijs et al. 2011). Turbidity not only affects visual signals (Utne-Palm 2002) but also affects the attenuation of sound as suspended particles reflect and diffract sound energy (Brown et al. 1998). In individuals living in environments with high turbidity and low visibility we would expect a higher degree of reliance on acoustic communication compared to individuals living in clearer environments which would rely more on visual signals. This leads us to one of the aims of this study, which was to investigate whether spotted grunter from two estuaries in different biogeographic regions, with contrasting turbidities, differ in their acoustic repertoires.

Study sites

The Breede River, situated on the Southwest Coast of South Africa, is 322 km long and enters the Indian Ocean in San Sebastian Bay. The estuary falls within the transition zone between the warm- and cool-temperate biogeographical regions and is one of the largest permanently open estuaries in South Africa (Emanuel et al. 1992). The catchment falls within both the winter rainfall and bimodal rainfall areas and the estuary experiences strong seasonal freshwater flows peaking in winter. There is high temporal variability in the physicochemical environment due to freshwater flow signals from the two rainfall areas and tidal exchange (Department of Water Affairs and Forestry 2003). Turbidity in the estuary is higher in winter with clearer conditions during the summer months. It experiences strong tidal currents and high flows which 'reset' the system within a tidal cycle (Lamberth et al. 2008). The estuary has a high biodiversity and is a popular spot for recreational fishing and boating activities.

The Kei Estuary, located in the Eastern Cape province of South Africa, is 8 km long and falls within the transition zone between the warm-temperate and subtropical biogeographical regions (Plumstead et al. 1985). The catchment area is approximately 20 673 km^2 over the geological Karoo Supergroup, which results in a high sediment load of silt and clays and high turbidity. The Kei Estuary experiences year-round rainfall and is permanently open but with highest flow occurring in the late summer months. Boat activity is dominated by the Kei Mouth ferry and recreational and commercial boats launching to go to sea. Recreational boating activities are relatively low compared to the Breede Estuary.

Do spotted grunter from the Kei and Breede estuaries speak with the same voice?

The analysis of vocalisations of spotted grunter (Figure 80) from both the Breede and Kei estuaries demonstrated that there are significant differences in the acoustic parameters of the sounds produced by these fish from two different estuaries and biogeographical regions. However, these results were contrary to the hypothesis that fish in the high turbidity and low visibility environment of the Kei Estuary would be more vocal, noisier, and louder compared to those individuals living in the clearer Breede Estuary which would rely more on visual stimuli. Specifically, the Breede Estuary spotted grunter seem to produce louder, lower-frequency sounds compared to those living in the Kei Estuary. There are two *a* priori hypotheses that could explain these results: the first hypothesis is related to anthropogenic noise conditions while the second is related to spotted grunter communication behaviour.

This study provided a successful first attempt at utilising fish vocalisation for studies of population structure. The results show, as hypothesised, that there are distinct differences in the acoustic parameters of sounds produced by spotted grunter from two estuaries with different environmental regimes. These results can be used as a stepping-stone in understanding

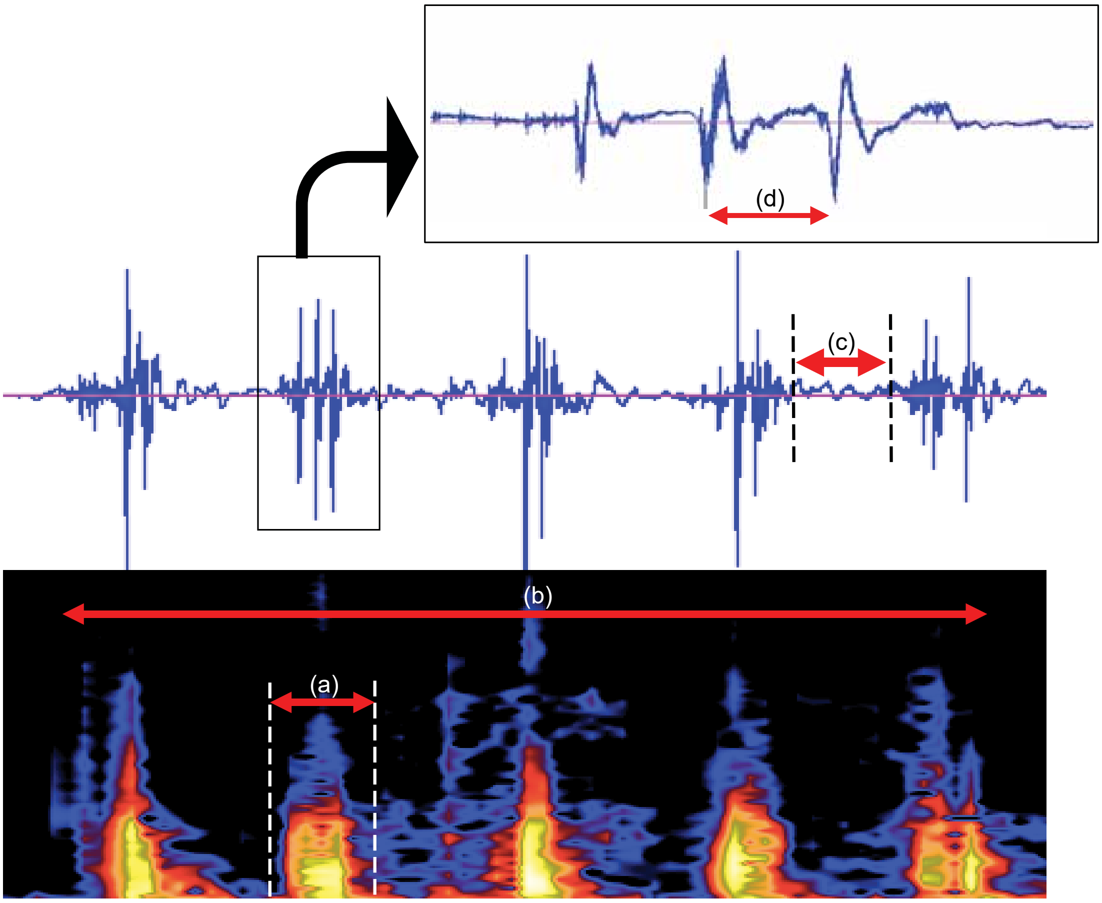


Figure 80: Oscillograms (top) and spectrograms (bottom; colours indicate the relative sound intensity with red = high and blue = low) showing the temporal features measured for sounds produced by spotted grunter *Pomadasys commersonnii*. Measured variables include: (a) grunt duration, (b) series duration, (c) inter-grunt interval and (d) inter-pulse interval

how spotted grunter adapt to environmental changes, including noise and other anthropogenic stress, which is important for successful management of this species. Future efforts can hopefully determine a greater understanding of the biological functioning of these sounds. Environmental conditions are known to influence fish communication modalities, and this has been clearly demonstrated in the above study. Whether this difference in communication is a function of phenotypic plasticity or has a genetic basis has yet to be determined. Regardless, this study provides the first research on the acoustic repertoire of spotted grunter in South Africa and successfully identified differences in the acoustic features of spotted grunter living in different environmental conditions.

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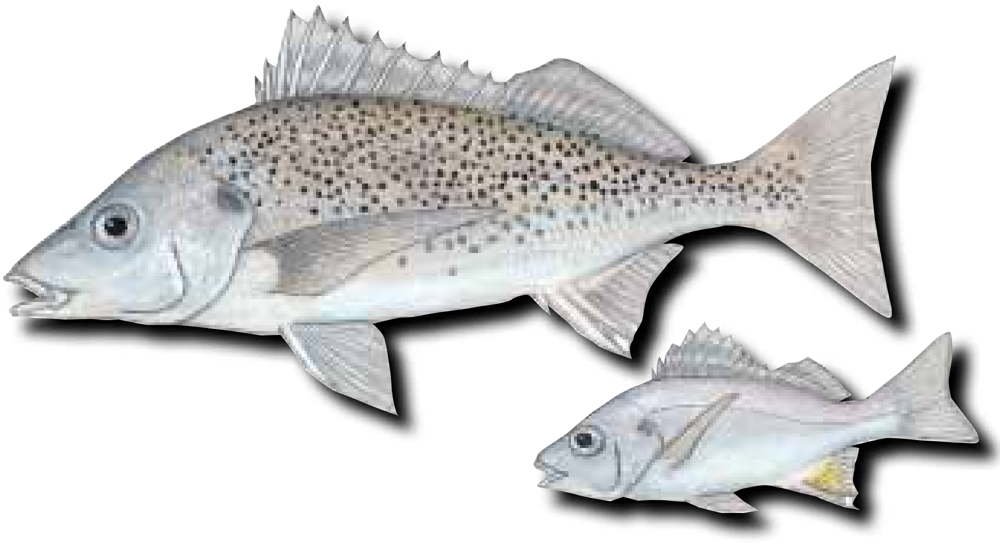

Unhappy Eddies? Potential impact of ocean acidification on endemic shark species

Global ocean acidification is expected to chronically lower the pH to 7.3 (>2 200 µatm seawater pCO_2) by the year 2300. Acute hypercapnia already occurs along the South African West and South coasts. Frequent upwelling events in austral summer cause periodic episodes of hypercapnia (pH levels 7.4–7.6) which can even reach pH 6.6 for several days during low oxygen events in autumn (Dziergwa et al. 2019). Upwelling takes place in 3–10-day cycles in spring and summer (Dziergwa et al. 2019), moving cold (~10 °C), hypercapnic water closer to the surface. As a result of climate change, upwelling events in eastern boundary current systems, and in turn hypercapnic episodes, are predicted to become longer, more frequent and more severe in the near future. The potential impacts of these changes on sharks are seldom studied, but a team of scientists from the Department, in collaboration with international partners, investigated potential impacts on an endemic shark species during a series of experiments within the Department's research aquarium (Dziergwa et al. 2019).

The team investigated the impact of hypercapnia on the puffadder shyshark *Haploblepharus edwardsii*, colloquially known as the "Happy Eddie", an endemic demersal shark species (Figure 81). Happy Eddies are already adapted to a highly variable environment and are restricted in their distribution to the southern tip of Africa without a possibility of a range shift to mitigate against negative effects of climate change. The species is well-suited for experimentation because it is relatively small, easy to rear and can easily be obtained in sufficient numbers for experimentation. At the time of the research, the species was not protected. In the present study, acid-base regulation during exposure of puffadder shysharks to (i) acute (32 h) and (ii) chronic (9 weeks) hypercapnia was specifically investigated in laboratory experiments. Furthermore, the effects of chronic hypercapnia on (iii) growth rates and (iv) denticle structure were examined, the latter by means of scanning electron microscope (SEM) and elemental composition analysis. It was hypothesised that Happy Eddies, due to their environmental adaptation, are able to acclimatise physiologically to acute and possibly chronic hypercapnia. It was further hypothesised that physiological compensation during chronic hypercapnia will come at an energetic cost that decreases somatic growth. Finally, it was investigated whether the lower pH would have a detrimental effect on the denticle structure of the shy shark, similar to human dental corrosion after exposure to carbonated drinks.

Figure 81: *Haploblepharus edwardsii*, colloquially known as "Happy Eddie", is a demersal shark species endemic to the southern tip of Africa. Although only occasionally caught in South African fisheries, the species has recently been identified as Endangered according to the IUCN Red List of Threatened Species. Climate change effects may play a role in the decline of this species

The main findings of the study were: (i) Happy Eddies adjust well physiologically (i.e. through regulation of the acid-base balance) to acute hypercapnia; (ii) this regulation can be maintained through during chronic hypercapnic exposure; (iii) the prolonged regulation is likely to be energetically costly but no depression of somatic growth was observed in the present study; and (iv) although the sharks can maintain their acid-base balance, prolonged exposure to hypercapnia has detrimental chemical effects that cannot be compensated, namely the dissolution of the surface of their denticles.As a result of upwelling, the habitat of Happy Eddies is characterised by short periods of strong hypercapnia. Acute environmental hypercapnia results in increased extracellular pCO_2 and a decline in pH and, if uncompensated, would most likely impact gas exchange of haemoglobin at the tissues. Here, it could be demonstrated that Happy Eddies possess the necessary compensation mechanisms to react to a sudden onset of hypercapnia. A rapid elevation of bicarbonate (+115%) after 24 h was observed, with a near-doubling after just 90 min of exposure (Figure 82), likely rapid enough to prevent a decline of arterial plasma pH. At the same time, the arterial plasma pCO_2 was elevated by a net 1.2 Torr (+50%). This increased the outward CO_2 gradient to 1.9 Torr, despite elevation of ambient pCO_2 by 1.4 Torr. The 1.7 Torr of the latter was well within the range of resting plasma pCO_2 and would have made gas exchange impossible. In the normocapnic sample, the gradient was 1.2 Torr after the same incubation period. Such a fast response is indicative of exposure and adaptation of the species to frequently elevated hypercapnia in its natural habitat (Heinrich at al. 2014). After the sharks were returned to normocapnic conditions after 24 h, alkalosis (high pH) persisted regardless of a substantial and rapid decline in bicarbonate concentration. Adjustment of pH to initial levels takes longer, probably to allow cellular processes to adjust. The rapid recovery indicates the reversibility of this mechanism. Esbaugh et al. (2012) have hypothesised that species that are adapted to low-level hypercapnia may no longer rely on traditional short-term acid-base regulation and use morphological changes (gill permeability, diffusion distances) instead or in addition.

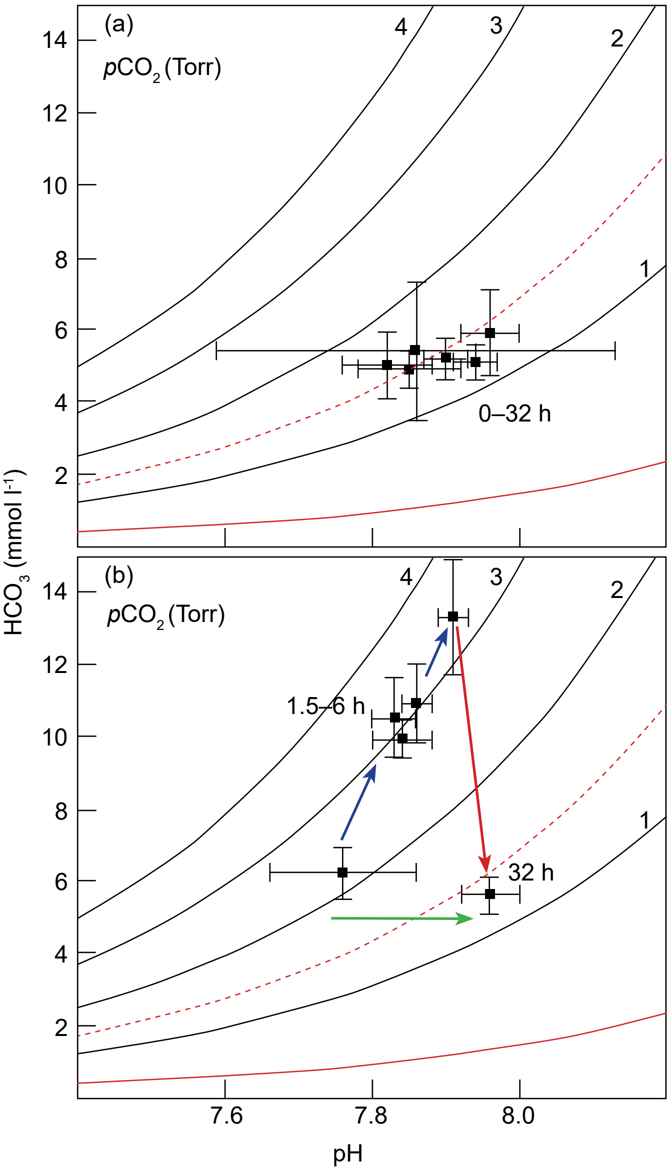

Figure 82: Henderson-Hasselbalch (pH-bicarbonate) diagrams for blood of *Haploblepharus edwardsii* during (a) 24 h normocapnia (normal pH) and subsequent 8 h recovery (n = 5); and (b) 24 h hypercapnia (low pH of 7.3) followed by 8 h of recovery (n = 7). Red solid line = normocapnic seawater isopleth, red dashed line = hypercapnic seawater isopleth. Values are means ± SD. Arrows indicate the course of bicarbonate buffering from start to 24 h hypercapnic incubation (blue) and recovery following 24 h of incubation (red). The green arrow indicates alkalosis. Compensation by an increase in bicarbonate started immediately, buffering the blood and leading to an alkalosis (shift to the right). In contrast, there is very little change in sharks exposed to normocapnic conditions

In *H. edwardsii*, the physiological response shown after acute exposure was maintained for a period of more than 60 days. In both treatments, plasma pH levels were very similar and there was no acidosis as would be expected if compensatory mechanisms could not be maintained for prolonged periods, thus ensuring that the outward pCO$_2$ gradient (0.6 Torr) is maintained at a level found in normocapnia (0.8 Torr). However, long-term compensation is likely to come at a cost: Lower metabolic rates, and dissolution of hard structures such as shells and carapaces, have been found (Pane and Barry 2007; Spicer et al. 2007; Fabry et al. 2008). Although metabolic depression (Hand 1991) is an adequate, reversible strategy to mitigate against short-term hypercapnic exposure, the concomitant reduction in somatic growth and reproductive output might have negative effects during chronic exposure.

Structural- and compositional changes of denticles under chronic hypercapnic conditions were evident from structural scans and elemental composition of samples. Weakening and deformation of CaCO$_3$ shell and skeleton elements have been observed in a host of different marine invertebrates (Orr et al. 2005) and fishes (Gagliano et al. 2008) and largely attributed to the negative effects of increased pCO$_2$ on calcification or on chemical dissolution. Shark denticles differ from invertebrate shells and skeletal structures as they are composed of calcium fluoro phosphate (fluorapatite) and calcium hydroxyl phosphate (hydroxyapatite) (Enax et al. 2014). Although both materials are only weakly soluble (Zhu et al. 2009), the H+ concentration of 50 nM in our experiment seems to have been sufficient to dissolve a measurable portion of the apatites. This is evident from the lower concentration of Ca, P, and F in denticles exposed to those conditions (Table 21). The observed changes here are not the result of a physiological process, as the time it takes to form new denticles is in the order of 4 months (Reif 1978) and therefore exceeds the duration of the experiment. The observed effects are thought to be the result of chemical dissolution, but there is no information on such an effect on shark denticles under chronic hypercapnia. Our results suggest that chronic exposure to severe hypercapnic (pH 7.3) conditions causes the dissolution of fluorapatite and in turn corrosion and weakening of the denticle surface (Figures 83, 84). However, further research is needed to examine this hypothesis.

Conclusions

H. edwardsii are already well adapted to hypercapnic conditions due to the frequent occurrence of these after coastal upwelling and subsequent low-oxygen events. Despite these adaptations, negative consequences during chronic hypercapnia were observed, i.e. denticle corrosion. Denticle corrosion and the resultant increase in denticle turnover can potentially compromise hydrodynamics and skin protection. As denticles and shark teeth are structurally and materially identical, chemical dissolution of teeth at a similar rate can be expected. It was speculated that a combination of these multiple effects might negatively affect the populations of this and other endemic, coastal elasmobranch species for which range shift is impossible as they reside at the southern tip of the African continent. This study suggests that these multiple stressors make chondrichthyans particularly susceptible to ocean acidification and additional studies are urgently needed to elucidate the extent of this effect on already vulnerable species.

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Table 21: Elemental composition (in wt %) of denticles from adult *Haploblepharus edwardsii* after chronic exposure to normocapnic and hypercapnic conditions for nine weeks. Values are means ± SD and significant differences between the two treatments are indicated

Element	**C**	N	O	F	Na	Mg	**P**	Au	Cl	Pd	**Ca**	Ca : P
Normocapnia ($n = 5$)	24.84 ± 4.40	3.34 ± 0.66	26.98 ± 4.48	0.59 ± 0.11	0.79 ± 0.10	0.23 ± 0.09	11.60 ± 2.08	5.57 ± 1.18	0.43 ± 0.15	1.62 ± 0.40	24.04 ± 6.15	2.05 ± 0.21
Hypercapnia ($n = 4$)	31.99 ± 2.66	4.05 ± 0.15	30.99 ± 3.87	0.52 ± 0.24	0.79 ± 0.03	0.32 ± 0.18	8.60 ± 0.83	5.26 ± 0.89	0.35 ± 0.35	1.59 ± 0.36	15.56 ± 1.95	1.80 ± 0.08
% difference to normocapnia	28.8*	21.3	14.9	–12.0	0.6	38.0	–26.2*	–5.6	–17.6	–1.4	–35.3*	

*Significantly different from normocapnia group (Student's *t*-test; $p < 0.05$).

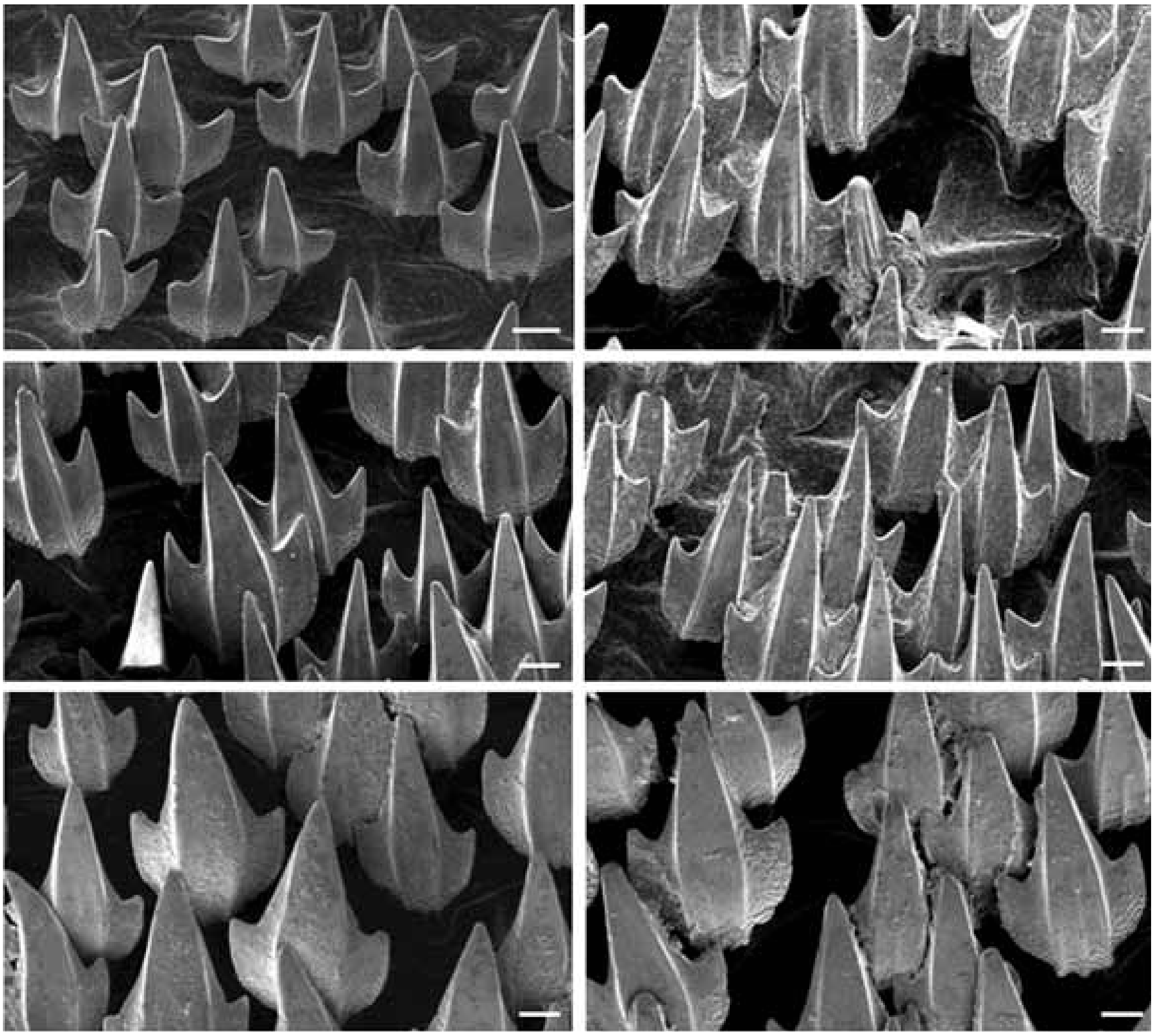

Figure 83: Scanning electron microscope (SEM) observations of a defined skin area, populated by denticles, from individual *Haploblepharus edwardsii* after experimental exposure of 9 weeks. Groups of denticles from three sharks that were kept in normocapnia are depicted in panels of the left column, those from hypercapnia in the right column. Size bars indicate 100 µm

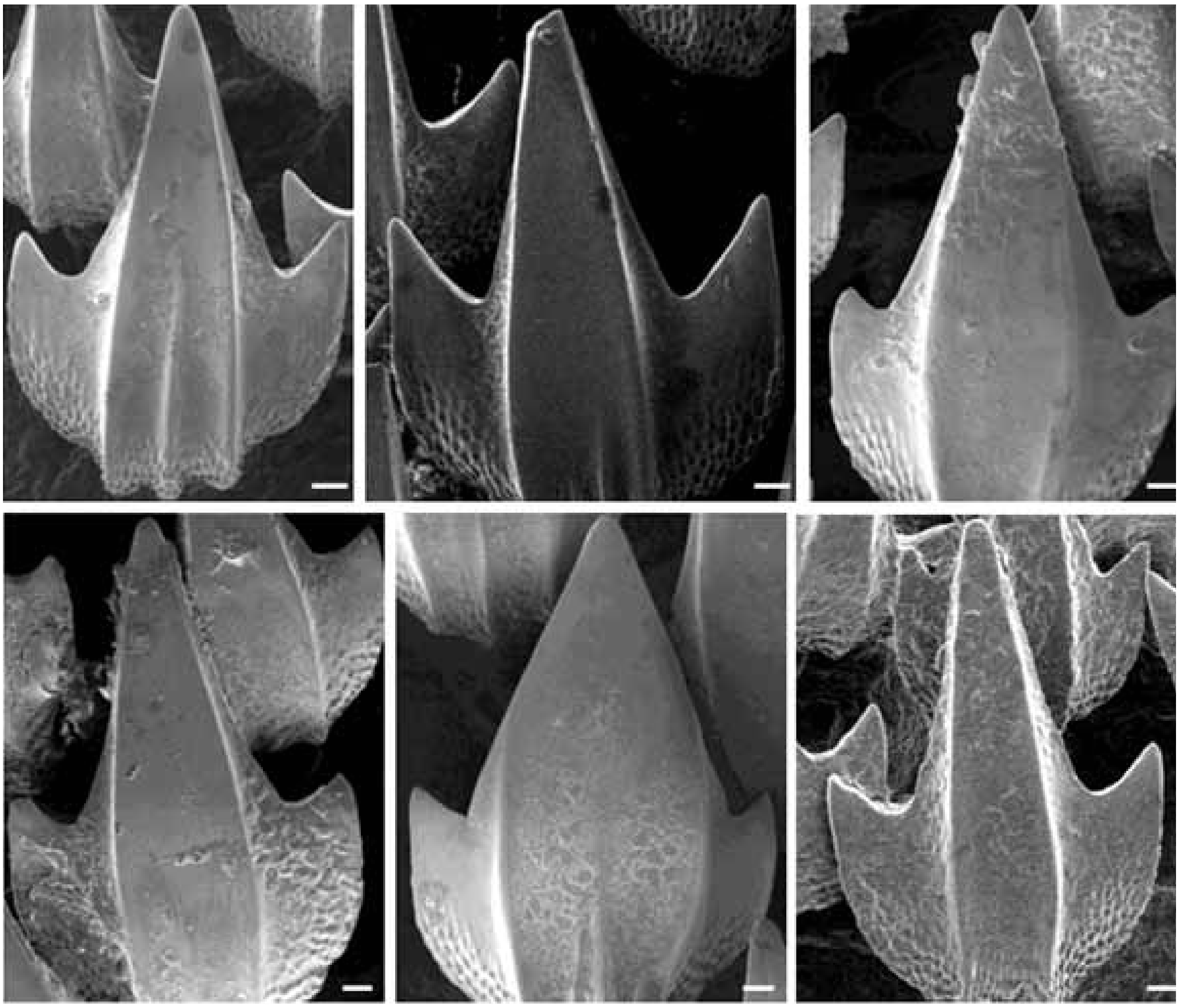

Figure 84: Close-up SEM view of select denticles from individual *Haploblepharus edwardsii* after experimental exposure of 9 weeks. Single denticles from three sharks (same as in Figure 83) that were kept in normocapnia are depicted in panels in the top row, those from hypercapnia in the bottom row. Size bars indicate 30 µm

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What's in the basket? An inventory of marine resources harvestable by small-scale fisheries in South Africa

Stock status*	**Unknown**	**Abundant** Bronze bream Stone bream *Ulva* spp.	**Optimal**	**Depleted** Zebra Blacktail	**Heavily depleted** Dusky kob Spotted grunter Elf
Fishing pressure*	**Unknown**	**Light** *Ulva* spp.	**Optimal**	**Heavy** Dusky kob Spotted grunter Elf Zebra Blacktail Bronze bream Stone bream	

*With the exception of dusky kob and elf, only a subset of species that do not overlap with any other commercial fisheries are shown here. Most high-value species as well as commercial species shared among several fisheries are already depleted and subjected to heavy fishing pressure, as shown in the respective sections of this report. However, opportunities exist for niche products and new species with potentially high commercial value

Introduction

In the South African context, the term "small-scale fishing" is used for a range of fishing activities which usually are low technology and labour intensive and employ manually set artisanal gear, characteristics which distinguish them from fully commercialised operations. Small-scale fishing encompasses an entire spectrum of activities, from subsistence harvesting of intertidal and estuarine invertebrates, fishes and seaweeds at one end, to small, boat-based operations at the other. There is considerable overlap with several other fishing sectors. Shore-based activities such as subsistence harvesting of invertebrates and angling, as well as subtidal collection of invertebrates, intersect with recreational fishing, whereas boat-based activities are similar to those of the smaller commercial fishing sectors such as line, beach-seine, gillnet and nearshore rock lobster. There are an estimated 25 000–30 000 small-scale fishers active along the South African coastline. At least two thirds of these reside in areas along the shores of the Eastern Cape and KwaZulu-Natal. There are differences between small-scale fishing operations along the coast. In general, true subsistence activities reliant on intertidal and subtidal resources increase towards the east, whereas motorised vessel-use and targeting of nearshore fish and crustacean species is far more common in the west. In the last two decades, starting with the promulgation of the Marine Living Resources Act (MLRA) in 1998, there have been multiple efforts to formally recognise this type of fishery, culminating in the development of the small-scale fishing policy in 2012 and the formal recognition of small-scale fishing cooperatives in 2021.

History and management

Subsistence harvesting of marine living resources has occurred around South Africa for at least 100 000 years, well into the last glacial period, although some of the archaeological evidence might be obscured by being submerged due to the rise in sea level after the last ice age. Still, available evidence, based on excavations and analyses of coastal middens, suggests that intertidal organisms such as shellfish were collected by hand or with simple tools. This type of harvesting is still most prevalent and has escalated along the Eastern Cape and KwaZulu-Natal coasts, although methods and gear have changed to incorporate more-modern techniques and materials, including diving equipment, spades, spears and crowbars. Most of these activities persist despite regulations that deem much to be illegal as they do not fit well into existing categories of commercial or recreational fishing. There is less such activity on the western part of the coast, which has been ascribed to lower population densities and the added impact of colonialism and its effect on the indigenous populations, who expanded their activities to include bartering and sale of marine living resources. On the other hand, the West Coast is the only area where line-fishing (hook gorges made of thorns or shell) preceded colonialism.

The early colonial era saw the introduction of beach-seine and line fishing to the Cape but it was limited under the strict control of the Governor. Gillnetting only started in the late 1800s. The abolition of slavery was accompanied by the lifting of restrictions on fishing activities, many fishing "rights" being formally ceded to former slaves and indentured labour on their emancipation. This also marks the time where fisheries started to develop in which finfish constituted the main target. Then, as now, fishers of either indigenous Khoisan or "Cape-Malay" and Filipino descent traditionally made up the largest group of fishers in the region. Despite the demise of slavery in the 1800s, almost the entire 1900s were characterised by increasingly restrictive discriminative policies that severely negatively affected the opportunities for business ownership and that restricted the mobility of non-white fishers, many of whom engaged in fishing part-time, seasonally or opportunistically. A small number became fully fledged commercial fishers with ownership of vessels and processing facilities, but the boundaries between the categories subsistence, recreational, small-scale, traditional and commercial fishing remained blurred.

Defining the different fishing categories proved to be among the most controversial issues during the development of small-scale fisheries management. Subsistence fishing had, for the first time, been recognised formally in the MLRA of 1998 and was distinguished from recreational and commercial fishing. A Subsistence Fisheries Task Group (SFTG) was established to collect information on the numbers, distribution, and socio-economic status of "subsistence fishers", as well as on which organisms were targeted and what gear was used. During the Long-term Rights Allocation Process of 2005–2006, individual fishing rights were allocated in 22 fisheries, including small-invertebrate-, line-, gillnet-, hake hand-line-, West Coast rock lobster- and squid fisheries, all of which have elements of subsistence and small-scale fishing. However, the process was deemed too complex and too competitive for some of the fishers in traditional fishing communities. Consequently, "interim-relief" permits were granted to fishers along the West and South coasts in 2007. After multiple rounds of stakeholder engagements, including a national summit on small-scale fisheries in 2007, small-scale fishers were formally recognised with the adoption of the Small-scale Fisheries Policy in 2012, followed by the small-scale regulations in 2016. The formal establishment and recognition of small-scale fishing co-operatives has not been completed for all provinces, but thus far there are 109 small-scale fishing co-operatives with about 7 200 small-scale fishers that have received 15-year fishing rights. Mussel, oyster and East Coast rock lobster, as well as parts of the line-, net-, squid-, West Coast rock lobster- and abalone fisheries, have been earmarked for allocation to the small-scale sector. In circumstances where co-ops are targeting commercial species, their fishing effort and catch are managed within the commercial TAEs and TACs of these species. For non-commercial species, and for estuarine fishing, small-scale fisheries regulations resemble those of the recreational fishery, with near-identical input and output controls. Input controls include gear restrictions (e.g. fishing method, number of hooks), closed seasons and protected areas, whereas output controls comprise mostly bag and size limits, but management regulations are not monitored and are seldom adhered to.

Several important species are already under considerable exploitation pressure from recreational and commercial fisheries, while others are already locally depleted by unregulated small-scale effort. An overarching, workable management plan needs to be developed urgently once the remaining small-scale cooperatives have been allocated. A wide range of new and innovative opportunities in product beneficiation and development of new product from under-utilised species exists to aid the small-scale fishers to become sustainable and economically viable.

Research and monitoring

The small-scale fishery operates countrywide and includes a range of shore- and boat-based activities and target species, many of which overlap with commercial and recreational fishing sectors. The "basket" of resources harvested by small-scale fishers depends on the biogeographical distribution of target organisms, their availability, the fishing method, and the individual customs of the respective fishing communities. The National Linefish Survey (1995–1996) indicated that, excluding the former Transkei region, >20 000 households depended on shore-angling to contribute to their subsistence (McGrath et al. 1997). The first comprehensive account of subsistence fisher distribution and targeted resources was the result of surveys conducted by the SFTG and published in 2002. Just under 30 000 people were identified as potential subsistence fishers, distributed around the entire coast, with 75% residing in KwaZulu-Natal and the former Transkei. This concurs with the previous estimate, if the assumption is made that these fishers represented an equivalent number of households.

Marine organisms are harvested for food, bait, and sales. A comprehensive list of harvested species can be found in Clark et al. (2002) and Cockcroft et al. (2002). This list, however, predates the development of the small-scale policy, which widened the definition of this category of resource users from subsistence to include small commercial operations, which overlap and are *de facto* identical to existing commercial fisheries. Since the initial research efforts in around 2000, culminating in a suite of papers in the *African Journal of Marine Science*, research around small-scale fisheries, unlike with most other South African fisheries, has moved away from natural sciences towards social and socio-political research and nationwide efforts with regard to resources research have become less comprehensive and quantitative than the national surveys that were carried out around the turn of the millennium.

With the increased focus on formalising the small-scale fishery around the country, a national, shore-based monitoring programme was implemented from June 2012 to May 2013; however, analyses of the data gathered by this programme have been limited. The resources that overlap with commercial fisheries, such as linefish, netfish, small invertebrates, squid and West Coast rock lobster, are routinely monitored, as detailed in other sections of this report, but for most of the organisms that are only taken under true subsistence or under recreational permits, no long-term, routine monitoring programme is in place. However, numerous local monitoring programmes aimed at marine living resources and fishers exist or have existed around the coast. Comparison between these is useful but difficult as none have followed a standardised approach; the latter now needs to be a priority (Sink et al. 2019).

Assessment

Assessments exist for most species with overlap with commercial fisheries. These are presented in the respective sections in this report. In general, data collection and the complexity and frequency of assessments are a function of the catch volumes and the value of the resource. Species that are rare, low value, or localised typically do not have focussed monitoring programmes and the assessments of their status, where they exist, rely on simple indicators based on life-history information, indices or on 'data-poor' models that require only size or age frequencies and often assume a population in an equilibrium state. Despite these limitations, very good life-history information is available for many South African coastal species and, together with existing surveys, these have been used in assessments.

The data from the shore-based monitoring programme in 2013 were used to assess stocks of seven of the most important fish species targeted along the Eastern Cape coast, one of the areas with the highest levels of subsistence effort. Spawner biomass-per-recruit analyses revealed that two of these species, bronze bream *Pachymetopon grande* and stone bream *Neoscorpis lithophilus*, are sustainably fished, but that the population status of dusky kob *Argyrosomus japonicus* is estimated to be critical at only 1.3% of pristine spawner biomass or breeding potential.

These assessments need to be considered during the implementation of the small-scale fishery and in the selection of the species baskets for co-operatives, as recovery of these stocks is essential for growing the potential revenue of fishers in this important sector. These data are also proving useful in understanding the dynamics of the fishery. For example, the two sustainably fished species in the analysis are almost exclusively kept for own consumption whereas most, if not all, of the fish from overexploited species, such as spotted grunter, shad/elf and dusky kob, are of high-value and sold, irrespective of being designated "no-sale" or not. The available baseline assessments (Figure 85) can represent the first step in the sustainable management of small-scale fishing and the selection of appropriate organisms and quantities for the basket of species.

In reality, small-scale fishing communities exist from Alexander Bay to Kosi Bay, yet marine resources in harvestable quantities are unequally distributed around the South African

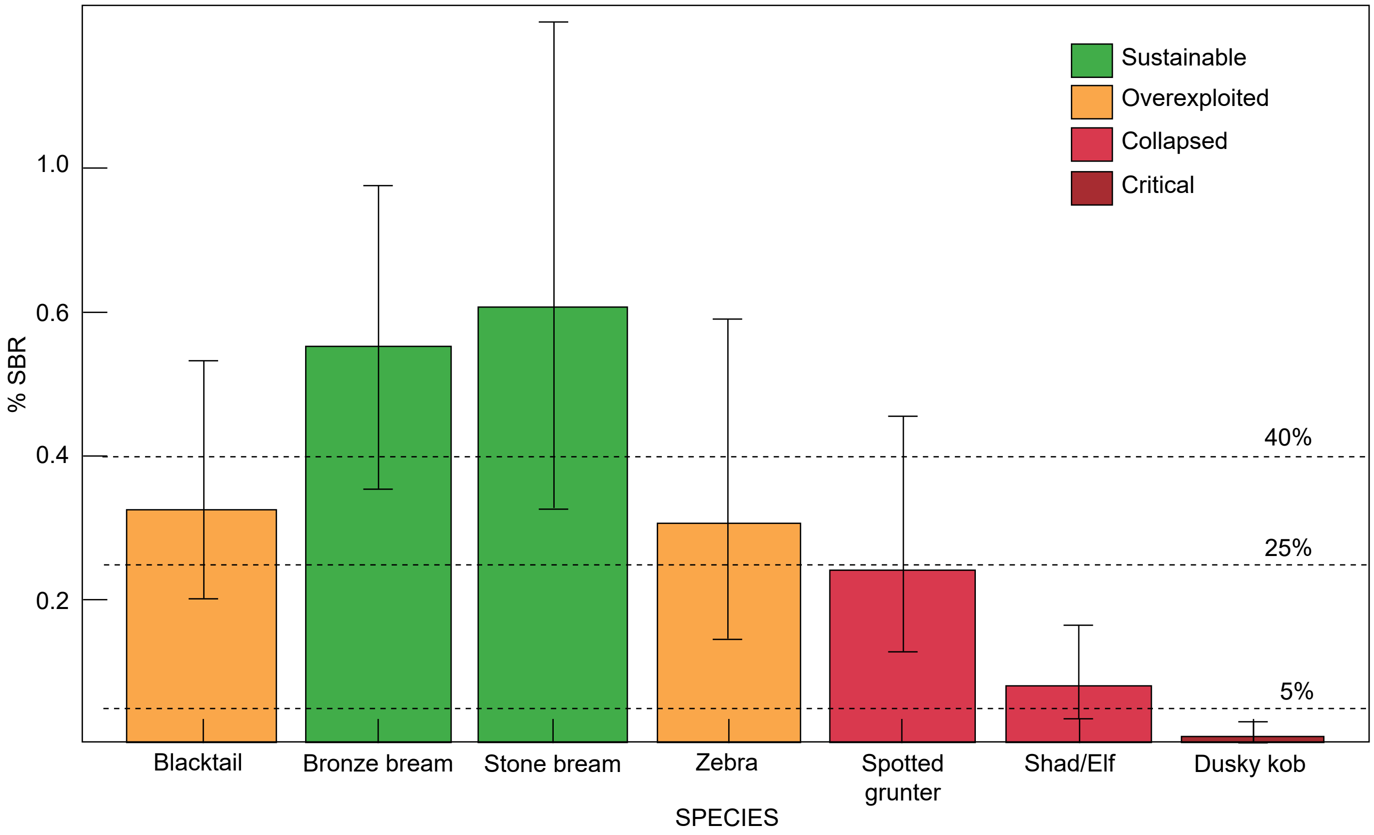

Figure 85: Representation of the stock status for seven important fish species targeted on the Eastern Cape coast, based on percentage spawner biomass (%SBR) of unfished levels. The error bars denote 95% confidence intervals derived from Monte-Carlo simulations

coastline. This highlighted the need for a comprehensive account of the "basket" of marine species accessible to small-scale fishers. To achieve this, available data and literature on past, national and local-level shore-based monitoring were reviewed. Based on a multivariate regression tree analysis of the most mobile species, the coastline was divided into five different zones, according to natural species breaks. For each of these zones, we accounted for fish, invertebrate and seaweed species that might form part of the "basket of harvestable species". Where available, we present basic information on population status and trajectory and indicate which species are exploited by existing fisheries.

Overall, we identified 188 species; 138 fish, 41 invertebrates, and 9 seaweeds and marine plants that could possibly be caught or collected in sufficient quantities by small-scale fishers in one or more of five "bio-basket" geographical regions. Available resources ranged from 61 species in Basket Area A on the West Coast to 150 species in Basket Area D on the Southeast Coast (Figure 86). Current designations of these 188 species are that 106 may be sold, 67 may be harvested for food security or own use, 4 are already harvested by experimental fisheries and 11 are prohibited across all fisheries. In turn, 94% of these species are harvested by commercial fisheries, 92% are harvested by recreational fisheries and more than 60% are already overexploited or in decline.

Formal stock assessments of fish species in the small-scale basket revealed 39% to be optimally exploited, 33% overexploited and 28% collapsed (Figure 87). Trends in CPUE showed 56% to be in decline, 26% stable, only 1% unexploited, whilst the trends for the remaining 17% were unknown. Both stock status and CPUE trend were largely a function of vulnerability, range extent and relative exploitation throughout that range (1–5 basket areas). Vulnerability was a measure of eight vulnerable life-history characteristics (Lamberth and Joubert 2014). These were estuarine dependence, sex changes, spawning migrations, predictable aggregations, high age at maturity, longevity, residency, and high catchability. Other life-history characteristics such as fecundity were also considered, but not included due to lack of data. General trends were that collapsed stocks shared 5–8 vulnerable life-history characteristics, overexploited 3–4 and optimally and underexploited ones, two or less. Details regarding the distributions, stock status, catch trends, and vulnerability scores; the input and output controls and use limitations; and relative catches across all fishery sectors of each of the 188 species are given in Tables 22, 23 and 24, respectively

Ecosystem interactions

As the small-scale fishery targets a wide range of species in varying intensities, ecosystem interactions are dependent on the individual fishing profile of small-scale fishing communities

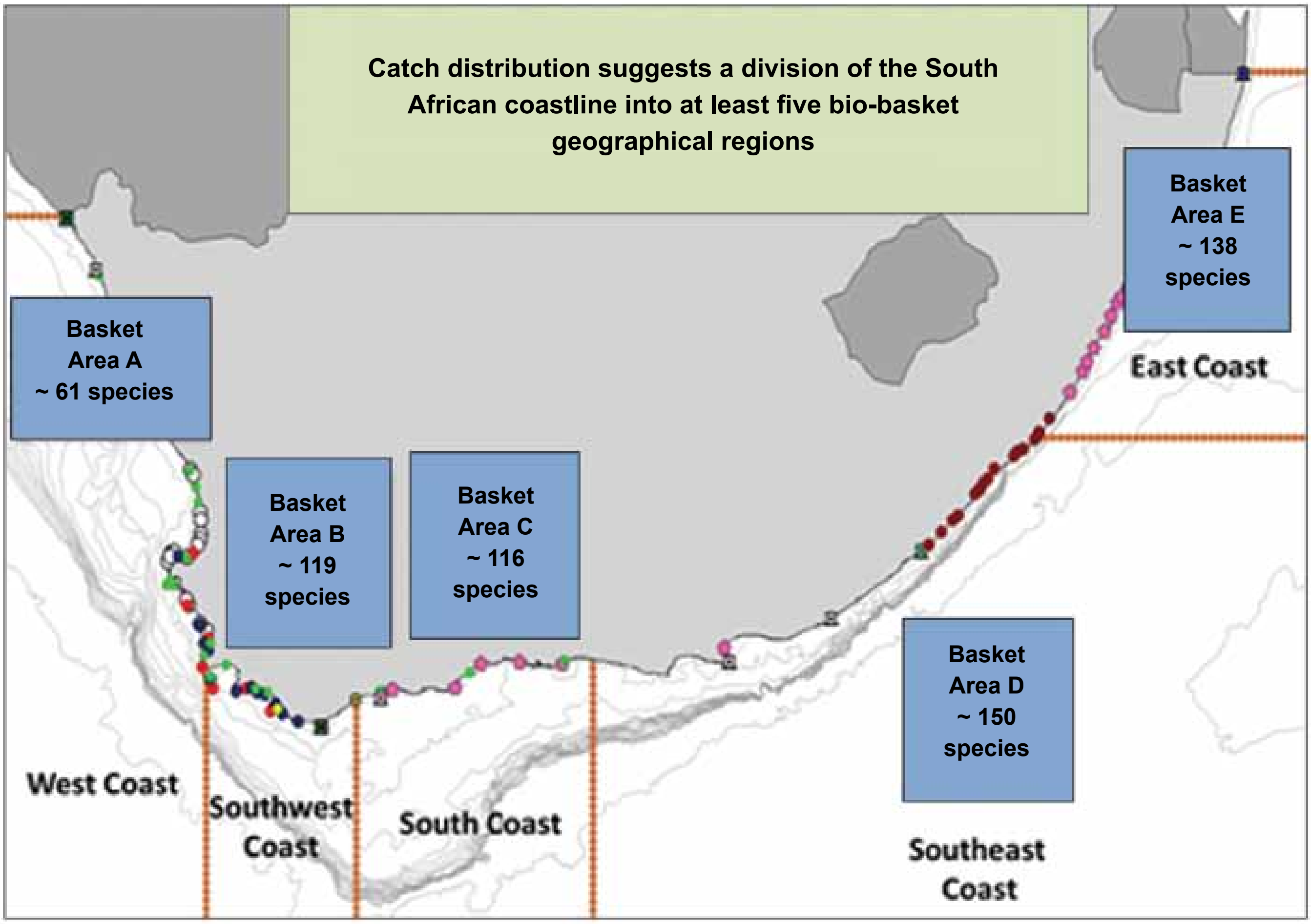

Figure 86: The number of species available to small-scale fishers in each of five Basket Areas on the South African coast. The coloured dots show the locations of identified small-scale fishing communities

Current designation (# of species)

Food security, not for sale	67
Can be sold	106
Exploratory fishery	4
Prohibited	11

Formal stock assessments (% of species)

Optimal	39
Overexploited	33
Collapsed	28

CPUE trend (% of species)

Decline	56
Stable	26
Unexploited	1
Unknown	17

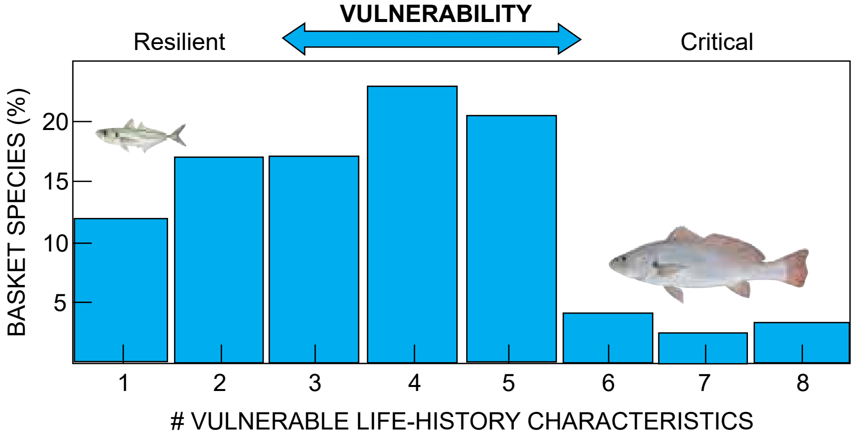

Figure 87: Current-use designation, stock status and CPUE trend of 188 species (138 fish, 41 invertebrates and 9 seaweeds and marine plants) potentially harvestable by small-scale fisheries; and a histogram showing the frequency distribution (%) of the number of vulnerable history characteristics of the of 188 potential basket species. Those species showing a decline in CPUE (56% of the total) had four or more vulnerable life-history characteristics whereas a stable CPUE was confined to those with two or less

and the habitat characteristics of the harvested area. Intensive subsistence mussel harvesting at rocky sites along the KZN and former Transkei coasts has been well studied and is known to locally deplete mussel populations and permanently change habitat and species composition towards a more algae-dominant community with cascading effects for the entire ecosystem. These altered systems do not change back to mussel-dominated communities, to the detriment of local harvesters. Coastal marine protected areas (MPAs) have been shown to enhance mussel recruitment within several kilometres of their boundaries. In general, small-scale fishing, when practiced in a traditional manner with artisanal methods, has less impact on the ecosystem than its commercial counterpart. Whereas true traditional methods such as the fish traps in Kosi Bay have been practiced for generations and found to have minimal ecosystem effects and negligible bycatch, more-recent introductions of modern gear have been shown to have a detrimental effect on target species and ecosystems alike. Gillnets are known to have significant negative effects such as removing fast-growing fecund fish from the population and having high rates of unwanted bycatch with high bycatch mortality, including birds, marine mammals and even crocodiles. Abandoned or lost gillnet gear increases coastal plastic pollution and constitutes a risk of ghost-fishing and entanglement. Traditional stonewall fish-traps or *visvywers* constitute permanent or semi-permanent structures, yet, if harvested without the use of gillnets, there is little in the way of effects on the ecosystem in the form of unwanted bycatch or mortalities.

Climate change

Fishery, fisher, and fleet responses

Small-scale fishing operations are typically restricted to small areas along the South African coast, the sizes of which range from a few hundred metres for invertebrate collection, seine-net operations or estuarine subsistence angling, to approximately 40 nautical miles in the case of the boat-based line-, lobster- or squid fisheries. Their small fishing "grounds" make these sectors particularly vulnerable to climate change. The main direct physical impacts include changes in wind strength and direction, combined with changes in storm surges, flooding and erosion patterns. Unfavourable wind and tides prevent setting of beach-seines and gillnets; strong surges and currents can restrict angling from the shore and along estuaries; coastal erosion can alter habitat and sever access to harvest areas, or destroy them; and open boats can only operate up to a certain wind speed, and launching and recovery are restricted by weather and tides. Many of these impacts have already been felt and have been documented and analysed. An analysis of linefish boat launches in the Arniston area from 1985 to 2012, for example, revealed that wind strength is a significant predictor for the proportion of boats that attempt to launch to fish (Figure 88). A rapid decline in fishing outings occurs at wind speeds of 5–9 m s^{-1} or mean daily wind speeds above 6.6 m s^{-1}. The proportion of days that exceed this value varies substantially between years but has seemingly increased over the last two decades. These results corroborate the local fishers' perceptions that the number of suitable sea days is decreasing due to an increase in unsuitable weather conditions. The Fisheries Climate Change Task Team has identified the small-scale fishery as being one of the most vulnerable and least resilient to climate change effects, which are already felt by some of the small-scale fishing communities along the coast.

Biological and behavioural responses

As with the physical impacts on fleet and fisher behaviour, biotic responses to climate change vary in nature and magnitude. Distributional changes – southwards for tropical, subtropical and warm temperate species and northwards for cool temperate species on both the East and West coasts – are evident in more than 50 species (fish, invertebrates and seaweeds) in the small-scale basket. Opportunities include the development of new fisheries and/or the targeting of new resources in zones where historically they did not occur. Negative outcomes include the resource moving away from

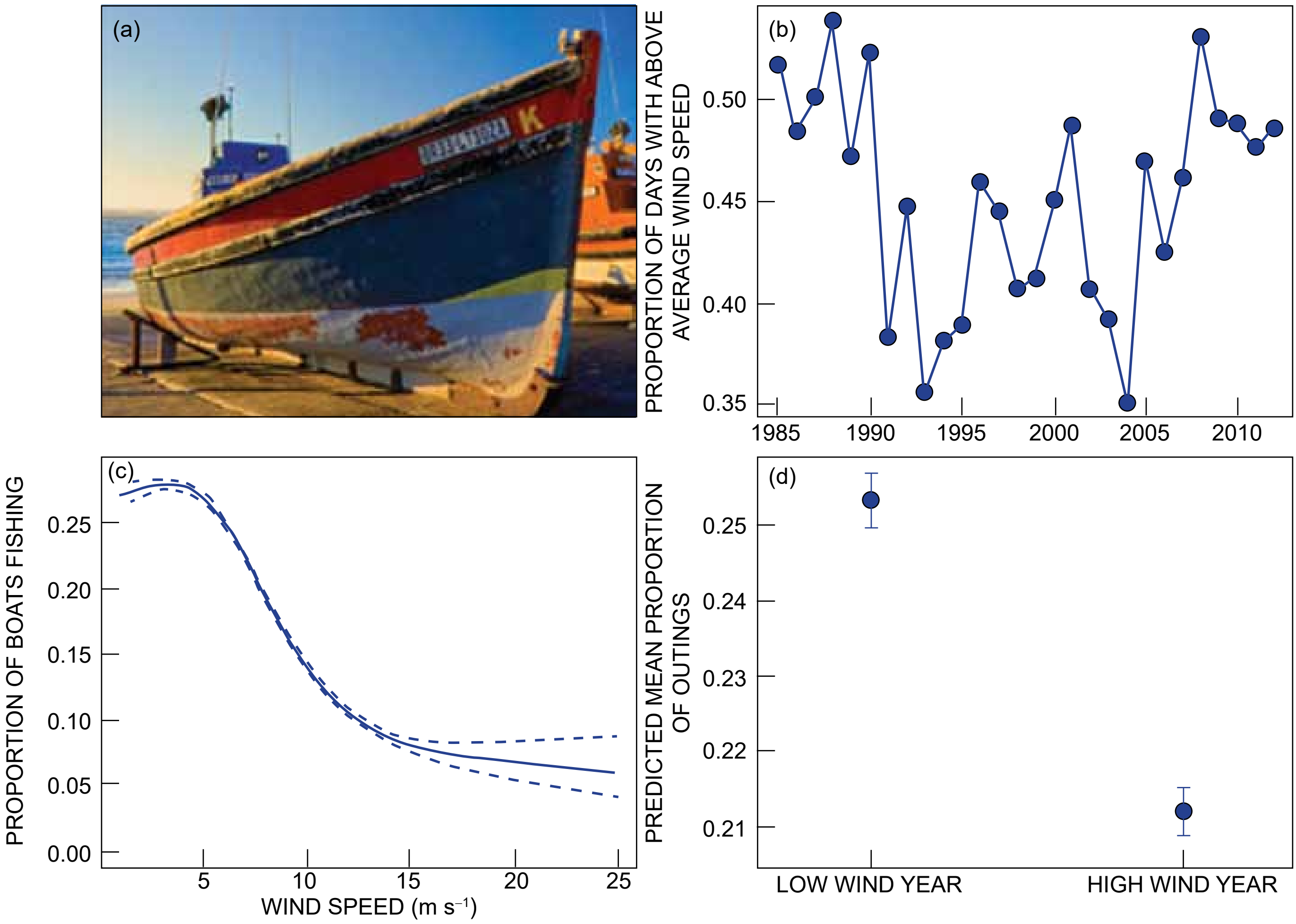

Figure 88: (a) Traditional linefish boats on the slipway in Arniston, a small fishing village 20 km east of Cape Agulhas. (b) Change in proportion of days with wind speeds above the climatological average (6.68 m s^{-1}) over the time-series 1985 to 2012. (c) The average daily wind speed is a significant predictor of the mean daily proportion of outings at Arniston. (d) Difference in mean proportion of outings of Arniston fisher boats predicted by wind strength for low wind years (1994, average daily wind speed 5.94 m s^{-1}) and high wind years (2008, average daily wind speed 7.48 m s^{-1}). After Augustyn et al. (2017)

those dependent upon it. Consequently, there is a need for a shift away from proposed “turf systems” and the local-level fisheries management paradigm and the realisation that spatial planning in small-scale and other fisheries is crucial for their future.

Changing meteorological and oceanographic conditions drive behavioural and physiological responses in the biota. Fresh water flowing from land influences marine and estuarine fish, invertebrates, seaweeds and fisheries both directly and indirectly through the export of nutrients, sediment and detritus. Shifting rainfall patterns and altered freshwater inputs (river and groundwater flows) will lead to changes in the magnitude and spatiotemporal distribution of these exports. Amongst other responses in the biota, both extended droughts and changes in the frequency or return-time of flood events have led to recruitment failure and a decline in species abundance and richness, especially of estuary-associated fish and invertebrate species. These species contribute more than 80% of the catch mass of nearshore, shore-based and estuarine small-scale fisheries.

Increased occurrences of major ocean weather anomalies are having direct and indirect impacts on marine life. The Agulhas Current is becoming more turbulent which may be associated with an increase in the occurrence of offshore cyclonic meanders (referred to as “Natal Pulses”) and the formation of Agulhas Rings, mechanisms driving heat exchange and dispersal of marine organisms along the coast. In early 2021, large fish- and invertebrate mortalities and washouts as well as “bleaching” of seaweeds were observed along South Africa’s East and South coasts. The mortalities on the East Coast coincided with a very large (>125 km) meander of the Agulhas Current and sequential marine heatwave, cold upwelling and cyclonic eddies propagating down the coast. Biological responses included seaweed bleaching and die-off on the Wild Coast, a higher incidence of tropical species off the South Coast, fish aggregating in the nearshore and estuaries from False Bay to Algoa Bay, and mass strandings and mortalities of >80 species on the East, South and West coasts. Fifty percent of these were in the small-scale basket of species.

Harmful Algal Blooms (HABs) are increasing in occurrence in estuaries and the sea on the South and East coasts. South and East Coast fishers and coastal communities are relatively naïve to HABs and HAB effects (e.g. shellfish poisoning), compared to those on the West Coast where these phenomena frequently occur. The immediate fisheries management response and mitigation needs to be the development of early warning systems and the raising of awareness in communities naïve to HABs.

Challenges & opportunities

Development of the small-scale fishery can be guided by analysis of existing markets. Of 458 fish species or products traded within South Africa, 75% are locally caught, but less than half of these in economically significant numbers. About 85 traded fish species are from aquaculture, of which 29 are from the local industry, but most of these are freshwater species. Of more than 300 invertebrates, seaweeds and marine plants traded in South Africa, only 20% are locally harvested, even though many occur here. Several, such as samphire, seaweeds, whelks and winkles, are also easily accessible from the shore so require less capital outlay and have great potential as cottage / boutique industries and niche markets.

In summary, the main challenges facing the implementation of the Small-scale Fisheries Policy are overlap with existing fisheries, stock assessment, monitoring and control of catch, and compliance with regulations. Priorities and opportunities include the identification and beneficiation of new products and a move towards high-value, sustainable resources and niche markets. Shore-based observer programmes need to be implemented and small-scale catch reporting integrated into existing catch-return systems. Stock status monitoring needs to be extended to non-commercial, own-use species as with priority commercial species that undergo regular assessments.

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Table 22a: Distribution, harvestable distribution (i.e. present in that Basket Area), stock status, assessment method (for species that were assessed), CPUE trend (for species where data were available), and vulnerability score of 138 fish species potentially available to the small-scale / subsistence sector

Species name	Common name	Distribution: Region (NAM = Namibia, NC = Northern Cape WC = Western Cape, EC = Eastern Cape, KZN = KwaZulu-Natal, MOZ = Mozambique)	Harvestable distribution (Yes = Y, No = N)					Assessment status (red = collapsed, orange = overexploited, green = ok) and method. Catch-per-unit-effort (CPUE), Vulnerability score (0 = least vulnerable; 7 = most vulnerable), trend (CU = currently underexploited, D = decline, S = stable, SD = stable decline, U = unknown, X = unexploited).			
		Region	Basket area A	Basket area B	Basket area C	Basket area D	Basket area E	Stock status	Assessment method	CPUE trend	Vulnerability score
FISH, SHARKS & RAYS											
Acanthocybium solandri	Wahoo	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	2
Acanthopagrus vagus	River bream	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Red	Per-recruit analyses	D	
Albula oligolepis	Bonefish	EC, KZN, MOZ	N	N	N	Y	Y			U	
Aprion virescens	Green jobfish	EC, KZN, MOZ	N	N	N	Y	Y			D	2
Argyrops spinifer	King soldierbream	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	4
Argyrosomus inodorus	Silver kob	NAM, NC, WC, EC	Y	Y	Y	Y	N	Red	Other	D	4
Argyrosomus japonicus	Dusky kob	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Red	Per-recruit analyses	D	7
Argyrosomus thorpei	Squaretail kob	EC, KZN, MOZ	N	N	N	Y	Y	Red	Per-recruit analyses	D	4
Argyrozona argyrozona	Carpenter/silverfish	WC, EC	N	Y	Y	Y	N	Orange	Other	D	4
Atractoscion aequidens	Geelbek	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Red	Other	D	4
Boopsoidea inornata	Fransmadam/karel grootoog	WC, EC, KZN	N	Y	Y	Y	Y			U	2
Callorhinchus capensis	St Joseph	NAM, NC, WC, EC, KZN	Y	Y	Y	Y	Y	Red	Per-recruit analyses	D	
Caranx ignobilis	Giant kingfish	EC, KZN, MOZ	N	N	N	Y	Y			D	2
Caranx papuensis	Brassy kingfish	EC, KZN, MOZ	N	N	N	Y	Y			U	
Caranx sexfasciatus	Bigeye kingfish	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	1
Carcharhinus brachyurus	Bronze whaler/copper shark	NAM, NC, WC, EC, KZN	Y	Y	Y	Y	Y			D	5
Carcharhinus leucas	Zambezi shark	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			D	5
Carcharhinus limbatus	Blacktip shark	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			D	4
Carcharhinus obscurus	Dusky shark	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			D	5
Carcharius taurus	Spotted ragged-tooth shark	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y			D	5
Carcharodon carcharias	White shark	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y				
Cheimerius nufar	Soldier/santer	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			S	5
Chelidonichthys capensis	Gurnard	WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Green	Demersal surveys	S	2
Chelon richardsonii	Harder	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	R ed	Other	D	3
Chelon tricuspidens	Striped mullet	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y			U	2

Species name	Common name	Distribution: Region (NAM = Namibia, NC = Northern Cape WC = Western Cape, EC = Eastern Cape, KZN = KwaZulu-Natal, MOZ = Mozambique)	Harvestable distribution (Yes = Y, No = N)					Assessment status (red = collapsed, orange = overexploited, green = ok) and method. Catch-per-unit-effort (CPUE), Vulnerability score (0 = least vulnerable; 7 = most vulnerable), trend (CU = currently underexploited, D = decline, S = stable, SD = stable decline, U = unknown, X = unexploited).			
		Region	Basket area A	Basket area B	Basket area C	Basket area D	Basket area E	Stock status	Assessment method	CPUE trend	Vulnerability score
Chirodactylus jessicalenorum	Natal fingerfin	EC, KZN	N	N	N	Y	Y			D	1
Chrysoblephus anglicus	Englishman	EC, KZN, MOZ	N	N	N	Y	Y	Red	Per-recruit analyses	D	5
Chrysoblephus gibbiceps	Red stumpnose	WC, EC	N	Y	Y	Y	N			D	5
Chrysoblephus laticeps	Red Roman	WC, EC	N	Y	Y	Y	N	Green	Per-recruit analyses	D	4
Chrysoblephus lophus	False Englishman	EC, KZN, MOZ	N	N	N	Y	Y			D	4
Chrysoblephus puniceus	Slinger	EC, KZN, MOZ	N	N	N	Y	Y	Red	Per-recruit analyses	S	5
Coryphaena hippurus	Dolphinfish/dorado	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y			D	1
Cymatoceps nasutus	Poenskop	WC, EC, KZN	N	Y	Y	Y	Y	Red	Other	D	5
Dasyatis chrysonota	Blue stingray	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y			D	0
Dichistius capensis	Galjoen	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Red	Per-recruit analyses	D	5
Dichistius multifasciatus	Banded galjoen	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			D	
Dinoperca petersi	Cave bass	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			S	
Diplodus capensis	Blacktail	NAM, WC, EC, KZN, MOZ	N	Y	Y	Y	Y			S	
Diplodus hottentotus	Zebra	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			D	
Elops machnata	Ladyfish/kingspringer/tenpounder	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	4
Epinephelus albomarginatus	White-edged rockcod	EC, KZN, MOZ	N	N	N	Y	Y	Red	Per-recruit analyses	D	5
Epinephelus andersoni	Catface rockcod	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Green	Per-recruit analyses	D	6
Epinephelus lanceolatus	Brindlebass	EC, KZN, MOZ	N	N	N	Y	Y			D	
Epinephelus malabaricus	Malabar rockcod	EC, KZN, MOZ	N	N	N	Y	Y			D	4
Epinephelus marginatus	Yellowbelly rockcod	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Orange	Per-recruit analyses	D	5
Epinephelus rivulatus	Halfmoon rockcod	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Green	Per-recruit analyses	S	3
Epinephelus tukula	Potato bass	KZN, MOZ	N	N	N	N	Y			D	4
Euthynnus affinis	Eastern little tuna	EC, KZN, MOZ	N	N	N	Y	Y			D	2
Galeichthys ater	Black seacatfish/barbel	WC, EC, KZN	N	Y	Y	Y	Y	Green	Per-recruit analyses	S	3
Galeicthys feliceps	White seacatfish	NAM, NC, WC, EC	Y	Y	Y	Y	N	Orange	Per-recruit analyses	S	
Galeocerdo cuvier	Tiger shark	EC, KZN, MOZ	N	N	N	Y	Y				4
Galeorhinus galeus	Soupfin shark	NAM, NC, WC, EC	Y	Y	Y	Y	N	Green	Per-recruit analyses	D	3

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		Region	Basket area A	Basket area B	Basket area C	Basket area D	Basket area E	Stock status	Assessment method	CPUE trend	Vulnerability score
Gymnocrotaphus curvidens	John Brown	WC, EC	N	Y	Y	Y	N			S	2
Gymnura natalensis	Butterfly/diamond ray	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y			S	3
Himantura gerrardi	Sharpnose stingray	EC, KZN, MOZ	N	N	N	Y	Y				2
Himantura uarnak	Honeycomb stringray	EC, KZN, MOZ	N	N	N	Y	Y				
Istiophorus platypterus	Sailfish	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			S	2
Isurus oxyrinchus	Mako shark	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Orange	Other	D	4
Johnius dorsalis	Small kob	EC, KZN, MOZ	N	N	N	Y	Y			S	
Kajikia audax	Striped marlin	WC, EC, KZN, MOZ	N	Y	Y	Y	Y				
Katsuwonus pelamis	Skipjack tuna	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Green	Other	D	
Lethrinus nebulosus	Blue emperor	KZN, MOZ	N	N	N	N	Y			U	5
Lichia amia	Leervis/garrick	NAM, WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Red	Per-recruit analyses	D	3
Lithognathus aureti	Westcoast steenbras	NAM, NC	Y	Y	Y	N	N	Green	Per-recruit analyses	D	4
Lithognathus lithognathus	White steenbras	NAM, NC, WC, EC, KZN	Y	Y	Y	Y	Y	Red	Per-recruit analyses	D	7
Lithognathus mormyrus	Sand steenbras	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y			D	0
Lutjanus argentimaculatus	Mangrove snapper	EC, KZN, MOZ	N	N	N	Y	Y			D	
Lutjanus rivulatus	Speckled snapper	EC, KZN, MOZ	N	N	N	Y	Y			S	3
Lutjanus sanguineus	Blood snapper	EC, KZN, MOZ	N	N	N	Y	Y			D	4
Lutjanus sebae	Emperor red snapper	KZN, MOZ	N	N	N	N	Y	Orange	Per-recruit analyses	S	
Makaira nigricans	Blue marlin	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			D	2
Megalops cyprinoides	Oxeye tarpon	EC, KZN, MOZ	N	N	N	Y	Y			U	3
Merluccius capensis	Shallow water Hake	NAM, NC, WC, EC, KZN	Y	Y	Y	Y	Y	Green	Dynamic, age-structured production modell	S	1
Mugil cephalus	Flathead/springer mullet	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y			D	3
Mustelus mustelus	Smooth houndshark	NAM, NC, WC, EC, KZN	Y	Y	Y	Y	Y	Green	Per-recruit analyses	D	3
Myliobatis aquila	Eagelray	NAM, NC, WC, EC, KZN	Y	Y	Y	Y	Y			D	
Neoscorpis lithophilus	Stonebream	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Green	Per-recruit analyses	D	3
Notorynchus cepedianus	Cow shark	NAM, NC, WC, EC	Y	Y	Y	Y	N			D	5

Species name	Common name	Distribution: Region (NAM = Namibia, NC = Northern Cape WC = Western Cape, EC = Eastern Cape, KZN = KwaZulu-Natal, MOZ = Mozambique)	Harvestable distribution (Yes = Y, No = N)					Assessment status (red = collapsed, orange = overexploited, green = ok) and method. Catch-per-unit-effort (CPUE), Vulnerability score (0 = least vulnerable; 7 = most vulnerable), trend (CU = currently underexploited, D = decline, S = stable, SD = stable decline, U = unknown, X = unexploited).			
		Region	Basket area A	Basket area B	Basket area C	Basket area D	Basket area E	Stock status	Assessment method	CPUE trend	Vulnerability score
Oplegnathus conwayi	Cape knifejaw	WC, EC, KZN	N	Y	Y	Y	Y			D	4
Oplegnathus robinsoni	Natal knifejaw	EC, KZN, MOZ	N	N	N	Y	Y			D	1
Otolithes ruber	Snapper kob	EC, KZN, MOZ	N	N	N	Y	Y	Orange	Per-recruit analyses	S	2
Pachymetopon aeneum	Blue Hottentot	WC, EC, KZN	N	Y	Y	Y	Y			S	6
Pachymetopon blochii	Hottentot	NAM, NC, WC, EC	Y	Y	Y	Y	N	Orange	Other	S	4
Pagellus natalensis	Red tjor-tjor	WC, EC, KZN	N	Y	Y	Y	Y			S	
Paracaesio xanthura	Yellowtail fusilier/protea bream	KZN, MOZ	N	N	N	N	Y			D	3
Petrus rupestris	Red steenbras	WC, EC, KZN	N	Y	Y	Y	Y	Red	Per-recruit analyses	D	6
Platycephalus indicus	Bartailed flathead	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	1
Plectorhinchus chubbi	Dusky rubberlip	EC, KZN, MOZ	N	N	N	Y	Y			U	
Plectorhinchus flavomaculatus	Lemon fish	EC, KZN, MOZ	N	N	N	Y	Y			U	2
Plectorhinchus playfairi	Whitebarred rubberlip	EC, KZN, MOZ	N	N	N	Y	Y			U	
Polysteganus coeruleopunctatus	Blueskin/trawl soldier	EC, KZN, MOZ	N	N	N	Y	Y			D	6
Polysteganus undulosus	Seventy-four	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Red	Per-recruit analyses	D	6
Pomadasys commersonnii	Spotted grunter	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Orange	Per-recruit analyses	D	
Pomadasys furcatus	Banded grunter	KZN, MOZ	N	N	N	N	Y			U	
Pomadasys kaakan	Javelin grunter	EC, KZN, MOZ	N	N	N	Y	Y			U	
Pomadasys olivaceus	Piggy	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Green	Per-recruit analyses	D	
Pomatomus saltatrix	Elf	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Orange	Per-recruit analyses	D	4
Porcostoma dentata	Dane	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			S	2
Poroderma africanum	Pyjama shark/striped catshark	WC, EC	N	Y	Y	Y	N			D	2
Poroderma pantherinum	Leopard catshark	WC, EC, KZN	N	Y	Y	Y	Y			D	
Prionace glauca	Blue shark	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Green	Other	S	4
Pristipomoides filamentosus	Rosy jobfish	EC, KZN, MOZ	N	N	N	Y	Y			U	2
Pterogymnus laniarius	Panga	WC, EC	N	Y	Y	Y	N	Green	Dynamic, age-structured production model	S	4
Rachycentron canadum	Prodigal son/cobia	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	1

Species name	Common name	Distribution: Region (NAM = Namibia, NC = Northern Cape WC = Western Cape, EC = Eastern Cape, KZN = KwaZulu-Natal, MOZ = Mozambique)	Harvestable distribution (Yes = Y, No = N)					Assessment status (red = collapsed, orange = overexploited, green = ok) and method. Catch-per-unit-effort (CPUE), Vulnerability score (0 = least vulnerable; 7 = most vulnerable), trend (CU = currently underexploited, D = decline, S = stable, SD = stable decline, U = unknown, X = unexploited).			
		Region	Basket area A	Basket area B	Basket area C	Basket area D	Basket area E	Stock status	Assessment method	CPUE trend	Vulnerability score
Rhabdosargus globiceps	White stumpnose	NAM, NC, WC, EC	Y	Y	Y	Y	N	Red	Per-recruit analyses	D	5
Rhabdosargus holubi	Cape stumpnose	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	4
Rhabdosargus sarba	Natal stumpnose	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Orange	Per-recruit analyses	D	4
Rhinobatos annulatus	Lesser guitarfish/sandshark	NAM, WC, EC, KZN	N	Y	Y	Y	Y			D	1
Rhizoprionodon acutus	Milkshark	EC, KZN, MOZ	N	N	N	Y	Y			U	1
Rhynchobatus djiddensis	Giant sandshark/guitarfish	EC, KZN, MOZ	N	N	N	Y	Y			D	4
Sarda orientalis	Striped bonito / katonkel	EC, KZN, MOZ	N	Y	Y	Y	Y	Orange	CPUE	S	0
Sarda sarda	Atlantic bonito / katonkel	WC	Y	N	N	N	N	Orange	CPUE	S	0
Sardinops sagax	Sardine/pilchard	WC,EC,KZN	N	N	N	N	Y			D	
Sarpa salpa	Strepie	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Green	Per-recruit analyses	D	3
Scomber japonicus	Mackerel	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Orange	Other	S	2
Scomberoides commersonnianus	Queenfish	EC, KZN, MOZ	N	N	N	Y	Y			U	
Scomberomorus commerson	King mackerel	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Orange	Per-recruit analyses	S	3
Scomberomorus plurilineatus	Queen mackerel	EC, KZN, MOZ	N	N	N	Y	Y	Green	Per-recruit analyses	S	1
Sebastes capensis	Jacopever	WC, EC, KZN	Y	Y	Y	N	N	Green	Demersal surveys	S	0
Seriola dumerili	Tropical yellowtail	EC, KZN, MOZ	N	N	N	Y	Y			U	
Seriola lalandi	Yellowtail	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Green	Other	S	
Seriola rivoliana	Longfin yellowtail	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	0
Sparodon durbanensis	White musselcracker	WC, EC, KZN	N	Y	Y	Y	Y			D	5
Sphyraena barracuda	Barracuda	EC, KZN, MOZ	N	N	N	Y	Y			U	2
Sphyraena jello	Pickhandle barracuda	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			U	1
Sphyrna lewini	Scalloped hammerhead	EC, KZN, MOZ	N	N	N	Y	Y			D	
Sphyrna zygaena	Smooth hammerhead shark	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			D	4

Species name	Common name	Distribution: Region (NAM = Namibia, NC = Northern Cape WC = Western Cape, EC = Eastern Cape, KZN = KwaZulu-Natal, MOZ = Mozambique)	Harvestable distribution (Yes = Y, No = N)					Assessment status (red = collapsed, orange = overexploited, green = ok) and method. Catch-per-unit-effort (CPUE), Vulnerability score (0 = least vulnerable; 7 = most vulnerable), trend (CU = currently underexploited, D = decline, S = stable, SD = stable decline, U = unknown, X = unexploited).			
		Region	Basket area A	Basket area B	Basket area C	Basket area D	Basket area E	Stock status	Assessment method	CPUE trend	Vulnerability score
Spondyliosoma emarginatum	Steentjie	WC, EC, KZN	N	Y	Y	Y	Y			S	2
Thunnus alalunga	Albacore	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Orange	Dynamic, age-structured production model	S	3
Thunnus albacares	Yellowfin tuna	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Green	Dynamic, age-structured production model	S	5
Thunnus obesus	Bigeye tuna	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Green	Dynamic, age-structured production model	S	1
Thyrsites atun	Snoek	NAM, NC, WC, EC	Y	Y	Y	Y	N	Green	Other	S	3
Trachinotus africanus	Southern pompano	WC, EC, KZN, MOZ	N	Y	Y	Y	Y			S	1
Trachinotus botla	Largespot pompano	EC, KZN, MOZ	N	N	N	Y	Y	Green	Per-recruit analyses	S	2
Trachurus capensis	Maasbanker/horse mackerel	WC, EC, KZN, MOZ	Y	Y	Y	Y	N	Green	Pelagic surveys	S	1
Triakis megalopterus	Spotted gullyshark	NAM, NC, WC, EC	Y	Y	Y	Y	N			D	4
Umbrina robinsoni	Baardman	WC, EC, KZN, MOZ	N	Y	Y	Y	Y	Red	Per-recruit analyses	D	
Xiphias gladius	Swordfish	NAM, NC, WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Green	Dynamic, age-structured production model	S	

Table 22b: Distribution, harvestable distribution (i.e. present in that Basket Area), stock status, assessment method (for species that were assessed), CPUE trend (for species where data were available), and vulnerability score of 41 invertebrate and 9 seaweed and marine plant species potentially available to the small-scale / subsistence sector

Species name	Common name	Distribution: Region (NAM = Namibia, NC = Northern Cape WC = Western Cape, EC = Eastern Cape, KZN = KwaZulu-Natal, MOZ = Mozambique)	Harvestable distribution (Yes = Y, No = N)						Assessment status (red = collapsed, orange = overexploited, green = ok) and method. Catch-per-unit-effort (CPUE), Vulnerability score (0 = least vulnerable; 7 = most vulnerable), trend (CU = currently underexploited, D = decline, S = stable, SD = stable decline, U = unknown, X = unexploited).		
		Region	Basket area A	Basket area B	Basket area C	Basket area D	Basket area E	Stock status	Assessment method	CPUE trend	Vulnerability score
INVERTEBRATES, SEAWEEDS, AQUATIC PLANTS											
Arabella iricolor	Moonshine worm	WC, EC	N	Y	N	N	N	Red	National linefish survey CPUE	D	5
Arenicola loveni	Blood worm	WC, EC, KZN	Y	Y	Y	N	N	Green	National linefish survey CPUE	D	6
Bullia laevissima	Whelk/plough shell	NAM, NC, WC, EC	Future	Future	N	N	N	Green	Exploratory fishery	U	5
Callianassa kraussi,	Sand/pink prawn	WC, EC, KZN	Y	Y	Y	Y	Y	Orange	National linefish survey CPUE	D	6
Cymbula spp.	Limpets / perdevoet	WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Orange	Intertidal surveys (localised)	D	5
Dinoplax gigas	Giant chiton	WC, EC	N	Y	Y	Y	N	Orange	National linefish survey CPUE	D	5
Donax serra	White mussel	WC, EC	Y	Y	Y	Y	N	Green	National linefish survey CPUE	S	5
Ecklonia maxima	Kelp *Ecklonia*	WC	Y	Y	N	N	N	Green	Biomass estimates, visuals	S	4
Emerita austroafricana	Mole crab / sea lice	KZN, MOZ	N	N	N	N	Y	Orange	National linefish survey CPUE	D	5
Eunice aphroditois	Bobbit worm (errant worm)	WC, EC, KZN, MOZ	N	N	N	N	N	Red	National linefish survey CPUE	D	6
Gelidium abbottiorum, pteridifolium, capense	*Gelidium* other spp	EC	N	N	N	Y	N	Green	Biomass estimates, visuals	S	3
Gelidium pristoides	*Gelidium pristoides*	WC, EC	N	N	N	Y	N	Green	Biomass estimates, visuals	S	3
Gracilaria	*Gracilaria*	WC Saldanha area only	Y	N	N	N	N	Green	Biomass estimates, visuals	CU	3
Grapsus spp.	Green & Natal rock crab	EC, KZN, MOZ	N	N	N	N	Y	Orange	National linefish survey CPUE	D	5
Gunnarea capensis	Coral worm/Cape reef worm	WC,EC	N	N	N	N	N	Red	National linefish survey CPUE	D	5
Haliotis midae	Abalone/perlemoen	WC, EC	Y	N	N	N	N	Red	Spatial & age structured assessment model (South Coast) & survey / fishery indicators (West Coast)	D	7
Haliotis spadicea	Siffie	WC, EC, KZN	N	Y	Y	Y	N	Red	National linefish survey CPUE	D	6
Haliporoides triarthrus	Pink prawn (deepwater trawl)	KZN	N	N	N	N	Y	Orange	DFFE prawn trawl database CPUE	D	3
Hippa adactyla	Mole crab/sea lice	KZN	N	N	N	N	Y	Orange	National linefish lurvey CPUE	D	5
Jasus lalandii	West Coast rock lobster	NC, WC	Y	Y	N	N	N	Orange		D	
Laminaria pallida	Kelp *Laminaria*	WC	Y	Y	N	N	N	Green	Biomass estimates, visuals	S	3
Loligo devaucelii	Indian squid	KZN	N	N	N	N	Y	Green	National linefish survey CPUE	S	5

Species name	Common name	Distribution: Region (NAM = Namibia, NC = Northern Cape WC = Western Cape, EC = Eastern Cape, KZN = KwaZulu-Natal, MOZ = Mozambique)	Harvestable distribution (Yes = Y, No = N)						Assessment status (red = collapsed, orange = overexploited, green = ok) and method. Catch-per-unit-effort (CPUE), Vulnerability score (0 = least vulnerable; 7 = most vulnerable), trend (CU = currently underexploited, D = decline, S = stable, SD = stable decline,		
		Region	Basket area A	Basket area B	Basket area C	Basket area D	Basket area E	Stock status	Assessment method	CPUE trend	Vulnerability score
Loligo reynaudii	Chokka squid	WC, EC	N	Y	Y	Y	N	Green	National linefish survey CPUE	S	5
Marphysa sanguinea	Wonder worm	WC, EC, KZN, MOZ	Y	Y	Y	Y	N	Red	National linefish survey CPUE	D	5
Metapenaeus monoceros	Brown swimming prawn	EC, KZN	N	N	N	Y	Y	Orange	DFFE prawn trawl database CPUE	D	8
Mytilus, Choromytilus	Black mussel	NC, WC, EC	Y	Y	Y	N	N	Green	National linefish survey CPUE	D	5
Octopus vulgaris	Octopus	WC, EC, KZN, MOZ	Y	Y	Y	Y	Y	Green	National linefish survey CPUE	S	5
Ocypode spp.	Ghost crabs	EC, KZN, MOZ	N	N	N	N	Y	Orange	National linefish survey CPUE	D	5
Ovalipes trimaculatus	Three-spotted swimming crab	NAM, NC, WC, EC	Y	Y	N	N	N	Green	Bycatch of exploratory whelk fishery	U	5
Oxystele sinensis	Periwinkle / pink-lipped topshell	WC, EC	Y	Y	Y	N	N	Orange	National linefish survey CPUE	D	5
Panulirus homarus	East Coast rock lobster	EC, KZN, MOZ	N	N	N	Y	Y	Orange	National linefish survey CPUE	D	6
Peneaus indicus	White swimming prawn	EC, KZN, MOZ	N	N	N	Y	Y	Orange	DFFE prawn trawl database CPUE	D	8
Perna perna	Brown mussel	EC, KZN, MOZ	N	Y	Y	Y	Y	Orange	National linefish survey CPUE	D	5
Plagusia chabrus	Cape/red rock crab	WC, EC	Y	Y	N	N	N	Orange	National linefish survey CPUE	D	5
Polybrachiorhynchus dayi	Tapeworm/ribbon worm	EC, KZN, MOZ	N	N	Y	Y	N	Red	National linefish survey CPUE	D	6
Porphyra/Pyropia spp.	Porphyra	WC	Y	Y	N	N	N	Green	Biomass estimates, visuals	X	5
Pseudonereis variegata	Mussel worm	WC, EC, KZN	Y	Y	Y	N	N	Red	National linefish survey CPUE	D	5
Pyura stolonifera	Red bait	WC, EC, KZN	Y	Y	Y	Y	Y	Green	National linefish survey CPUE	S	5
Saccostrea cucculata	Natal rock oyster	EC, KZN, MOZ	N	N	Y	Y	Y	Green	Recreational invertebrate survey - KZN	U	5
Salicornia spp.	Samphire, glassworts	WC, EC, KZN	Y	Y	Y	Y	N	Orange	Biomass estimates, visuals	U	5
Sarcocornia spp.	Samphire, glassworts	WC, EC, KZN	Y	Y	Y	Y	N	Orange	Biomass estimates, visuals	U	5
Scylla serrata	Mud/mangrove/Knysna crab	EC, KZN, MOZ	N	N	Y	Y	Y	Red	CPUE (Robertson 1996)	D	8
Solen capensis	Pencil bait	WC, EC	N	N	Y	Y	N	Red	National linefish survey CPUE	D	6
Solen cylindricus	Pencil bait	EC. KZN, MOZ	N	N	N	N	Y	Orange	National linefish survey CPUE	D	6
Striostrea margaritacea	Cape rock oyster	WC, EC, KZN, MOZ	N	N	Y	Y	Y	Orange-green	DFFE oyster database CPUE	SD	5
Talorchestia capensis	Sandflea	WC, EC	Y	Y	N	N	N	Orange	National linefish survey CPUE	D	5
Turbo cidaris cidaris	Smooth turban shell	WC, EC	Y	Y	Y	N	N	Orange	National linefish survey CPUE for *O. sinensis*	U	5
Turbo sarmaticus	Alikreukel	WC, EC	N	Y	Y	N	N	Red	National linefish survey CPUE	D	5
Ulva spp.	Sea lettuce	WC	Y	Y	N	N	N	Green	Biomass estimates, visuals	X	4
Upogebia africana	Mud prawns	WC, EC, KZN, MOZ	Y	Y	Y	Y	N	O range	National linefish survey CPUE	D	8

Table 23a: Input and output controls (bag and size limits [TL = Total Length], closed seasons), primary fishery sector, gear regulations, and sale limitations for 138 fish species potentially available to the small-scale / subsistence sector

Species name	Common name	Management approach (bag, size, area and season limits),"primary fishery, and gear regulations." Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
FISH, SHARKS & RAYS							
Acanthocybium solandri	Wahoo	10	None	None	Linefish boat	Boat angling with hook and line only	S
Acanthopagrus vagus	River bream	5	25 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Albula oligolepis	Bonefish	10	None	None	Linefish shore	Linefish shore with hook and line only	F
Aprion virescens	Green jobfish	10	None	None	Linefish boat	Boat angling with hook and line only	S
Argyrops spinifer	King soldierbream	10	None	None	Linefish boat	Boat angling with hook and line only	S
Argyrosomus inodorus	Silver kob	1	50 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Argyrosomus japonicus	Dusky kob	1	60 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Argyrosomus thorpei	Squaretail kob	1	40 cm TL	None	Linefish shore	Linefish shore with hook and line only	S
Argyrozona argyrozona	Carpenter/silverfish	10	35 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Atractoscion aequidens	Geelbek	2	60 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Boopsoidea inornata	Fransmadam/karel grootoog	10	None	None	Linefish boat	Boat angling with hook and line only	S
Callorhinchus capensis	St Joseph	1	None	None	Linefish boat/shore	Basket A: Beach seine/gillnet only in St Helena Bay	S
Caranx ignobilis	Giant kingfish	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Caranx papuensis	Brassy kingfish	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Caranx sexfasciatus	Bigeye kingfish	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Carcharhinus brachyurus	Bronze whaler/copper shark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	S
Carcharhinus leucas	Zambezi shark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	P
Carcharhinus limbatus	Blacktip shark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	F
Carcharhinus obscurus	Dusky shark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	C
Carcharius taurus	Spotted ragged-tooth shark	1	None	None	Linefish boat/shore	Linefish shore with hook and line only	F
Carcharodon carcharias	White shark	0	None	N/A	Linefish boat/shore	Prohibited species	P
Cheimerius nufar	Soldier/santer	5	30 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Chelidonichthys capensis	Gurnard	10	None	None	Linefish boat	Boat angling	S
Chelon richardsonii	Harder	50	None	None	Linefish shore/castnet	Linefish shore with hook and line/castnet	S
Chelon tricuspidens	Striped mullet	50	None	None	Linefish shore	Linefish shore with hook and line only	S

Species name	Common name	Management approach (bag, size, area and season limits),”primary fishery, and gear regulations.” Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
Chirodactylus jessicalenorum	Natal fingerfin	10	None	None	Linefish boat	Boat angling with hook and line only	S
Chrysoblephus anglicus	Englishman	2	40 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Chrysoblephus gibbiceps	Red stumpnose	1	30 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Chrysoblephus laticeps	Red Roman	2	30 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Chrysoblephus lophus	False Englishman	10	None	None	Linefish boat	Boat angling with hook and line only	S
Chrysoblephus puniceus	Slinger	5	25 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Coryphaena hippurus	Dolphinfish/dorado	10	None	None	Linefish boat	Boat angling with hook and line only	S
Cymatoceps nasutus	Poenskop	1	50 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Dasyatis chrysonota	Blue stingray	1	None	None	Linefish shore	Linefish shore with hook and line only	F
Dichistius capensis	Galjoen	2	35 cm	15 Oct–Feb	Linefish shore	Linefish shore with hook and line only	F
Dichistius multifasciatus	Banded galjoen	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Dinoperca petersi	Cave bass	10	None	None	Linefish boat	Boat angling with hook and line only	S
Diplodus capensis	Blacktail	5	20 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Diplodus hottentotus	Zebra	5	30 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Elops machnata	Ladyfish/kingspringer/tenpounder	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Epinephelus albomarginatus	White-edged rockcod	5	40 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Epinephelus andersoni	Catface rockcod	5	50 cm TL	None	Linefish shore	Linefish shore with hook and line only	S
Epinephelus lanceolatus	Brindlebass	0	N/A	N/A	Linefish boat/shore	Prohibited species	P
Epinephelus malabaricus	Malabar rockcod	5	None	None	Linefish boat	Boat angling with hook and line only	S
Epinephelus marginatus	Yellowbelly rockcod	1	60 cm TL	None	Linefish shore	Linefish shore with hook and line only	S
Epinephelus rivulatus	Halfmoon rockcod	5	None	None	Linefish boat	Boat angling with hook and line only	S
Epinephelus tukula	Potato bass	0	N/A	N/A	Linefish boat/shore	Prohibited species	P
Euthynnus affinis	Eastern little tuna	10	None	None	Linefish boat	Boat angling with hook and line only	S
Galeichthys ater	Black seacatfish/barbel	10	None	None	Linefish boat	Boat angling with hook and line only	S

Species name	Common name	Management approach (bag, size, area and season limits),"primary fishery, and gear regulations." Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
Galeicthys feliceps	White seacatfish	10	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only, West Coast beach-seine & gillnet	S
Galeocerdo cuvier	Tiger shark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	P
Galeorhinus galeus	Soupfin shark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	S
Gymnocrotaphus curvidens	John Brown	5	None	None	Linefish shore	Linefish shore with hook and line only	P
Gymnura natalensis	Butterfly/diamond ray	1	None	None	Linefish boat/shore	Linefish boat/shorewith hook and line only	P
Himantura gerrardi	Sharpnose stingray	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	P
Himantura uarnak	Honeycomb stringray	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	P
Istiophorus platypterus	Sailfish	5	None	None	Linefish boat	Boat angling with hook and line only	P
Johnius dorsalis	Small kob	10	None	None	Linefish boat	Boat angling with hook and line only	S
Kajikia audax	Striped marlin	5	None	None	Linefish boat	Boat angling with hook and line only	F
Katsuwonus pelamis	Skipjack tuna	10	None	None	Linefish boat	Boat angling with hook and line only	S
Lethrinus nebulosus	Blue emperor	10	None	None	Linefish boat/shore	Boat angling with hook and line only	S
Lichia amia	Leervis/garrick	2	70 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Lithognathus aureti	West Coast steenbras	10	40 cm TL, only 2 over 65 cm TL/day	None	Linefish shore	Linefish shore with hook and line only	F
Lithognathus lithognathus	White steenbras	1	60 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Lithognathus mormyrus	Sand steenbras	10	None	None	Linefish shore	Linefish shore with hook and line only	S
Lutjanus argentimaculatus	Mangrove snapper	2	40 cm TL	None	Linefish boat	Boat angling with hook and line only	F
Lutjanus rivulatus	Speckled snapper	10	None	None	Linefish shore	Linefish shore with hook and line only	S
Lutjanus sanguineus	Blood snapper	10	None	None	Linefish boat	Boat angling with hook and line only	S
Lutjanus sebae	Emperor red snapper	10	None	None	Linefish boat/shore	Boat angling with hook and line only	S
Makaira nigricans	Blue marlin	5	None	None	Linefish boat	Boat angling with hook and line only	F
Megalops cyprinoides	Oxeye tarpon	10	None	None	Linefish shore	Linefish shore with hook and line only	S

Species name	Common name	Management approach (bag, size, area and season limits),”primary fishery, and gear regulations.” Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
Merluccius capensis	Shallow water hake	5	None	None	Linefish boat	Boat angling with hook and line only	S
Mugil cephalus	Flathead/springer mullet	50	None	None	Linefish shore/castnet	Linefish shore with hook and line /Castnet	S
Mustelus mustelus	Smooth houndshark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	S
Myliobatis aquila	Eagleray	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	F
Neoscorpis lithophilus	Stonebream	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Notorynchus cepedianus	Cow shark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	F
Oplegnathus conwayi	Cape knifejaw	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Oplegnathus robinsoni	Natal knifejaw	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Otolithes ruber	Snapper kob	10	None	None	Linefish boat	Boat angling with hook and line only	F
Pachymetopon aeneum	Blue Hottentot	5	None	None	Linefish boat	Boat angling with hook and line only	S
Pachymetopon blochii	Hottentot	10	22 cm	None	Linefish boat/shore	Boat angling with hook and line only	S
Paracaesio xanthura	Yellowtail fusilier/protea bream	10	None	None	Linefish boat	Boat angling with hook and line only	S
Petrus rupestris	Red steenbras	0	N/A	N/A	Linefish boat/shore	Prohibited species	P
Platycephalus indicus	Bartailed flathead	10	None	None	Linefish shore	Linefish shore with hook and line only	S
Plectorhinchus chubbi	Dusky rubberlip	10	None	None	Linefish boat	Boat angling with hook and line only	S
Plectorhinchus flavomaculatus	Lemon fish	10	None	None	Linefish shore	Linefish shore with hook and line only	S
Plectorhinchus playfairi	Whitebarred rubberlip	10	None	None	Linefish shore	Linefish shore with hook and line only	S
Polysteganus coeruleopunctatus	Blueskin/trawl soldier	10	None	None	Linefish boat	Boat angling with hook and line only	S
Polysteganus undulosus	Seventy-four	0	N/A	N/A	Linefish boat/shore	Prohibited species	P
Pomadasys commersonnii	Spotted grunter	5	40 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Pomadasys furcatus	Banded grunter	10	None	None	Linefish shore	Linefish shore with hook and line only	S
Pomadasys kaakan	Javelin grunter	10	None	None	Linefish boat	Boat angling with hook and line only	S
Pomadasys olivaceus	Piggy	10	7.5 cm TL	None	Linefish shore	Linefish shore with hook and line only	S
Pomatomus saltatrix	Elf	4	30 cm TL	1 Oct–31 Nov	Linefish shore	Linefish shore with hook and line only	S

Species name	Common name	Management approach (bag, size, area and season limits),”primary fishery, and gear regulations.” Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
Porcostoma dentata	Dane	10	None	None	Linefish boat	Boat angling with hook and line only	S
Poroderma africanum	Pyjama shark/striped catshark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	F
Poroderma pantherinum	Leopard catshark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	F
Prionace glauca	Blue shark	1	None	None	Linefish boat	Boat angling with hook and line only	S
Pristipomoides filamentosus	Rosy jobfish	10	None	None	Linefish boat	Boat angling with hook and line only	S
Pterogymnus laniarius	Panga	10	None	None	Linefish boat	Boat angling with hook and line only	S
Rachycentron canadum	Prodigal son/cobia	10	None	None	Linefish boat	Boat angling with hook and line only	S
Rhabdosargus globiceps	White stumpnose	10	25 cm TL	None	Linefish boat/shore	Linefish boat/shore with hook and line only	S
Rhabdosargus holubi	Cape stumpnose	5	20 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Rhabdosargus sarba	Natal stumpnose	5	25 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Rhinobatos annulatus	Lesser guitarfish/sandshark	1	None	None	Linefish boat/shore	Linefish boat/shore with hook and line only	S
Rhizoprionodon acutus	Milkshark	1	None	None	Linefish boat	Linefish boat/shore with hook and line only	S
Rhynchobatus djiddensis	Giant sandshark/guitarfish	1	None	None	Linefish boat/shore	Prohibited species	P
Sarda orientalis	Striped bonito/katonkel	10	None	None	Linefish boat/shore	Boat angling with hook and line only; beach seine	S
Sarda sarda	Atlantic bonito/katonkel	10	None	None	Linefish boat/shore	Boat angling with hook and line only; beach seine	S
Sardinops sagax	Sardine/pilchard	50			Beach seine	Beach seine, small motorised/row boats	S
Sarpa salpa	Strepie	10	15 cm TL	None	Linefish shore	Linefish shore with hook and line only	S
Scomber japonicus	Mackerel	50	None	None	Linefish boat	Boat angling with hook and line only	S
Scomberoides commersonnianus	Queenfish	10	None	None	Linefish shore	Linefish shore with hook and line only	S
Scomberomorus commerson	King mackerel	10	None	None	Linefish boat	Boat angling with hook and line only	F
Scomberomorus plurilineatus	Queen mackerel	10	None	None	Linefish boat	Boat angling with hook and line only	S
Sebastes capensis	Jacopever	10	None	None	Linefish boat	Boat angling with hook and line only	S
Seriola dumerili	Tropical yellowtail	10	None	None	Linefish boat	Boat angling with hook and line only	S
Seriola lalandi	Yellowtail	10	None	None	Linefish boat	Boat angling with hook and line only; beach seine	S
Seriola rivoliana	Longfin yellowtail	10	None	None	Linefish boat	Boat angling with hook and line only	S

Species name	Common name	Management approach (bag, size, area and season limits),”primary fishery, and gear regulations.” Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
Sparodon durbanensis	White musselcracker	2	60 cm TL	None	Linefish shore	Linefish shore with hook and line only	F
Sphyraena barracuda	Barracuda	10	None	None	Linefish boat	Boat angling with hook and line only	S
Sphyraena jello	Pickhandle barracuda	10	None	None	Linefish boat	Boat angling with hook and line only	S
Sphyrna lewini	Scalloped hammerhead	1	None	None	Linefish boat/shore	Prohibited species	P
Spondyliosoma emarginatum	Steentjie	10	None	None	Linefish boat	Boat angling with hook and line only	S
Thunnus alalunga	Albacore	10	None	None	Linefish boat	Boat angling with hook and line only	S
Thunnus albacares	Yellowfin tuna	10	3.2 kg (comm & recrn)	None	Linefish boat	Boat angling with hook and line only	S
Thunnus obesus	Bigeye tuna	10	2.3 kg	None	Linefish boat	Boat angling with hook and line only	S
Thyrsites atun	Snoek	10	60 cm TL	None	Linefish boat	Boat angling with hook and line only	S
Trachinotus africanus	Southern pompano	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Trachinotus botla	Largespot pompano	5	None	None	Linefish shore	Linefish shore with hook and line only	F
Trachurus capensis	Maasbanker	50	None	none	Linefish boat	Boat angling; beach seine; gillnet	S
Triakis megalopterus	Spotted gullyshark	1	None	None	Linefish boat/shore	Linefish shore with hook and line only	F
Umbrina robinsoni	Baardman	5	40 cm	None	Linefish shore	Linefish shore with hook and line only	F
Xiphias gladius	Swordfish	5		None	Linefish boat	Boat angling with hook and line only	S

Table 23b: Input and output controls (bag and size limits [SW = Shell Width], closed seasons), primary fishery sector, gear regulations, and sale limitations for 41 invertebrate and 9 seaweed and marine plant species potentially available to the small-scale / subsistence sector

Species name	Common name	Management approach (bag, size, area and season limits),"primary fishery, and gear regulations." Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
INVERTEBRATES, SEAWEEDS, AQUATIC PLANTS							
Arabella iricolor	Moonshine worm	10 or 250 ml container	None	None	Small invertebrate collection	Only by hand or suction pump	F
Arenicola loveni	Blood worm	5	None	None	Small invertebrate collection	Only by hand, suction pump and/or wire	F
Bullia laevissima	Whelk/plough shell	None	None	None	Experimental/ exploratory	Boat-based ring net or trap exploratory fishery	N
Callianassa kraussi,	Sand/pink prawn	50	None	None	Small invertebrate collection	Only by hand or suction pump	S
Cymbula spp.	Limpets/perdevoet	15	None	none	Small invertebrate collection	Only by hand or with a specified tool	F
Dinoplax gigas	Giant chiton	6	None	None	Small invertebrate collection	Only by hand	F
Donax serra	White mussel	50	35 mm	None	White mussel	Only by hand or with a specified tool	S
Ecklonia maxima	Kelp *Ecklonia*	TAC	None	None	Seaweed	Harvest off boat, by diver, or collect off beach. (Boat only Area B)	S
Emerita austroafricana	Mole crab/sea lice	30	None	None	Small invertebrate collection	By hand or triangular trap	F
Eunice aphroditois	Bobbit worm (errant worm)	10 or 250 ml container	None	None	Small invertebrate collection	Only by hand	F
Gelidium abbottiorum, pteridifolium, capense	*Gelidium* other spp.	N/A	None	None	Seaweed	Picking by hand	C
Gelidium pristoides	*Gelidium pristoides*	N/A	None	None	Seaweed	Picking by hand	C
Gracilaria	*Gracilaria*	Beach-cast only	None	None	Seaweed	Beach-cast only, Saldanha & St Helena Bays. By hand, pitchforks, bulldozers	C
Grapsus spp.	Green & Natal rock crab	15	None	None	Small invertebrate collection	Only by hand	F
Gunnarea capensis	Coral worm/Cape reef worm	10 or 250 ml container	None	None	Small invertebrate collection	Only by hand	F
Haliotis midae	Abalone/perlemoen	None	114 mm SW	1 Aug–31 Oct	Abalone	Boat-based diving with hookah breathing system	S
Haliotis spadicea	Siffie	15	32 mm	None	Small invertebrate collection	Prohibited species	P
Haliporoides triarthrus	Pink prawn (deepwater trawl)	50	None	None	Small invertebrate collection		S
Hippa adactyla	Mole crab/sea lice	30	None	None	Small invertebrate collection	By hand or triangular trap	F

Species name	Common name	Management approach (bag, size, area and season limits),”primary fishery, and gear regulations.” Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
Jasus lalandii	West Coast rock lobster	TAC	75mm Carapace Length	15 Nov–30 Jun	Rock lobster	Small boats and hoop nets. Within existing TAC	S
Laminaria pallida	Kelp *Laminaria*	TAC	None	None	Seaweed	Harvest off boat, by diver, or collect off beach (Beach cast only Area B)	S
Loligo devaucelii	Indian squid	20	None	None	Bycatch	Only by rod and/or line	S
Loligo reynaudii	Chokka squid	20	None	19 Oct–23 Nov	Squid	Only by hand-held jig	S
Marphysa sanguinea	Wonder worm	10 or 250 ml container	None	None	Small invertebrate collection	Only by hand or suction pump	F
Metapenaeus monoceros	Brown swimming prawn	50	None	None	Small invertebrate collection	Only by hand or hand-held scoop-net not measuring more than 50X50cm	S
Mytilus, Choromytilus	Black mussel	30	None	None	Small invertebrate collection	Only by hand or with a specified tool	F
Octopus vulgaris	Octopus	2	None	None	Small invertebrate collection	Only by hand, rod and/or line, gaff	F
Ocypode spp.	Ghost crabs	15	None	None	Small invertebrate collection	Only by hand	F
Ovalipes trimaculatus	Three-spotted swimming crab				Experimental/ exploratory	Boat-based ring net or trap exploratory fishery - bycatch	N
Oxystele sinensis	Periwinkle/pink-lipped topshell	50	None	None	Small invertebrate collection	Only by hand	F
Panulirus homarus	East Coast rock lobster	8	65 mm	1 Nov-end Feb	Small invertebrate collection	Only by hand or circular net not more than 30 cm in diameter	S
Peneaus indicus	White swimming prawn	50	None	None	Small invertebrate collection	Only by hand or hand-held scoop-net not measuring more than 50X50cm	S
Perna perna	Brown mussel	30	None	None	Small invertebrate collection	Only by hand or with a specified tool	F
Plagusia chabrus	Cape/red rock crab	15	None	None	Small invertebrate collection	Only by hand	F
Polybrachiorhynchus dayi	Tapeworm/ribbon worm	10 or 250 ml container	None	None	Small invertebrate collection	Only by hand or suction pump	F
Porphyra/Pyropia spp.	Porphyra	TAC	None	None	Seaweed	Picking by hand (Area B limited harvest)	C
Pseudonereis variegata	Mussel worm	10 or 250 ml	None	None	Small invertebrate collection	Only by hand	F
Pyura stolonifera	Red bait	2 kg w/o shell	None	None	Small invertebrate collection	Only by hand or with a specified tool. Removal of flesh only, test to remain on rock	F
Saccostrea cucculata	Natal rock oyster	25	None	None	Small invertebrate collection	Only by hand or with a specified tool	F

Species name	Common name	Management approach (bag, size, area and season limits),”primary fishery, and gear regulations.” Sale? (C = commercial, only for export; F = only for food security; N = not recommended for the small-scale / subsistence basket at this time; P = prohibited species that may not be landed; S = can be sold)					
		Bag limit	Minimum size limit	Closed season	Primary fishery	Gear regulations	Sale?
Salicornia spp.	Samphire, glassworts	None	None	None	Saltmarsh collection	Picking by hand	S
Sarcocornia spp.	Samphire, glassworts	None	None	None	Saltmarsh collection	Picking by hand	S
Scylla serrata	Mud/mangrove/Knysna crab	6	140 mm	None	Small invertebrate collection	Only by hand, rod and/or line	F
Solen capensis	Pencil bait	20	None	None	Small invertebrate collection	Only by hand, suction pump and/or wire	F
Solen cylindricus	Pencil bait	20	None	None	Small invertebrate collection	Only by hand, suction pump and/or wire	F
Striostrea margaritacea	Cape rock oyster	25	None	None	Small invertebrate collection	Only by hand or with a specified tool	S
Talorchestia capensis	Sandflea	None	None	None	Small invertebrate collection	Only by hand	S
Turbo cidaris cidaris	Smooth turban shell	50	None	None	Small invertebrate collection	Only by hand	F
Turbo sarmaticus	Alikreukel	5	63.5 mm	None	Small invertebrate collection	Only by hand	F
Ulva spp.	Sea lettuce	TAC	None	None	Seaweed	Picking by hand (Area B limited harvest)	C
Upogebia africana	Mud prawns	50	None	None	Small invertebrate collection	Only by hand, suction pump or inverted tin	S

Table 24a: Heat map of relative catches across all fishing sectors for 138 fish species potentially available to the small-scale / subsistence sector. The numbers and colour shading indicate the relative ranking and range from 1 (darkest blue) indicating the highest catches to 9 (lightest blue) indicating the lowest catches of each species

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
FISH, SHARKS & RAYS																								
Acanthocybium solandri	Wahoo			4											3	1			2					Y
Acanthopagrus vagus	River bream									4						1	2				3			Y
Albula oligolepis	Bonefish		2														1							Y
Aprion virescens	Green jobfish															1			2					Y
Argyrops spinifer	King soldier bream			1												2								Y
Argyrosomus inodorus	Silver kob	5	6	1	3											2	4							Y
Argyrosomus japonicus	Dusky kob			4						6						3	1		5		2			Y
Argyrosomus thorpei	Squaretail kob			2										3		1	4							Y
Argyrozona argyrozona	Carpenter/ silverfish	4		1	2	3										5								Y
Atractoscion aequidens	Geelbek	5	4	1	2											3								Y
Boopsoidea inornata	Fransmadam/ karel grootoog			1												1	2				3			Y
Callorhinchus capensis	St Joseph		2		1					2						4	6	5			3			Y
Caranx ignobilis	Giant kingfish															2	1		3					Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Caranx papuensis	Brassy kingfish																1		3		2			Y
Caranx sexfasciatus	Bigeye kingfish															2	1		3					Y
Carcharhinus brachyurus	Bronze whaler/ copper shark		9	5	6	7					8		2				1	3						Y
Carcharhinus leucas	Zambezi shark									2						3	1							N
Carcharhinus limbatus	Blacktip shark															2	1							Y
Carcharhinus obscurus	Dusky shark			2													1	3						Y
Carcharius taurus	Spotted ragged-tooth shark			3												2	1							Y
Carcharodon carcharias	White shark			2												3	1	4						N
Cheimerius nufar	Soldier/santer			1	3											2	4							Y
Chelidonichthys capensis	Gurnard		5	3	1	2	4									6								Y
Chelon richardsonii	Harder	6	2	7						1					7	4	3	9	5	8				y
Chelon tricuspidens	Striped mullet									1							2				2			y
Chirodactylus jessicalenorum	Natal fingerfin																		1					Y
Chrysoblephus anglicus	Englishman			1												2			3					Y
Chrysoblephus gibbiceps	Red stumpnose			1	4											2			3					Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Chrysoblephus laticeps	Red Roman			1	4											2	5		3		6			Y
Chrysoblephus lophus	False Englishman			1												2								Y
Chrysoblephus puniceus	Slinger	2		1												3								Y
Coryphaena hippurus	Dolphinfish/ dorado			2									3			1			4					Y
Cymatoceps nasutus	Poenskop			2												1	3		4		5			Y
Dasyatis chrysonota	Blue stingray		4	5	2											3	1							Y
Dichistius capensis	Galjoen		4							2							1		5		3			Y
Dichistius multifasciatus	Banded galjoen																1		3		2			Y
Dinoperca petersi	Cave bass			2												1	3		3		3			Y
Diplodus capensis	Blacktail		3														1				2			Y
Diplodus hottentotus	Zebra															4	1		3		2			Y
Elops machnata	Ladyfish/ kingspringer/ tenpounder									2						1	1		3					Y
Epinephelus albomarginatus	White-edged rockcod			1												2								Y
Epinephelus andersoni	Catface rockcod			2												1	4		3		4			Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Epinephelus lanceolatus	Brindlebass			3										5		2	4			1				N
Epinephelus malabaricus	Malabar rockcod			1						2						1	3		2		3			Y
Epinephelus marginatus	Yellowbelly rockcod			2										3		1	4			4				Y
Epinephelus rivulatus	Halfmoon rockcod			1												2			3					Y
Epinephelus tukula	Potato bass			3												4	2		1					N
Euthynnus affinis	Eastern little tuna			2												1								Y
Galeichthys ater	Black seacatfish/ barbel		4	1												2	3							Y
Galeicthys feliceps	White seacatfish	5	6	1	8					7						4	2				3			Y
Galeocerdo cuvier	Tiger shark			2												3	4		1					N
Galeorhinus galeus	Soupfin shark	4		1	3											6	5	2						Y
Gymnocrotaphus curvidens	John Brown															4	2		1		3			Y
Gymnura natalensis	Butterfly/diamond ray		4											2		5	1							Y
Himantura gerrardi	Sharpnose stingray		5											2		3	1		4					Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Himantura uarnak	Honeycomb stringray		5											2		3	1							Y
Istiophorus platypterus	Sailfish	5		4								3	2			1								Y
Isurus oxyrinchus	Mako shark			3						4			1			2	5							Y
Johnius dorsalis	Small kob		4		1											2				3				Y
Kajikia audax	Striped marlin						2						1			3								Y
Katsuwonus pelamis	Skipjack tuna			4									1			3				2				Y
Lethrinus nebulosus	Blue emperor			1												2	4		3					Y
Lithognathus aureti	West coast steenbras			2												3	1							Y
Lithognathus lithognathus	White steenbras		2							3					4		1		5		6			Y
Lithognathus mormyrus	Sand steenbras		3														1				2			Y
Lutjanus argentimaculatus	Mangrove snapper			4						2						1	3		3		2			Y
Lutjanus rivulatus	Speckled snapper	3															1		4		2			Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Lutjanus sanguineus	Blood snapper			1												2			3					Y
Lutjanus sebae	Emperor red snapper			2												1			3					Y
Makaira nigricans	Blue marlin						2						1			3								Y
Megalops cyprinoides	Oxeye tarpon									2						1	1							Y
Merluccius capensis	Hake				2	1		5	3		4													Y
Mugil cephalus	Flathead/springer mullet		2							1														Y
Mustelus mustelus	Smooth houndshark	2	5	1	4									8		7	6	3						Y
Myliobatis aquila	Eagleray		2		3												1							Y
Neoscorpis lithophilus	Stonebream																1		3		2			Y
Notorynchus cepedianus	Cow shark	4		2											3		1							Y
Oplegnathus conwayi	Cape knifejaw																		1					Y
Oplegnathus robinsoni	Natal knifejaw															2			1					Y
Otolithes ruber	Snapper kob		3											1		2								Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Pachymetopon aeneum	Blue hottentot			1												2			3					Y
Pachymetopon blochii	Hottentot	2		1												3	5				4			Y
Pagellus natalensis	Red tjor-tjor			3	1									2		4	5							Y
Paracaesio xanthura	Yellowtail fusilier/ protea bream			1												2			3					Y
Petrus rupestris	Red steenbras	3		2	4											1		5	6					N
Platycephalus indicus	Bartailed flathead									4						2	1				3			Y
Plectorhinchus chubbi	Dusky rubberlip			3												2			1					Y
Plectorhinchus flavomaculatus	Lemon fish															4	2		1		3			Y
Plectorhinchus playfairi	Whitebarred rubberlip															4	1		2		3			Y
Polysteganus coeruleopunctatus	Blueskin/trawl soldier			1												3								Y
Polysteganus undulosus	Seventy-four			1												2								N
Pomadasys commersonnii	Spotted grunter									4				6		3	1		5		2			Y
Pomadasys furcatus	Banded grunter																2				1			Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Pomadasys kaakan	Javelin grunter			4						2				1		3	3				3			Y
Pomadasys olivaceus	Piggy		4											3		5	1				2			Y
Pomatomus saltatrix	Elf		3	4	7									6		5	1		8		2			Y
Porcostoma dentata	Dane			1												2								Y
Poroderma africanum	Pyjama shark/ striped catshark			4	2											5	1	3						Y
Poroderma pantherinum	Leopard catshark			3	4											2	1							Y
Prionace glauca	Blue shark												1			3		2						Y
Pristipomoides filamentosus	Rosy jobfish			1												2			3					Y
Pterogymnus laniarius	Panga			3	1	2										4								Y
Rachycentron canadum	Prodigal son/cobia			2												1	4		3					Y
Rhabdosargus globiceps	White stumpnose	5	6	1	2					7						3	4							Y
Rhabdosargus holubi	Cape stumpnose									3							2				1			Y
Rhabdosargus sarba	Natal stumpnose		6							4						3	1		5		2			Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Rhinobatos annulatus	Lesser guitarfish/ sandshark		2		3												1							Y
Rhizoprionodon acutus	Milkshark			4										2		3	1				5			Y
Rhynchobatus djiddensis	Giant sandshark/ guitarfish													2			1							N
Sarda orientalis	Striped bonito/ katonkel		3	1								4	5	7		2				6				Y
Sarda sarda	Atlantic bonito/ katonkel		3	1								4	5	7		2				6				Y
Sardinops sagax	Sardine/pilchard		2												1									Y
Sarpa salpa	Strepie		3														1				2			Y
Scomber japonicus	Mackerel	8	5	7	3	4					2				1	6								Y
Scomberoides commersonnianus	Queenfish															1	2		3					Y
Scomberomorus commerson	King mackerel	3	7	4						6						1	5		2					Y
Scomberomorus plurilineatus	Queen mackerel	2	6	3						5						1	7		4					Y
Sebastes capensis	Jacopever			3	1	2										4								Y
Seriola dumerili	Tropical yellowtail			2												1			3					Y
Seriola lalandi	Yellowtail	6	4	1												2	7		5	3	8			Y
Seriola rivoliana	Longfin yellowtail			3												1			2					Y
Sparodon durbanensis	White musselcracker															1	4		2		3			Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Sphyraena barracuda	Barracuda									1						2	4		3					Y
Sphyraena jello	Pickhandle barracuda									3						2	4		1					Y
Sphyrna lewini	Scalloped hammerhead shark	2		7									5	4		6	3							N
Sphyrna zygaena	Smooth hammerhead shark			2									3			6	1	5						N
Spondyliosoma emarginatum	Steentjie	3		1	4											2	5							Y
Thunnus alalunga	Albacore			2									3			4				1				Y
Thunnus albacares	Yellowfin tuna			5									1			4				5				Y
Thunnus obesus	Bigeye tuna			4									1			3				2				Y
Thyrsites atun	Snoek	5		1		2		7			6				8	4				3				Y
Trachinotus africanus	Southern pompano		2														1		4		3			Y
Trachinotus botla	Largespot pompano																1				2			Y
Trachurus capensis	Maasbanker		5	3	1	2	4									6								Y
Triakis megalopterus	Spotted gullyshark	5		3												4	1	2			3			Y
Umbrina robinsoni	Baardman		4													5	2		1		3			Y
Xiphias gladius	Swordfish												1			2								Y

Table 24b: Heat map of relative catches across all fishing sectors for 41 invertebrate and 9 seaweed and marine plant species potentially available to the small-scale / subsistence sector. The numbers and colour shading indicate the relative ranking and range from 1 (darkest blue) indicating the highest catches to 9 (lightest blue) indicating the lowest catches of each species

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
INVERTEBRATES, SEAWEEDS, AQUATIC PLANTS																								
Arabella iricolor	Moonshine worm	5		4												3	1				2			Y
Arenicola loveni	Blood worm	5		4												3	1				2			Y
Bullia laevissima	Whelk/plough shell																						1	N
Callianassa kraussi	Sand/pink prawn	5		4												3	1				2			Y
Cymbula spp	Limpets/ perdevoet	3	4														2				1			Y
Dinoplax gigas	Giant chiton	5		4												3	1				2			Y
Donax serra	White mussel	5		4												3	1				2	1		Y
Ecklonia maxima	Kelp Ecklonia																							Y
Emerita austroafricana	Mole crab/ sea lice	5		4												3	1				2			Y
Eunice aphroditois	Bobbit worm (errant worm)	5		4												3	1				2			Y
Gelidium abbottiorum, pteridifolium, capense	*Gelidium* other spp																							Y
Gelidium pristoides	*Gelidium pristoides*																							Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Gracilaria	Gracilaria																							Y
Grapsus spp.	Green & Natal rock crab	5		4												3	1				2			Y
Gunnarea capensis	Coral worm/ Cape reef worm	5		4												3	1				2			Y
Haliotis midae	Abalone/ perlemoen	1		1																			1	Y
Haliotis spadicea	Siffie	5		4												3	1				2			N
Haliporoides triarthrus	Pink prawn (deepwater trawl)	5		4												3	1				2			Y
Hippa adactyla	Mole crab/ sea lice	5		4												3	1				2			Y
Jasus lalandii	West Coast rock lobster	2		1												3								Y
Laminaria pallida	Kelp *Laminaria*																							Y
Loligo devaucelii	Indian squid		2	5										3		4								Y
Loligo reynaudii	Chokka squid			1																				Y
Marphysa sanguinea	Wonder worm	5		4												3	1				2			Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Metapenaeus monoceros	Brown swimming prawn	2	6											1		5	4				3			Y
Mytilus, Choromytilus	Black mussel	5		4												3	1				2			Y
Octopus vulgaris	Octopus	5		4												3	1				2			Y
Ocypode spp.	Ghost crabs	5		4												3	1				2			Y
Ovalipes trimaculatus	Three-spotted swimming crab																1						1	N
Oxystele sinensis	Periwinkle/ pink-lipped topshell	5		4												3	1				2			Y
Panulirus homarus	East Coast rock lobster	5		4												3	1				2			Y
Peneaus indicus	White swimming prawn	2	6											1		5	4				3			Y
Perna perna	Brown mussel	5		4												3	1				2			Y
Plagusia chabrus	Cape/red rock crab	5		4												3	1				2			Y
Polybrachiorhynchus dayi	Tapeworm/ribbon worm	5		4												3	1				2			Y
Porphyra/ Pyropia spp.	*Porphyra*																							Y
Pseudonereis variegata	Mussel worm	5		4												3	1				2			Y

Species name	Common name	Artisanal boat	Beach seine	Commercial boat	Demersal trawl (inshore)	Demersal trawl (offshore)	Drift gillnets	Hake handline	Hake longline	Inshore/estuarine gillnets	Midwater trawl	Pelagic gillnets	Pelagic longline	Prawn trawl	Purse seine	Recreational boat	Recreational shore	Shark longline	Spear fishing	Tuna pole	Subsistence shore	Commercial shore	Experimental/exploratory	In small-scale?
Pyura stolonifera	Red bait	5		4												3	1				2		X	Y
Saccostrea cucculata	Natal rock oyster																1							Y
Scylla serrata	Mud/mangrove/ Knysna crab	4														2	1				3			Y
Salicornia spp.	Samphire, glassworts																							Y
Sarcocornia spp.	Samphire, glassworts																							Y
Solen capensis	Pencil bait	5		4												3	1				2			Y
Solen cylindricus	Pencil bait	5		4												3	1				2			Y
Striostrea margaritacea	Cape rock oyster																1					1		Y
Talorchestia capensis	Sandflea	5		4												3	1				2			Y
Turbo cidaris cidaris	Smooth turban shell																1							Y
Turbo sarmaticus	Alikreukel	5		4												3	1				2			Y
Ulva spp.	Sea lettuce																							Y
Upogebia africana	Mud prawns	5		4												3	1				2			Y

SCIENTIFIC OUTPUT OF THE BRANCH: FISHERIES MANAGEMENT OF THE DEPARTMENT OF ENVIRONMENT, FORESTRY AND FISHERIES (DEFF)

2020

This section lists the scientific output of the Fisheries Management Branch for 2020, arranged by output category. Figures in brackets represent the output for the previous two years, 2019 and 2018, respectively, and are included for comparison. From late March 2020 onwards, travel and physical meetings were severely curtailed by restrictions associated with the COVID-19 pandemic, which affected certain categories of output. In the category 'peer-reviewed publications' there were 56 (41, 30) papers, a substantial increase compared with the previous two years. Given the time-lag associated with the publication process, it is possible that output in this category does not reflect the effects of the pandemic to the same extent as that in certain other categories. There were 11 (12, 9) documents in the category 'theses/dissertations/tertiary projects', none of which were DEFF-authored but all of which were DEFF-supervised or co-supervised. There were 20 (50, 11) documents in the category 'book chapters, published reports and popular articles'. Although this represents a considerable decline compared with 2019, the output in that year was strongly influenced by two particular types of periodic published report, *The IUCN Red List of Threatened Species* and the *South African National Biodiversity Assessment 2018*. There were only 11 (40, 27) 'contributions to symposia and conferences, and public presentations', a category of output that was severely affected by the pandemic. Presentations were made in person prior to the lockdown of late March 2020, or virtually thereafter. There were 17 (64, 53) 'contributions to workshops, short courses, and management and scientific bodies, and unpublished technical reports', another pandemic-affected category. Of these, 8 were contributions to virtual meetings of regional fisheries management organisations, the *Indian Ocean Tuna Commission* (IOTC) (6) and the *International Commission for the Conservation of Atlantic Tunas* (ICCAT) (2). Finally, there were 55 (59, 68) unpublished working group documents. This last category represents the output of the research component of the Branch in terms of its line function to provide scientific advice for resource management. The number of contributions is very similar to previous years, suggesting that the output of the working groups was consistent, despite the pandemic

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SCIENTIFIC OUTPUT OF THE BRANCH: FISHERIES MANAGEMENT OF THE DEPARTMENT OF FORESTRY, FISHERIES AND THE ENVIRONMENT (DFFE)

2021

This section lists the scientific output of the Fisheries Management Branch for 2021, arranged by output category. Figures in brackets represent the output for the previous two years, 2020 and 2019, respectively, and are included for comparison. For the second consecutive year, travel and in-person meetings were severely curtailed by restrictions associated with the COVID-19 pandemic, which limited certain categories of output. In the category ‘peer-reviewed publications’ there were 37 (56, 41) papers. There were 12 (11, 12) documents in the category ‘theses/dissertations/tertiary projects’, none of which were DFFE-authored but all of which were DFFE-supervised or co-supervised. There were 24 (20, 50) documents in the category ‘book chapters, published reports and popular articles’, and only 18 (11, 40) ‘contributions to symposia and conferences, and public presentations’, a category of output that, as was the case in 2020, was affected by the pandemic. Easing of lockdown restrictions allowed some presentations to be made in person, rather than virtually, towards the end of the year. There were 22 (17, 64) ‘contributions to workshops, short courses, and management and scientific bodies, and unpublished technical reports’, another pandemic-affected category. Of these, 10 were contributions to virtual meetings of the *Indian Ocean Tuna Commission* (IOTC). Finally, there were 51 (55, 59) unpublished working group documents. This last category represents the output of the research component of the Branch in terms of its line function to provide scientific advice for resource management. As in 2020, the number of contributions was similar to previous years, suggesting consistent output of the working groups, notwithstanding the pandemic.

Peer-reviewed Publications (names of Fisheries Management staff shown in bold, Ocean & Coasts in italics

Asbury TA, Bennett R, Price AS, **da Silva C**, Bürgener M, Klein JD, Maduna SN, Sidat N, Fernando S, Bester-van der Merwe AE. 2021. Application of DNA mini-barcoding reveals illegal trade in endangered shark products in southern Africa. *African Journal of Marine Science* 43: 511–520.

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Discomedusae) off Namibia inferred from stable isotopes (δ^{15}N and δ^{13}C). *African Journal of Marine Science* 43: 87–93.

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Adams L. 2021. An assessment of the Amathole benthic fauna to aid marine spatial planning. MSc thesis, University of Cape Town, South Africa. Supervisors: Karenyi N, **Parker D**.

Bachoo T. 2021. Reproductive state and characterization of wild and cultured *Ulva* species from South Africa. MSc thesis, University of Cape Town, South Africa. Supervisors: Bolton JJ, **Macey BM**, Reddy MM.

Baur NF. 2021. Detecting the marine haemogregarine parasite *Haemogregarina koppiensis* in evileye pufferfish *Amblyrhynchotes honckenii* using DNA barcoding. BSc Hons thesis, University of Cape Town. Supervisors: Reed C, **Christison KW**, **Lamberth SJ**.

De Souza C. 2021. Long-term faunal and physico-chemical changes of the Keurbooms-Bitou Estuary. BSc Hons thesis, University of Cape Town. Supervisors: Griffiths CL, Botha PA, **Lamberth SJ**.

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Groenewald G. 2021. Developing dynamic energy budget (DEB) models for small pelagic fishes in the Southern Benguela. PhD thesis, University of Cape Town, South Africa. Supervisors: Moloney CL, **van der Lingen CD**.

Komane G. 2021. Molecular characterization of Flavobacteriaceae isolated from farmed rainbow trout (*Onchorhynchus mykiss*). MSc thesis, University of Cape Town, South Africa. Supervisors: **Macey BM**, Coyne VE, Flemming L.

Lester NC. 2021. The interaction of acidification and warming on the South African abalone, *Haliotis midae*, and the potential for mitigation in aquaculture. PhD thesis, University of Cape Town, South Africa. Supervisors: Bolton JJ, Lucas M, **Auerswald L**.

Mdhluvu RM. 2021. Growth performance, blood parameters and meat quality in dusky kob (*Argyrosomus japonicus*, Sciaenidae) offered crocodile meal as a replacement for the fish-meal. MSc thesis, University of Mpumalanga, South Africa. Supervisors: Mlambo V, O'Brien G, **Madibana MJ**.

Mare C. 2021. Examining the trophic ecology of five myctophid genera in the southern Benguela using morphological, stomach content and stable isotope analysis. MSc mini-thesis, University of Cape Town, South Africa. Supervisors: **van der Lingen CD**, Reed CC.

Rakgoale A. 2021. Development of broodstock conditioning-, induced spawning-, and hatchery methods for the South African spotted grunter (*Pomadasys commersonnii*). MSc thesis, University of Cape Town, South Africa. Supervisors: Marco H, **Fouche CH**.

Reed JR. 2021. Integrating spatial fisheries management and marine spatial planning in South Africa. PhD thesis, Nelson Mandela University. Supervisors: Lombard A, Sink K, **Kerwath S**.

Book Chapters, Published Reports and Popular Articles

Bernard S, Kudela R, Robertson Lain L, **Pitcher GC** (eds). 2021. *Observation of harmful algal blooms with ocean colour radiometry*. *IOCCG Report Series* No. 20. Dartmouth, Canada: International Ocean Colour Coordinating Group.

Elliott M, Houde ED, **Lamberth SJ**, Lonsdale J-A, Tweedley JR. 2021. Management of fishes and fisheries in estuaries. In: Whitfield AK, Able KW, Blaber SJM, Elliot M (eds), *Fish and fisheries in estuaries: a global perspective*, vol. II. Hoboken, NJ, USA: John Wiley & Sons Ltd. pp 706–796.

Glibert PM, **Pitcher GC**. 2021. Harmful algal blooms, changing ecosystem dynamics and related conceptual models. In: Bernard S, Kudela R, Robertson Lain L, **Pitcher GC** (eds), *Observation of harmful algal blooms with ocean colour radiometry*. *IOCCG Report Series* No. 20. Dartmouth, Canada: International Ocean Colour Coordinating Group. pp 13–24.

GlobalHAB. 2021. Guidelines for the study of climate change effects on HABs. In: Wells M, Burford M, Kremp A, Montresor M, **Pitcher GC** (eds), *IOC Manuals and Guides* No. 88. Paris, France: UNESCO-IOC/SCOR.

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Hampton I, **Githaiga-Mwicigi J**, **Lamberth SJ**, **Pitcher G**, **Pretorius M**, Samodien F, **van der Lingen CD**, **Yemane D**. 2021. Report of the Fisheries Climate Change Task Team Workshop on Fisheries Vulnerability to Climate Change, Foretrust Building, Cape Town. Department of Forestry, Fisheries and the Environment. ISBN: 978-0-621-48870-8.

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Contributions to Symposia and Conferences, and Public Presentations

Becker FK, **Shabangu FW**, Gridley T, Wittmer HU, Marsland S. 2021. Sounding out a continent: seven decades of bio-acoustics research in Africa. *Society for Conservation Biology's 30th International Congress for Conservation Biology (ICCB 2021), 13–17 December, online virtual conference*. (oral presentation)

Brinkman F, Wilhelm M, **Geja Y**, **van der Lingen C**. 2021. Using otolith bio-chronologies from sardine (*Sardinops sagax*) in the southern Benguela to identify ecosystem shifts. *TRIATLAS General Assembly, 27 September–1 October, online virtual conference*. (poster presentation)

Daly R, **Parker D**, Cliff G, Jordaan GL, Nomfundo N, Bennett RH, Mann BQ. 2021. Long-term catch trends and risk assessment of the critically endangered whitespotted wedgefish (*Rhynchobatus djiddensis*) from South Africa. *6th Southern African Shark and Ray Symposium, 17–19 November, Gansbaai, South Africa*. (oral presentation)

Dames NR, Wallschuss S, Rocke E, **Pitcher G**, Rybicki E, *Pfaff M*, Fawcett S, Moloney CL. 2021. Short-term dynamics of nanoplankton and picoplankton production and nitrogen uptake during winter in an embayment of the Southern Benguela upwelling region. *South African Society for Microbiology Conference, 4–6 May, online virtual conference*. (poster presentation)

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da Silva C, **Parker D**, **Lamberth SJ**, **Kerwath SE**. 2021. Using charismatic species to drive conservation; helpful or harmful? *6th Southern African Shark and Ray Symposium, 17–19 November, Gansbaai, South Africa.* (oral presentation)

Lamberth SJ, da Silva C, Hutchings K, **Kerwath SE**. 2021. Nice story little data, estimating illegal gillnet catches in SA? *6th Southern African Shark and Ray Symposium, 17–19 November, Gansbaai, South Africa.* (oral presentation)

Nhleko J, **Lamberth SJ**. 2021. Spatio-temporal distribution of benthic macrofauna of the large fluvially-dominated Kei Estuary, South Africa in response to a flood. *ECSA 58–EMECS 13: Estuaries and coastal seas in the Anthropocene – structure, functions, services and management, 6–10 September, Hull, United Kingdom.* (oral presentation)

Nhleko J, **Lamberth SJ**. 2021. Temporal and spatial variability of the benthic invertebrates of the Orange River Estuary. *The Annual Science and Governance Forum of the Benguela Current Convention, 3–5 November, online virtual conference*. (oral presentation)

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Notes