STATUS OF THE SOUTH AFRICAN MARINE FISHERY RESOURCES 2025

forestry, fisheries
& the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

2030 NDP

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ISBN: 978-1-77997-470-9
DOI: http://dx.doi.org/10.15493/DFFE.10000008
How to cite this document: DFFE (Department of Forestry, Fisheries and the Environment). 2025. Status of the South African marine fishery resources 2025. Cape Town: DFFE
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Cover photo: Photo library, DFFE
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Acronyms and abbreviations

ABNJ	Area beyond national jurisdiction
ASPM	Age-structured production model
BCLME	Benguela Current Large Marine Ecosystem
B_{MSY}	Biomass that would produce MSY
B^{sp}	Spawning biomass
CAFMLR	Consultative Advisory Forum for Marine Living Resources
CCAMLR	Convention for Conservation of Antarctic Marine Living Resources
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CITES	Convention on International Trade in Endangered Species
CL	Caudal length
CMM	Conservation and management measure
CO_2	Carbon dioxide
CPUE	Catch per unit effort
CR	Critically endangered
DFFE	Department of Forestry, Fisheries & the Environment
DNA	Deoxyribonucleic acid
EAF	Ecosystem approach to fisheries
EC	Exceptional circumstances
EEZ	Exclusive economic zone
EFZ	Exclusive fishing zone
EM	Electronic monitoring
EN	Endangered
ERH	Exploratory right holder
ETP	Endangered, threatened or protected
FAD	Fish aggregating device
FAO	Food and Agriculture Organisation of the United Nations
FIAS	Fisheries independent abalone survey
FIMS	Fisheries independent monitoring survey
FIP	Fisheries improvement project
FMA	Fishery management area
FRS	Fisheries research ship
F_{MSY}	Fishing mortality that would produce MSY level
FRAP	Fishing rights allocation process
GIS	Geographic information system
GLM	General linear model
GLMM	General linear mixed model
ICCAT	International Convention for the Conservation of Atlantic Tunas
ICE	Island closure experiment
ICSEAF	International Commission for the South East Atlantic Fisheries
IOTC	Indian Ocean Tuna Commission
IPOA	International plan of action
IUCN	International Union for the Conservation of Nature
IUU	Illegal, unreported and unregulated fishing
JABBA	Just another Bayesian biomass assessment model
JARA	Just another risk assessment
KZN	KwaZulu-Natal
LC	Least concern
LOA	Length overall
LPL	Large pelagic longline fishery
MARIP	Marine remote imagery platform
MIBA	Marine important bird area
MLRA	Marine Living Resources Act
MPA	Marine protected area
MSC	Marine Stewardship Council
MSY	Maximum sustainable yield
MSYL	Maximum sustainable yield level
NDF	Non-detrimental finding
NGO	Non-governmental organisation
NMLS	National marine linefish system
NPOA	National plan of action
OMP	Operational management procedure
ORI	Oceanographic Research Institute
PEI-EEZ	Prince Edward Island exclusive economic zone
PMCL	Precautionary management catch limit
POPS	Persistent organic pollutants
PUCL	Precautionary upper catch limit
PVC	Polyvinyl chloride
RFMO	Regional fisheries management organization
RH	Right holder
RY	Replacement yield
SADSTIA	South African Deep Sea Trawling Industry Association
SAEON	South African Environmental Observation Network
SAIAB	South African Institute for Aquatic Biodiveristy
SANBI	South African National Biodiversity Institute
SAR	Shark assessment report
SB	Shell breadth
sBRUV	Stereo baited remoted underwater video

SECIFA	South East Coast Inshore Fishing Association
SEFRA	Spatially explicit fisheries risk assessment
SNP	Single nucleotide polymorphism
SPR	Spawning potential ratio
SSB	Spawning stock biomass
SSB_{MSY}	Spawning stock biomass at MSY level
SST	Sea surface temperature
TAB	Total allowable bycatch
TAC	Total allowable catch
TAE	Total allowable effort
TNP	Tsitsikamma National Park
TPL	Tuna pole-line fishery
TRAFFIC	The Wildlife Trade Monitoring Network
tRFMO	Tuna regional fisheries management organization
TRO	Total reproductive output
TURF	Territorial user rights in fisheries
UCT	University of Cape Town
USA	United States of America
VU	Vulnerable
WWF	World Wide Fund for Nature
SOLSTICE	Sustainable Oceans, Livelihoods and Food Security Through Increased Capacity in Ecosystem Research in the Western Indian Ocean

Overview

This report presents the most up-to-date information and analyses of the status of the marine fishery resources in South Africa at the time of compilation. 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 presented in the section entitled "About this report", which follows the overview. The number of fish resources covered in this report has trebled from the 22 included in 2008 when this report was first produced, to 65 in the current report (Figure I).

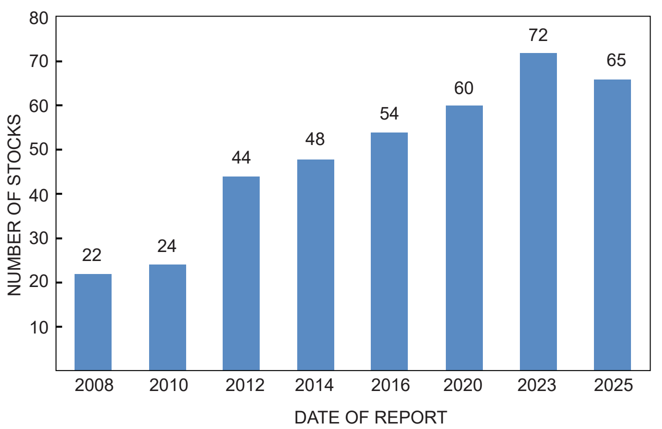


Figure I: The number of fish stocks assessed between 2008 and 2025

The most recent information regarding stock status indicates that almost 70% of South Africa's marine fishery resources are considered not to be of concern (being of unknown, abundant, or optimal status)[1], while 31% are of concern (being of depleted or heavily depleted status) (Table I). The apparent regression in the percentage of stocks considered not to be of concern from 2008 to the present is an artefact of the larger number of stocks being assessed today and the nature of the stocks assessed, as research effort has grown towards also conducting assessments on a wider range of non-target stocks for which concern has been raised by the scientific community or by civil society groups.

Viewing the same information in graphical form (Figure II) indicates that although there is fluctuation between years in the percentage of stocks considered of concern or not, the overall pattern has remained relatively stable throughout the period of production of these reports

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

	2008	2010	2012	2014	2016	2020	2023	2025
Stocks not of concern	17 (77%)	18 (75%)	25 (57%)	31 (65%)	36 (67%)	36 (60%)	48 (67%)	45 (69%)
Stocks of concern	5 (23%)	6 25%)	19 (43%)	17 (35%)	18 (33%)	24 (40%)	24 (33%)	20 (31%)
Number of stocks assessed per year.	22	24	44	48	54	60	72	65

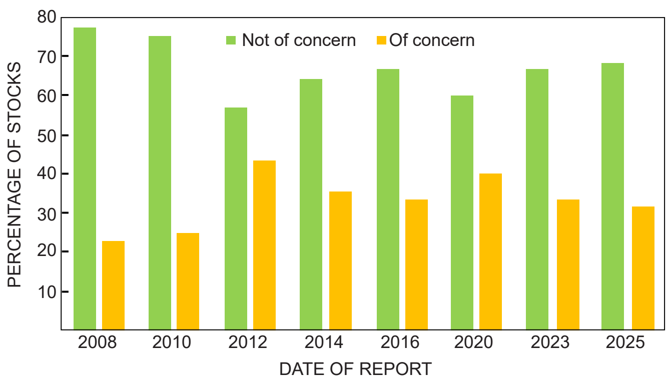


Figure II: Percentage of stocks considered of concern or not

Over the past 10 years since the 2014 report, the status of 58% of the stocks assessed then and in the current report has remained the same, while 15% showed an improvement in status, and 28% indicated a deterioration. Those for which the perception[2] of stock status made gains include some linefish species, such as silver kob and snoek. Also making gains over the past 10 years were deep-water prawns, and South Coast rock lobster, which has recovered in response to the stock recovery plan implemented for this resource. The status of the sardine resource has shown improvement over the past 5 years, returning to the status that it was a decade ago. The status of yellowfin tuna in the Atlantic Ocean has increased over the past 10 years, while the status of the resource in the Indian Ocean has declined since 10 years ago, although has shown some improvement in the past 5 years. The status of bigeye tuna in the Atlantic Ocean has also increased over the past 5 years.

[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 improvements or deteriorations in the perception of the status may not necessarily be indicative of actual changes in the stock status.

The status of a number of resources has deteriorated over the past 5 to 10 years. The status of anchovy has declined since 10 years ago, but has remained stable over the past 5 years. A similar pattern is observed for harders, Patagonian toothfish, West Coast rock lobster, West Coast round herring, and soupfin shark. The status of swordfish and bigeye tuna in both the Indian and Atlantic Oceans has deteriorated over both the last 5 and 10 years, and albacore in the Atlantic Ocean has also deteriorated in the past 10 years but remained stable over the past 5 years.

The following presents a brief summary for each resource group:

- **Abalone:** The abalone resource remains in a depleted state, with the collective fishing pressure from both the legal commercial fishery and illegal harvesting being higher than is sustainable, and therefore likely to worsen the resource status in the future.
- **Agulhas sole:** Uncertainty continues around the status of the Agulhas sole resource, but recent assessment points to the resource status as being abundant, and the resource being fished at sustainable levels.
- **Cape hakes:** The assessment of the deepwater hake resource indicates that the status remains optimal, with fishing pressure being at levels which will retain this resource above the maximum sustainable yield level. The status of the shallow-water hake resource has not changed over the past decade, and the resource status and fishing pressure remain optimal.
- **Cape horse mackerel:** The status of Cape horse mackerel remains optimal, with the resource well above the maximum sustainable yield level, while fishing pressure remains at a level likely to maintain the resource status at this level.
- **Kingklip:** The kingklip resource status remains optimal, and this has not changed over the past 10 years.
- **Linefish:** The status of silver kob and snoek has improved since 2014, and has and remained stable since then. A number of linefish species, including carpenter, Cape bream[3], slinger and yellowtail, remain stable. The most heavily depleted linefish species, including dageraad, dusky kob, red steenbras and seventy-four, remain in this state, with fishing pressure still considered to be heavy for these resources (other than for seventy-four for which the moratorium remains in place).
- **Monkfish:** The updated assessment indicates that the resource status remains stable in the optimal state, with fishing pressure being aligned to retain this status.
- **Netfish:** The status of harders has declined over the past 10 years, and this resource is now considered heavily depleted. Fishing pressure remains heavy, and is likely to compromise recovery of the harder resource. In particular, illegal gillnetting appears to be having a significant negative impact on this resource.
- **Oysters:** The oyster resource along the KwaZulu-Natal coast is considered to be optimally utilised, although uncertainties around the true stock status remain. There is evidence of over-harvesting of oysters in the Southern Cape, and there are concerns around the harvesting of subtidal 'mother beds' here, leading to the fishing pressure on this resource being assessed as heavy.
- **Patagonian toothfish:** The assessment of Patagonian toothfish indicates that the resource remains above the maximum sustainable yield level, and its status is therefore considered to be optimal. Fishing pressure is at a level likely to keep the resource above the maximum sustainable yield level.
- **Seaweeds:** The status of kelp resources continues to be optimal, with fishing pressure remaining at a level likely to maintain this status. Other seaweed species are considered to be under-utilised.
- **Sharks:** The most heavily depleted sharks are soupfin, and the status of several other cartilaginous fish resources, including twineye skate, dusky shark, yellowspotted skate and puffadder shyshark remain of concern. Fishing pressure is higher than optimal for a number of shark and ray resources, including smoothhound and shortfin mako sharks.
- **Small invertebrates and new fisheries:** The status of the white mussel, octopus and East Coast round herring resources remains uncertain. Investigations are ongoing to assess the potential for new fisheries.
- **Small pelagic fishes:** The status of the sardine resource has improved from being considered between depleted and optimal in the 2023 Status of the South African Marine Fishery Resources report, to being optimal, given sustained increases in biomass over the last 3 years and the most recent (2023) biomass estimate, which was well above the long-term average. The anchovy resource is considered optimal. The status of West Coast round herring is considered to be optimal, with fishing pressure at a level likely to maintain this resource status.
- **South Coast rock lobster:** The status of the South Coast rock lobster resource has improved over the past 10 years in response to the stock rebuilding plan, and the resource status is considered to be optimal, with fishing pressure light to optimal.
- **Squid:** The assessment of the squid resource indicates that the status of this resource continues to be optimal, with fishing pressure also at the optimal level.
- **KwaZulu-Natal crustaceans:** Uncertainty remains around the true status of deep-water prawns, although fishing pressure on deep-water prawns is considered to be heavy.
- **Tunas and swordfish:** The status of both yellowfin tuna and albacore in the Atlantic and Indian Oceans is considered to be optimal, with fishing pressure at a level likely to retain this status. Swordfish, bigeye tuna and Southern bluefin tuna are all considered to be depleted in both the Atlantic and Indian Oceans, with fishing pressure regarded as heavy for swordfish and Indian Ocean bigeye tuna, but optimal for Southern bluefin tuna and Atlantic bigeye tuna.
- **West Coast rock lobster:** The West Coast rock lobster resource is considered to be heavily depleted, with fishing pressure continuing to be heavy and likely to result in a further decline in the status.

[3] Cape bream was formerly known as "Hottentot" or "Hottentot seabream".

Fishing pressure	Unknown	Unknown/ Abundant	Abundant	Abundant/ Optimal	Optimal	Optimal/ Depleted	Depleted	Depleted/ Heavily depleted	Heavily depleted
Heavy	Oysters (S Cape); Rajidae spp.; Bronze whaler shark Deep-water crustaceans; Shortfin mako shark	Spearnose skate	Biscuit skate; Bluntnose dogshark		Blue shark		Swordfish (Atl.); Bigeye tuna (Ind.)	Abalone	Dageraad; Red steenbras; Dusky kob; Soupfin shark; Harders; West Coast rock lobster
Optimal/ Heavy									
Optimal	Oysters (KZN); White mussel		Shallow-water hake	South Coast rock lobster	Deep-water hake; Cape horse mackerel; Kingklip; Yellowtail; Slinger; Carpenter; Monkfish; Patagonian toothfish; Kelp; Anchovy; Sardine; Squid; Yel-lowfin tuna (Ind. & Atl.); West Coast round herring; Albacore (Ind. & Atl.)		Swordfish (Ind.); Bigeye tuna (Atl.); Santer; Silver kob; Southern bluefin tuna (Ind. & Atl.); Shortfin mako shark		
Optimal/ Light					South Coast rock lobster				
Light	Agulhas sole; Octopus; East Coast round herring		Cape bream; Snoek; Slime skate; Whitespotted smooth-hound shark; Seaweeds (non-kelps)				Twineye skate; Dusky shark		
Unknown/ Light									
Unknown	Leg skates; African softnose skate; Roughbelly skate; Munchkin skate; Leopard skate; Lesser guitar-shark; Izak catshark						Yellowspotted skate; 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 2024.

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 economically 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' through 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' through '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 status 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, or roughly 40% of pre-exploitation (pristine) biomass. Biomass can refer to that part of the population susceptible to capture (exploitable biomass), or a particular part of the population such as mature fish only (spawner biomass), or female fish. Limit reference points are generally formulated as a percentage of pre-exploitation biomass (i.e. biomass <25% of 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 less than 20 m depth, but the highest densities occur in waters 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

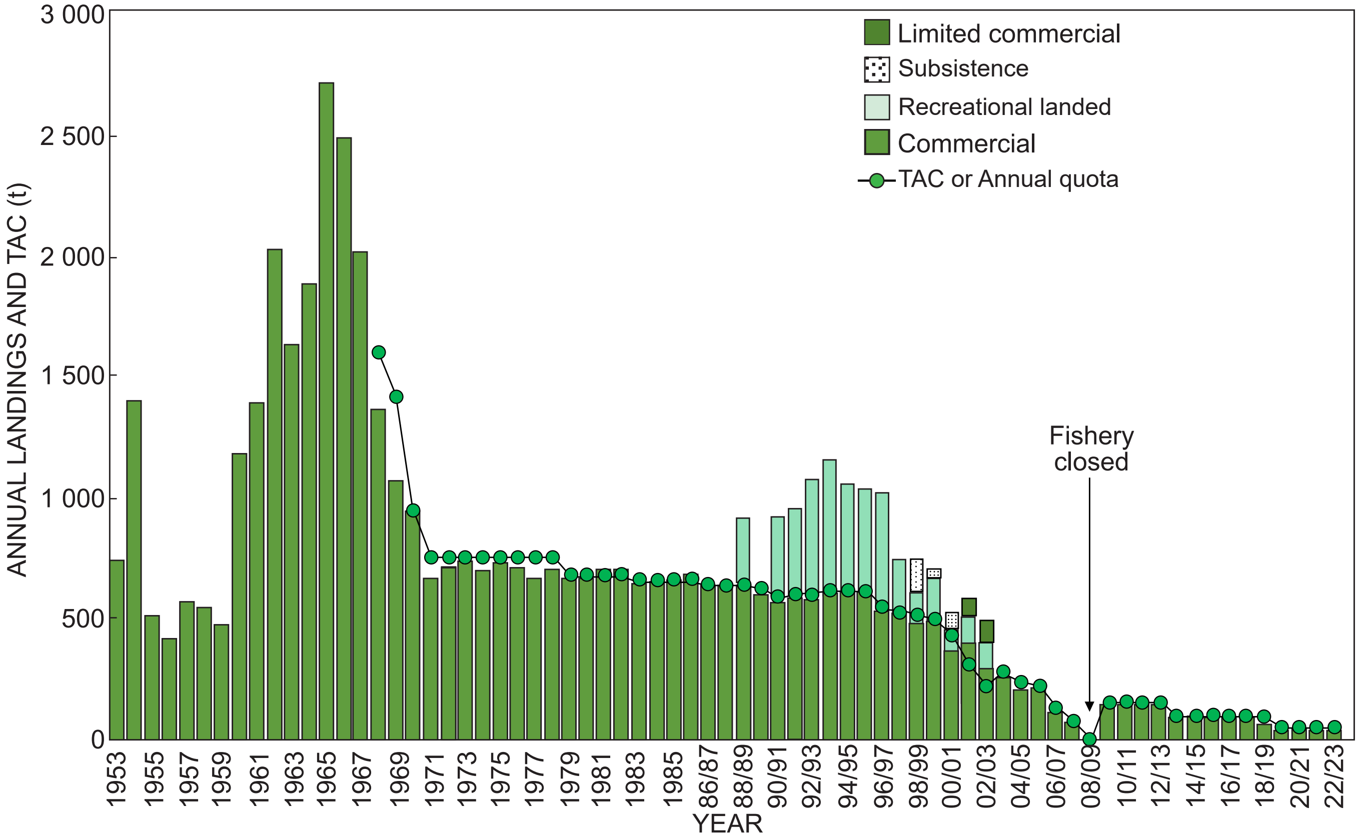


Figure 1: TAC and recorded (legal) annual landings for the abalone fishery from 1953 to 2022/23. Landings for the recreational sector are only available since 1988/1989. Note that the substantial illegal catches are not shown

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

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 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 and most productive, abalone fishing areas. The commercial 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

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		Y – up to 2020		
	Abundance		N	
	Size composition	Y – up to 2020	N	
Commercial	CPUE	Standardised – up to 2020	Nominal only	
	Size composition	N	N	
Poaching	Compliance	N	N	
	TRAFFIC	N	N	Y

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 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 (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 *Haliotis 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 2017. 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 for Zones A to D and E to G 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 of imports of *Haliotis midae* into key importing countries provided by TRAFFIC. The aggregated poaching information (TRAFFIC) is available from 2018 to 2021, while the compliance data on confiscations and policing efforts has been obtained since 2015.

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 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 2017, data on trends in illegal catch (poaching), FIAS data and commercial CPUE that had become available since the 2016 assessment were inspected to determine if any change to the TAC recommendation made in 2016 was required.

An Abalone Scientist was appointed by the Department in 2023, filling a position that had been vacant since 2017. Since the full 2016 assessment, 2020 FIAS data have been obtained for Zones B, C and Dyer Island and an updated model-based assessment was conducted. No new data have been obtained for Zones A and D and there is no justification in moving away from the recommendations based upon the last projections made. As a result, these projections were used in the 2024 recommendation.

TAC recommendations for Zones E, F and G (Figure 2) have not been subject to similar model analyses in the past because of data limitations, and advice for these zones has been based

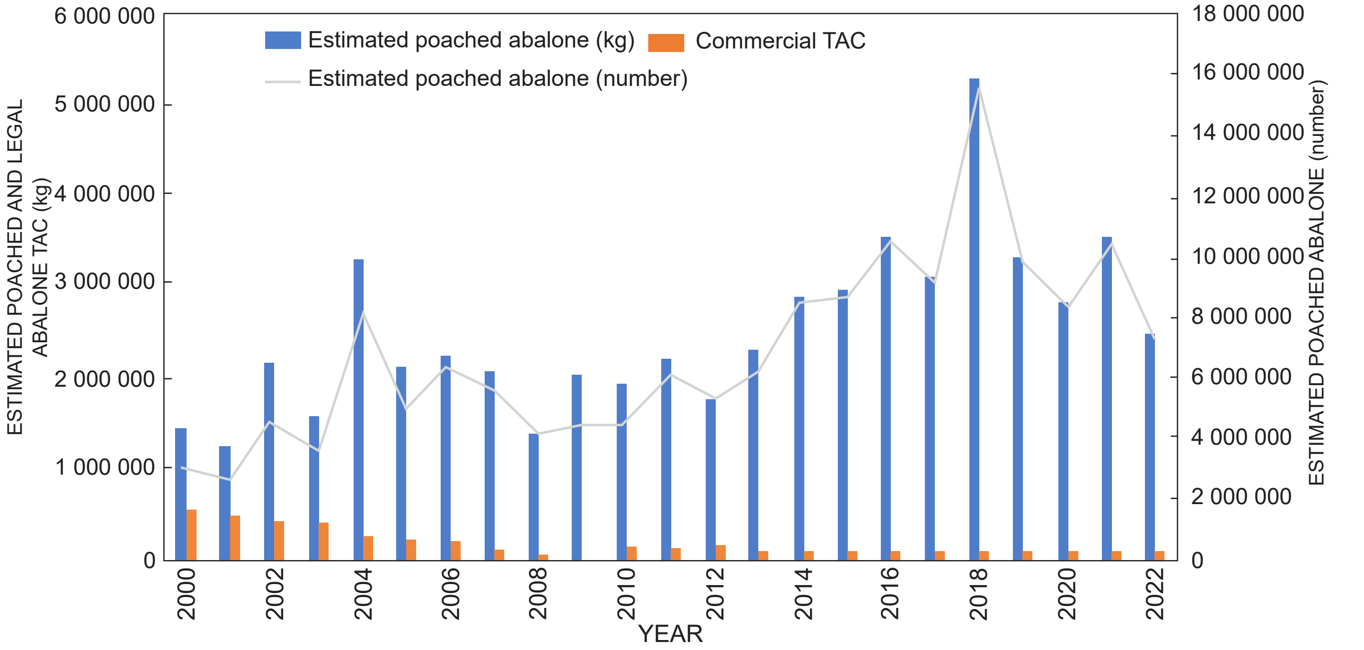


Figure 3: Estimated weight and number of poached abalone based on international trade data for the calendar years 2000–2022 (after Bürgener M, Tsolo K. 2023. An update to the estimate of poached *Haliotis midae*. Cape Town: TRAFFIC)

on inspection of trends in commercial CPUE, density from FIAS (for Zone F) and size composition.

As in 2017, an update of the 2016 model-based assessment was not undertaken and the 2024 recommendations for Zones A to D were basedon the examination of available indices to ascertain whether there had been any meaningful changes since the full assessment completed in 2016. Absence of compelling evidence to the contrary justified the continued use of these projections in 2024. In addition, in the absence of any new information, the decision rules used for Zones E to G since 2016 have been applied in 2024.

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). From 2019 to 2022, the estimated mass of poached abalone has remained around the level in the years prior to the 2018 peak, where we see between 8 and 10 million animals poached. For the last two seasons (2022/23 and 2023/24), no updated data have been received and a comprehensive trade data based poaching assessment will become available only for the following fishing season (TRAFFIC, pers. comm., August 2024). Further poaching data on abalone confiscations have been obtained and will be used in the 2025 assessment.

Commercial catch per unit effort (CPUE)

Zones A and B (Figure 4)

An inspection of the nominal CPUE data shows no marked changes in the CPUE from Zone A over the past three seasons. The apparent slight increase in the nominal CPUE in Zone B over the past three seasons must however be weighed against the consideration that these are nominal and not standardised CPUE data, and concerns that have been raised about the accuracy of CPUE data-reporting in Zones A and B in recent years. One of these is the concern that abalone commercial fishing vessels have been observed around the Dyer Island

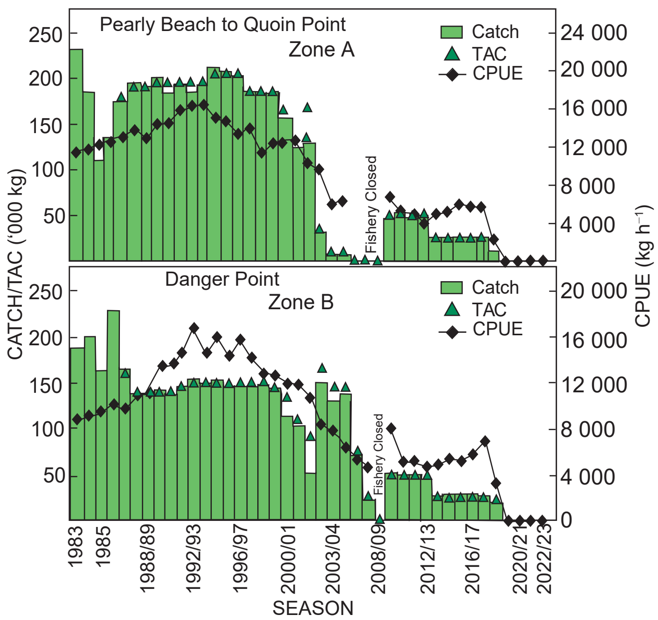


Figure 4: Catch and nominal (unstandardised) CPUE, with annual TAC indicated for Zones A and B for the period 1983 to 2022/23. There was a 0 TAC for Zones A and B for the 2019/20 season until 2022/23. Note that the fishery was closed during the 2008/09 season

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.

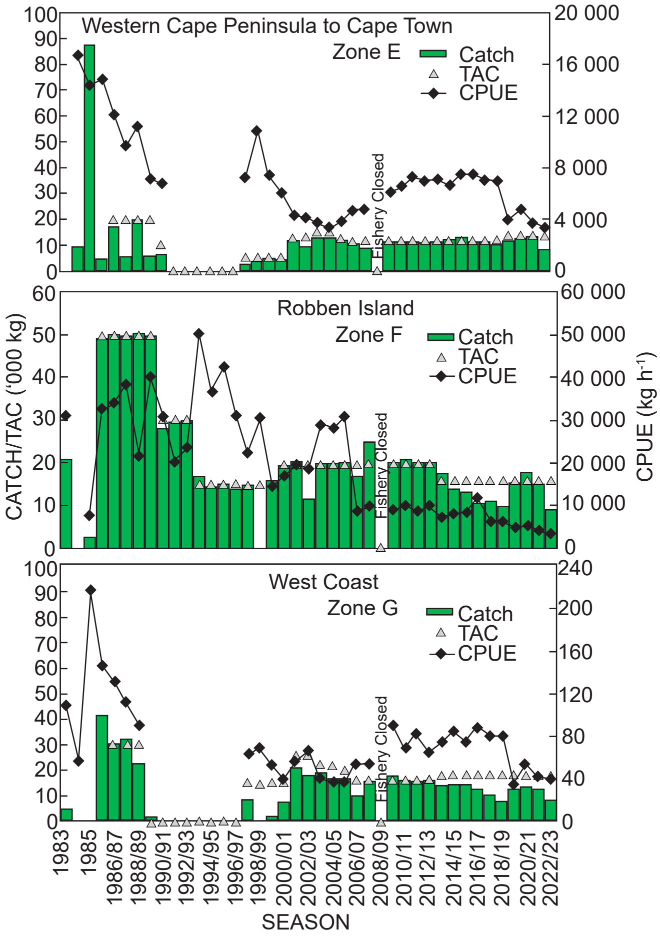


Figure 5: Catch and nominal (unstandardised) CPUE, with annual TACs indicated for Zones E, F and G for the period 1983 to 2021/22. Note that the fishery was closed for the 2008/09 season

Zones E to G (Figure 5)

Inspection of the nominal CPUE data shows a decline over the past three seasons (2020/21 to 2022/23) in Zones E, F and G. Under-reporting of catch data has been a challenge, and it is being investigated by the Department.

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 largescale 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 most 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 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 meant the loss of the main conservation area for abalone. As a result, Dyer Island has been closed to commercial fishing since the 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.

Further reading

Blamey LK, Branch GM, Reaugh-Flower KE. 2010. Temporal changes in kelp-forest benthic communities following an invasion by the rock lobster *Jasus lalandii*. *African Journal of Marine Science* 32: 481–490.

Lester NC. 2021. The interaction of acidification and warming on South African abalone, *Haliotis midae*, and the potential for mitigation in aquaculture. PhD thesis, University of Cape Town, Cape Town.

Okes N, Burgener M, Moneron S, Rademeyer J. 2018. Empty shells. An assessment of abalone poaching and trade from Southern Africa. TRAFFIC Report September 2018.

Plagányi ÉE, Butterworth DS. 2010. A spatial- and age-structured as- sessment model to estimate the impact of illegal fishing and ecosystem change on the South African abalone *Haliotis midae* resource. *African Journal of Marine Science* 32: 207–236.

Raemaekers S, Hauck M, Bürgener M, Mackenzie A, Maharaj G, Plagányi ÉE, Britz PJ. 2011. Review of the causes of the rise of the illegal South African abalone fishery and consequent closure of the rights-based fishery. *Ocean and Coastal Management* 54:433–445.

Tarr RJQ. 2000. The South African abalone (*Haliotis midae*) fishery: a decade of challenges and change. *Canadian Special Publications in Fisheries and Aquatic Science* 130: 32–40.

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	143	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	60	0
2019/20	50.5	41	0
2020/21	50.5	45	0
2021/22	50.5	41	0
2022/23	50.5	36	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 and 120 m depth, although they have occasionally also been caught in deeper water during research surveys. Agulhas sole landed by commercial vessels typically range between 30 cm and 40 cm total length.

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

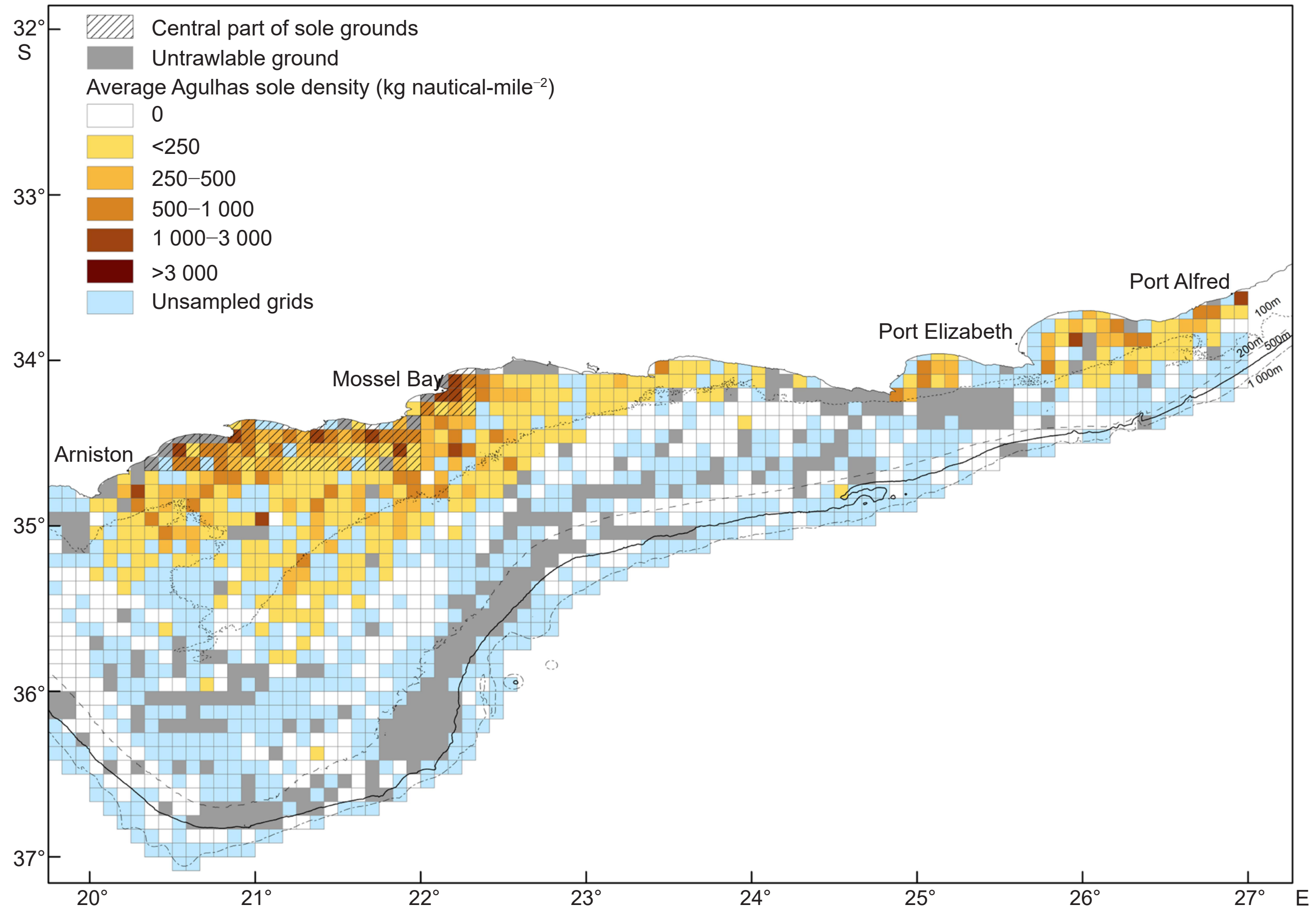


Figure 6: Distribution of Agulhas sole *Austroglossus pectoralis* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block. The area considered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

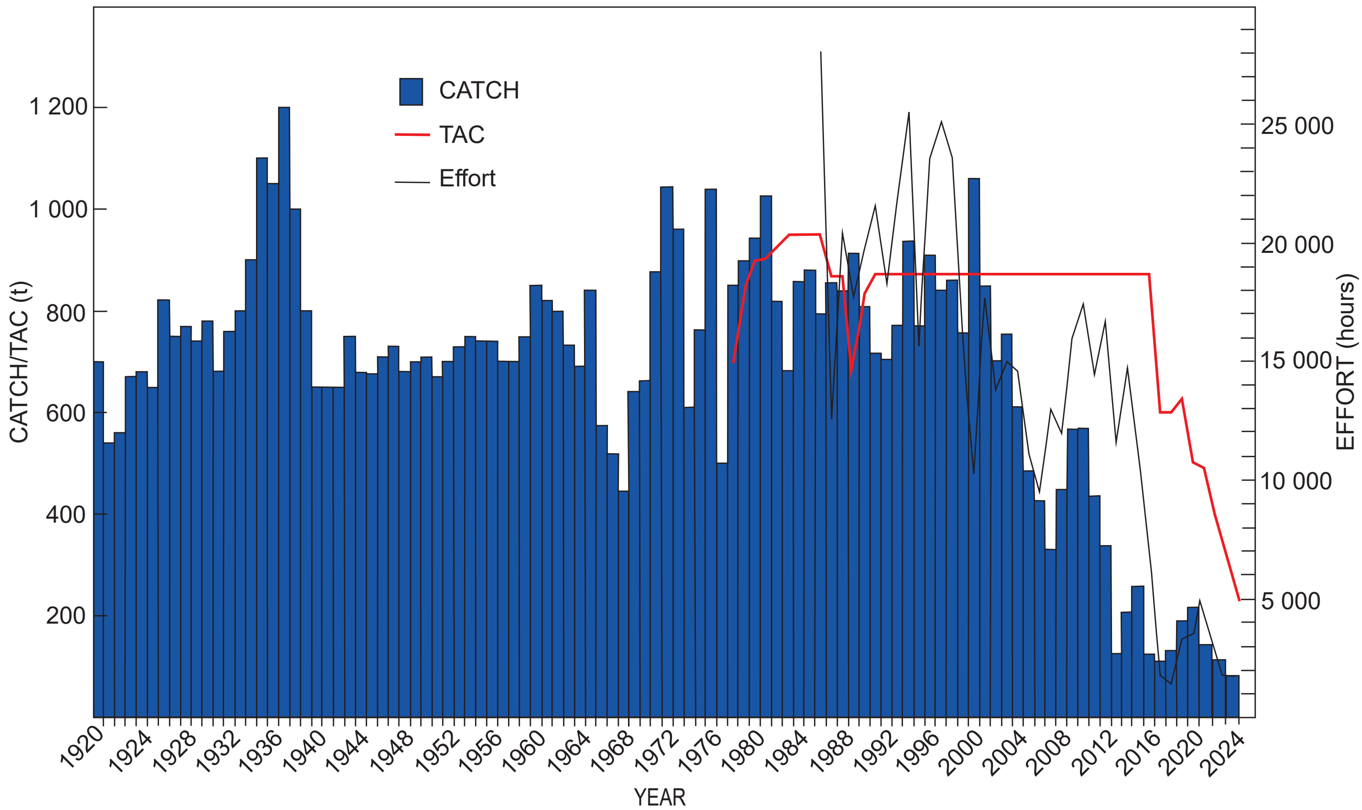


Figure 7: Annual catches (landings), TACs (both in t) and an estimate of annual total sole-directed fishing effort on the Agulhas sole grounds (hours) in the Agulhas sole fishery 1920–2023

fishery 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 was 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 by the late 1970s the fishery had gradually shifted to targeting several additional species, including hake and various linefish species. 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 deep-sea 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 east 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 Figure 6 and the section on Cape hakes).

Landings of Agulhas sole declined substantially after 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, 14 in 2015 and 7 by 2018). 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 fishing 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 deep-sea 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.

Despite 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 relative abundance) became apparent subsequent to 2009, with CPUE reaching unusually low levels over the period 2012 to 2016 and again from 2021 to 2023 (Figure 8). While this decline could reflect a decrease in resource abundance, the

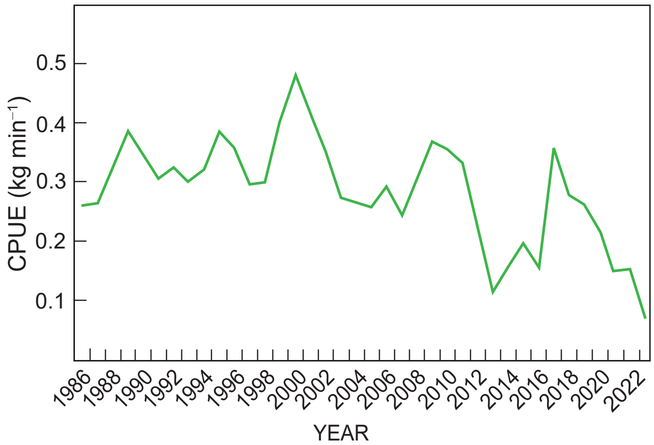


Figure 8: The commercial catch per unit effort (CPUE) index of abundance for Agulhas sole. A nominal index (kg min^{-1}) is calculated from cumulative annual catch and effort data for the period 1986–2023

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 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 forward 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 if 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 t.

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 in several respects from those conducted in the years immediately before:

- 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, the uninformative nature of the data coupled with only two years of higher CPUE values indicated that a precautionary approach would be appropriate. The scientific advice for the 2020 fishing season was consequently to reduce the TAC to 502 t and to retain the effort limitation imposed on the sole-directed component of the fishery. The same analytical approach was adopted for the 2020 and 2021 updates, which resulted in further reductions to the TAC (to 491 t for 2021 and 400 t for 2022). During the 2021 analysis, it was noted that three successive years of data updates had provided little or no support for the increased-mortality hypothesis, suggesting that there was no justification for retaining the effort limitation strategy imposed on sole-directed fishing on the sole grounds which had been in place since 2015. This management measure was consequently discarded, and the TAC resumed its role as the primary management measure applied to regulate the fishery.

The 2022 assessment update again used the same analytical approach and suite of r_1 and r_2 values (measures of intrinsic population growth rates pre- and post-2000 respectively) as considered in the previous two assessment updates but was confronted with circumstances where the commercial CPUE index of abundance had again declined to a low level (Figure 8). The results of this assessment differed from those conducted in 2020 and 2021 in that the models that best fitted the updated dataset were those that used the lowest post-2000 intrinsic growth rate parameter value ($r_2 = 0.05$). The parameter estimates of these models suggest that the status of the resource was lower than previously estimated, and while the results indicated that the resource was above B_{MSY} (the biomass yielding maximum sustainable yield), this was not by as large an extent as before. Furthermore, estimates of MSY and replacement yield were somewhat lower than indicated by the 2020 and 2021 assessment results. The assessment

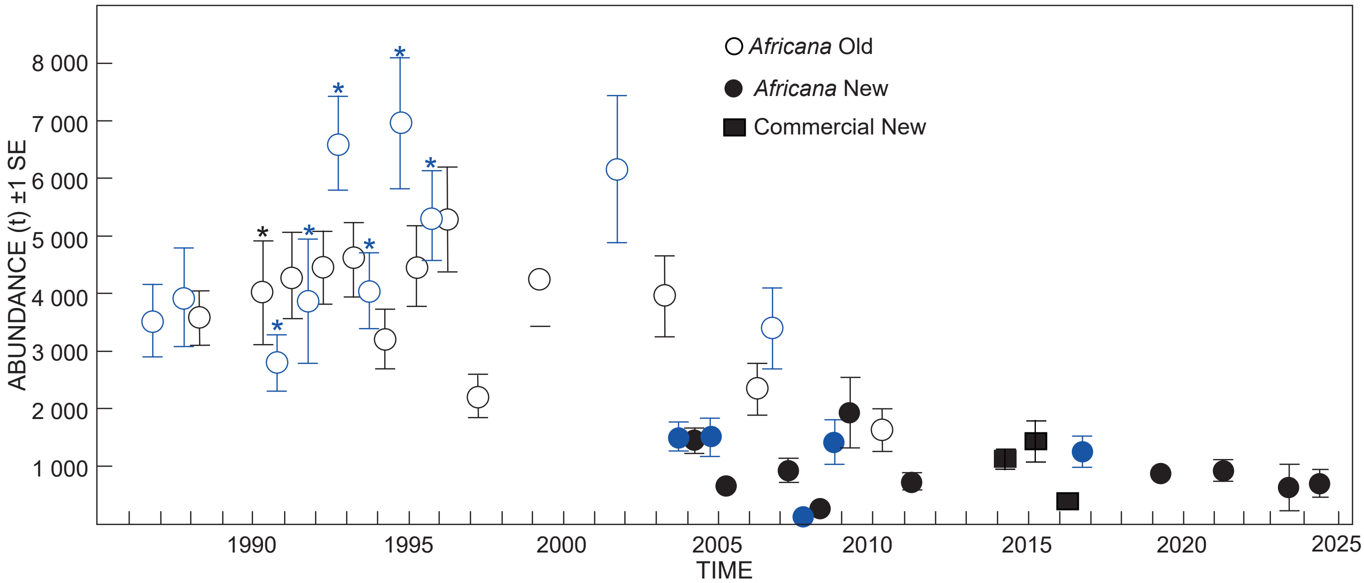


Figure 9: Agulhas sole abundance estimates (t) derived from fishery-independent swept-area demersal surveys. Estimates are illustrated for the various vessel-gear combinations. Autumn South Coast surveys are indicated with black symbols, while spring South Coast surveys are indicated with blue symbols. Surveys that only extended to the 200-m isobath have been included in the figure (indicated by asterisks) 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 FRS *Africana*, Commercial = commercial fishing vessel

results were used to set the Agulhas sole TAC for 2023 at 328 t.

The trend of increasingly pessimistic results from successive assessment updates continued in the 2023 update, which was conducted in circumstances where the nominal commercial CPUE index of abundance for 2022 was at a low level for the second consecutive year (Figure 8), and the 2023 autumn South Coast demersal survey index of abundance was also lower than had been observed in 2019 and 2021 (Figure 9). Estimates of resource depletion (current biomass relative to pre-exploitation biomass) yielded by the 2021 assessments were in the 74–78% range, dropping to 64–69% in the 2022 assessments and 58–63% in the 2023 assessment. Given the model assumption that B_{MSY} is 50% of pre-exploitation biomass (K), the results indicated that the resource is still above B_{MSY} as was indicated by the previous assessments, although not by as large an extent as before. Furthermore, estimates of MSY and replacement yield were lower than was the case in the 2021 and 2022 assessments. In view of these observations, the TAC for 2024 was set as the "composite" estimate of MSY averaged over the three best-fitting models, which yielded a value of 228 t (a reduction of 100 t from the 328-t TAC set for 2023).

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 covered 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 Agulhas 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

As described above, perceptions of the status and productivity of Agulhas sole have, in recent years, been complicated by declines in both catches and fishing effort since 2000 and marked fluctuations in commercial CPUE in recent years (and particularly the low values over 2013–2016 followed by a rapid increase to high values in 2018 and 2019, with another period of low values during 2022 and 2023) that have not really been matched by similar trends in the fishery-independent demersal survey abundance indices, which have remained relatively stable since the early 2000s. That the survey abundance index has not responded to the extended period of low catches and fishing effort with an increasing trend has led to the inclusion of a post-2000 regime-shift scenario in the recent assessments. It is a cause for concern that the assessments that have taken this regime shift into consideration generally "prefer" the lowest (and arguably unrealistically low) intrinsic-population-growth-rate parameter that was considered (r_2 = 0.05). A 2022 international stock assessment review panel recommended that several avenues should be explored before further attempts to model Agulhas sole dynamics are conducted. Work is consequently being directed at addressing the apparent conflict between the fishery-dependent (commercial

CPUE) and fishery-independent (demersal surveys) indices of abundance through spatiotemporal analyses of these data using advanced geostatistical modelling techniques. Attention should also be directed at evaluating possible evidence such as changes in environmental conditions, habitat, range distribution or ecological interactions to justify inclusion of the regime-shift hypothesis in the assessment modelling. Pending resolution of these issues, a *status quo* approach has been adopted in managing the fishery and the TAC for 2025 has been maintained at the 2024 level of 228 t, based on the observations that while the commercial CPUE index of abundance has continued to decline, with the level in 2023 being the lowest on record, the fishery-independent index of abundance in 2024 is at a level that is slightly higher than that for the preceding year. There is consequently little indication that recent catches have had a serious negative impact on the status of the resource.

Ecosystem interactions

Since 2006, measures aimed at reducing the ecosystem impacts of the hake- and sole-directed demersal trawl fisheries are contained in annually updated permit conditions. These include measures aimed at minimising seabird mortalities, reducing damage to the seabed and reducing bycatch through per-trip catch limits, move-on rules and fishery management areas. 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 (more detail is provided in the section on Cape hakes in this report).

A novel study that compared a unique historical dataset from the early 1900s with 2015 demersal survey data showed pronounced changes in demersal fish assemblages over the 111-year period. Historical assemblages included a substantial proportion of taxa that associate with reef habitats, whereas the 2015 assemblages were characterised by species that inhabit unconsolidated sediments or both reef and non-reef habitats. While the results suggested that a century of trawling may have altered benthic habitats, indirectly contributing to changes in the fish community, it was recognised that other factors such as climate change, changes in riverine inputs, pollution and life-history characteristics could also play a role. It is notable that Agulhas sole appears to have displayed an appreciable decrease in abundance over the study period. A study that used geostatistical techniques applied to fishery-independent demersal survey data covering the period 1986 to 2016 indicated a slight spatial shift (towards the northwest) in Agulhas sole distribution accompanied by a slight decrease in the effective area occupied by the species, but neither of these trends were statistically significant.

Further reading

Attwood CG, Petersen SL, Kerwath SE. 2011. Bycatch in South Africa's inshore trawl fishery as determined from observer records. *ICES Journal of Marine Science* 68: 2163–2174.

Branch GM, Griffiths CL, Branch ML, Beckley LE. 1994. *Two oceans: a guide to the marine life of southern Africa*. Cape Town: David Philip.

Currie JC, Thorson JT, Sink KJ, Atkinson LJ, Fairweather TP, Winker H. 2019. A novel approach to assess distribution trends from fisheries survey data. *Fisheries Research* 214: 98–109.

Currie JC, Atkinson LJ, Sink KJ, Attwood CG. 2020. Long-term change of demersal fish assemblages on the Inshore Agulhas Bank between 1904 and 2015. *Frontiers in Marine Science* 7: article 355.

Heemstra P, Heemstra E. 2004. *Coastal fishes of southern Africa*. Grahamstown: National Inquiry Service Centre (NISC) and South African Institute for Aquatic Biodiversity (SAIAB).

Smith MM, Heemstra PC (eds). 1991. *Smiths' sea fishes*. Johannesburg: Southern Book Publishers.

Useful statistics

Total catch of Agulhas sole per calendar year and the annual TAC for the period 1920–2023

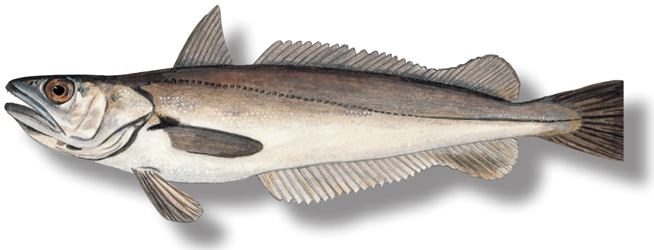
Year	Catch	TAC
1920	700	
1921	540	
1922	560	
1923	670	
1924	680	
1925	650	
1926	820	
1927	750	
1928	770	
1929	740	
1930	780	
1931	680	
1932	760	
1933	800	
1934	900	
1935	1 100	
1936	1 050	
1937	1 200	
1938	1 000	
1939	800	
1940	650	
1941	650	
1942	650	
1943	750	
1944	680	
1945	675	
1946	710	
1947	730	
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	

Useful statistics *cont.*

Year	Catch	TAC
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

Year	Catch	TAC
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	219	502
2021	143	491
2022	119	400
2023	80	328
2024		228

Cape hakes



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

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 11). 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 the demersal shark longline fisheries, and to a lesser extent in the commercial 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 11). 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 resources by the South African government. Apart from a

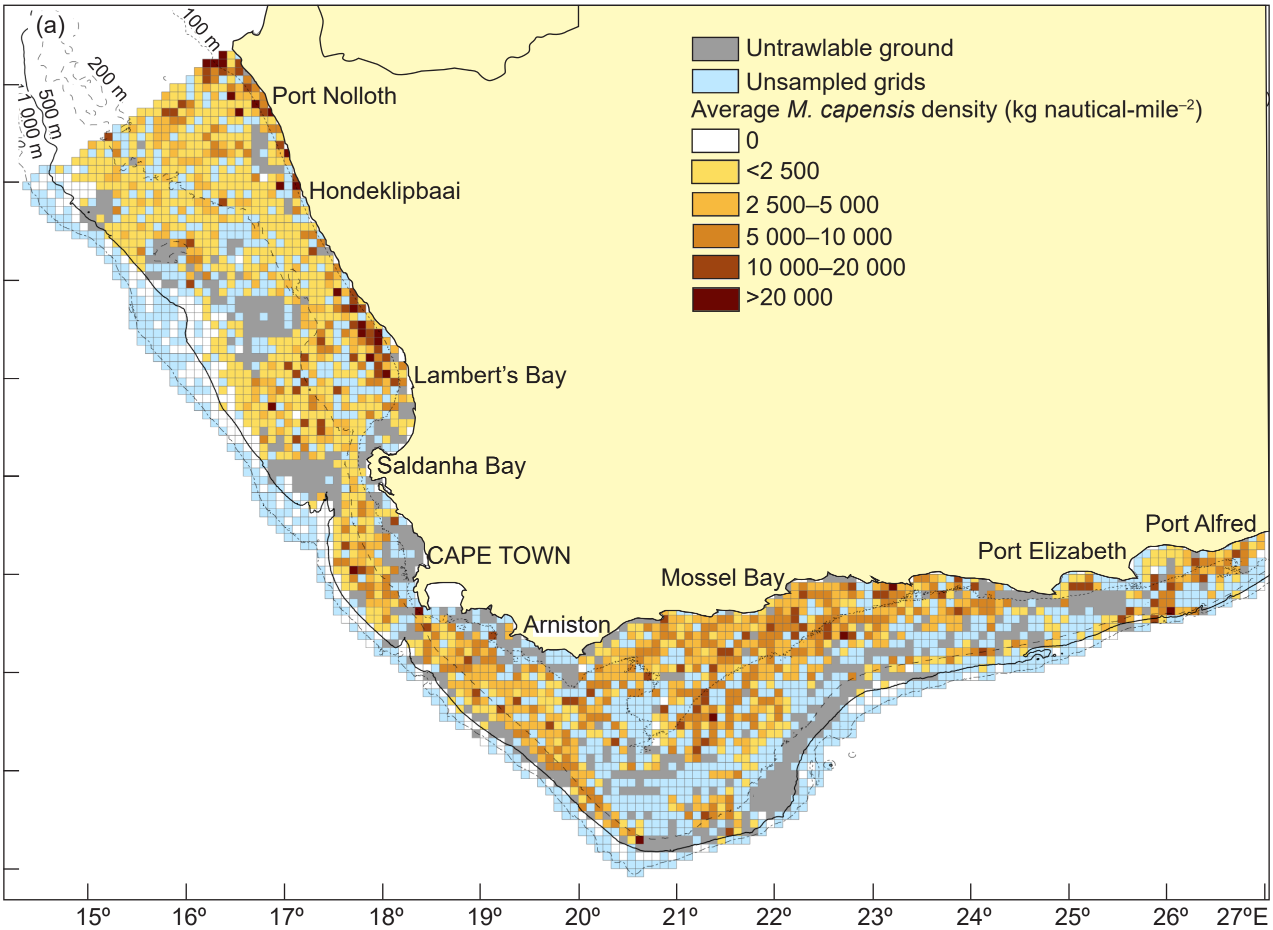


Figure 10(a): Distribution of shallow-water hake *Merluccius capensis* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

few vessels operating under bilateral agreements and being subject to South African regulations, foreign vessels were excluded from South African waters.

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 four-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.

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 11). 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 estimated 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.

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

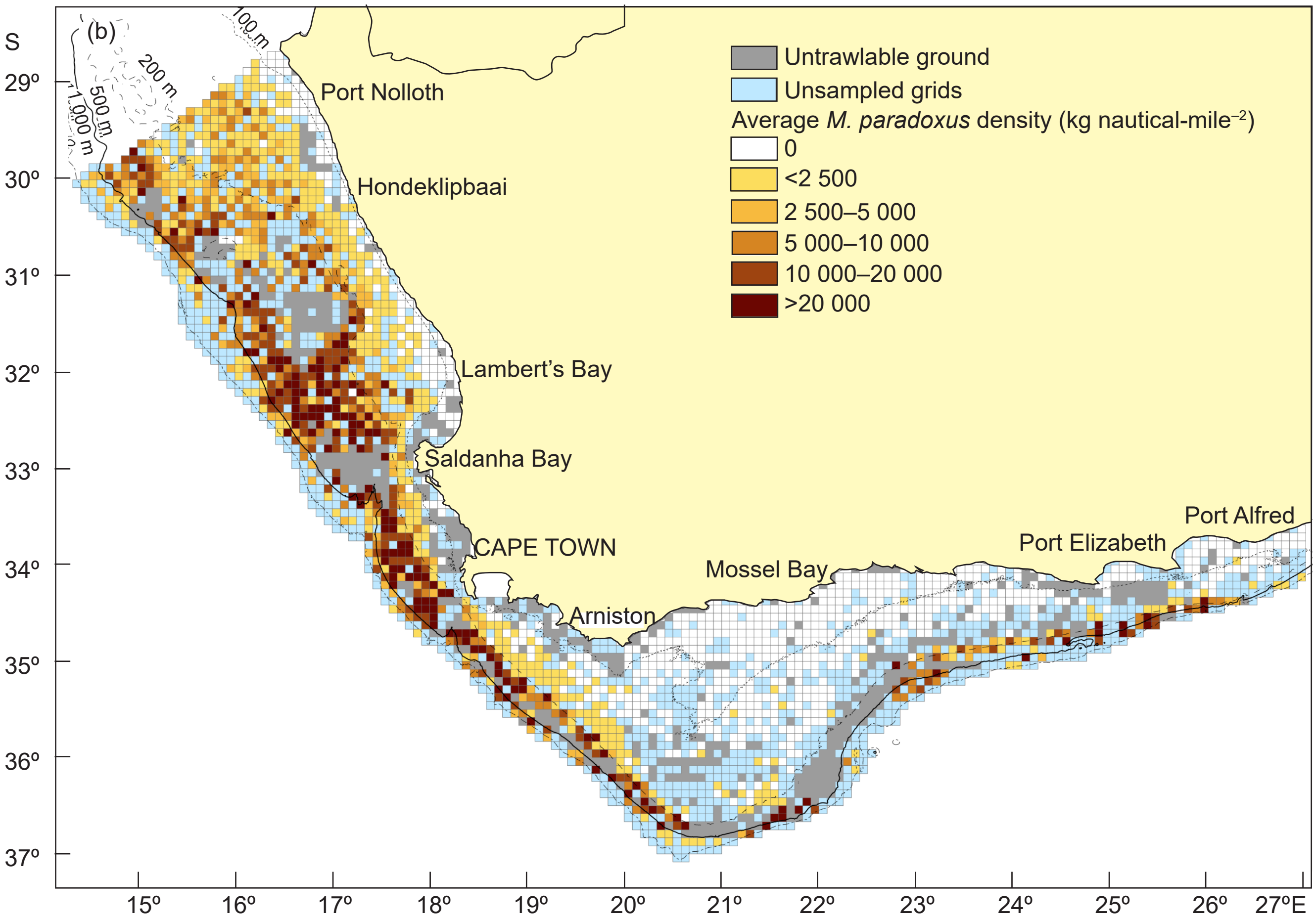


Figure 10(b): Distribution of deep-water hake *Merluccius paradoxus* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

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 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, 2014, 2018, and most recently in 2022, to provide TAC recommendations for the years 2011–2014, 2015–2018, 2019–2022 and 2023–2026 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 B_{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

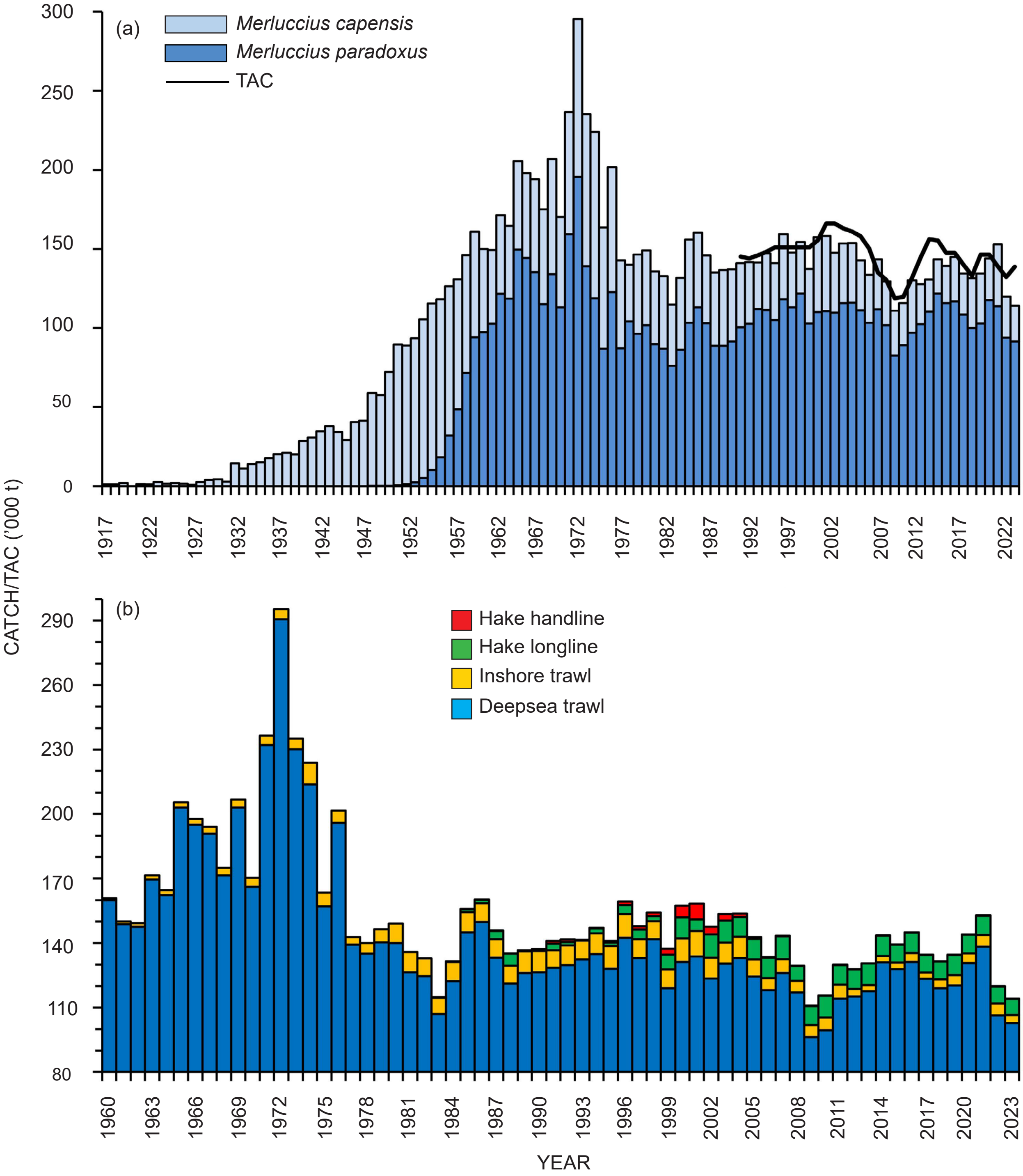


Figure 11: (a) Total catches ('000 t) of Cape hakes split by species over the period 1917–2023 and the TAC set each year since the implementation of the OMP approach in 1991. Prior to 1978, where the data required to split the catch by species are not available, the split is calculated using an algorithm 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 1960–2023. Prior to 1960, all catches are attributed to the deep-sea trawl sector. Note that the vertical axis commences at 80 000 t to better clarify the contributions by each sector

previously, the *M. paradoxus* resource was appreciably above B_{MSY} from 2010 onwards. More recent assessments have conformed to this perception (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 the exploitation of the resource was considered and adopted during the 2018 review of the hake OMP.

As per the four-year cycle in hake OMP revision, the hake OMP was reviewed during 2022 using updated datasets and various improvements to the operating models and supporting analyses.

Management objectives of OMP-2022 are:

- Maintain the spawning biomass of both species of hake fluctuating about or slightly above maximum sustainable yield level (MSYL) (MSYL is the target reference point required for Marine Stewardship Council (MSC) certification).
- The median for the spawning biomass of *M. paradoxus* should not decrease below the 2007 level estimated by the reference set of operating models (this is the limit reference point required for MSC certification).
- The lower 2.5 percentile for the lowest TAC anticipated should be as high as possible.
- Interannual changes in TACs should be kept as low as possible (to facilitate stability in the industry) except in circumstances where catch rates fall below specified threshold levels.

OMP-2022 has the following general specifications:

(a) The TAC for 2023 is fixed at 138 760 t (a 5% increase of the 2022 TAC).
(b) The TAC for 2024 will be at least 138 760 t, i.e., the 2024 TAC may be above the 2023 TAC, but may not be reduced below the 2023 TAC.
(c) For 2025 and 2026, the TAC for each year is calculated as the sum of the intended species-disaggregated TACs.
(d) 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.
(e) A 160 000 t upper “hard cap” (i.e. the TAC over the period 2023–2026 may not exceed 160 000 t per annum).
(f) The TAC may not be changed by more than 5% (upwards or downwards) from one year to the next.
(g) Notwithstanding point (f) above, a “safeguard” meta-rule over-rides the percentage 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.
(h) A threshold for *M. capensis* abundance below which action would need to be taken to reduce the catches of this species without unnecessarily reducing catches of *M. paradoxus*.
(i) “Exceptional Circumstances” provisions that regulate the procedures to be followed if future monitoring data fall outside of the range simulated in the development of the OMP.

Note that specifications (a) and (b) above were largely intended to provide some stability to assist the industry in recovering from the operational difficulties resulting from the COVID19 pandemic.

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 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 five-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 maintaining it fluctuating around that level had to be considered during the development of OMP-2010 and OMP-2014 and has remained a key consideration in the more recent OMPs.

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 in summer on the West Coast and in autumn on the South Coast each year since 1985. While some winter West Coast and spring South Coast surveys have been conducted, budgetary and/or operational constraints have prevented these surveys from being routinely conducted. Prior to 2011, surveys typically encompassed the area between the coastline and the 500-m isobath. Since 2011, 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 on the West Coast or longitude on the South Coast 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

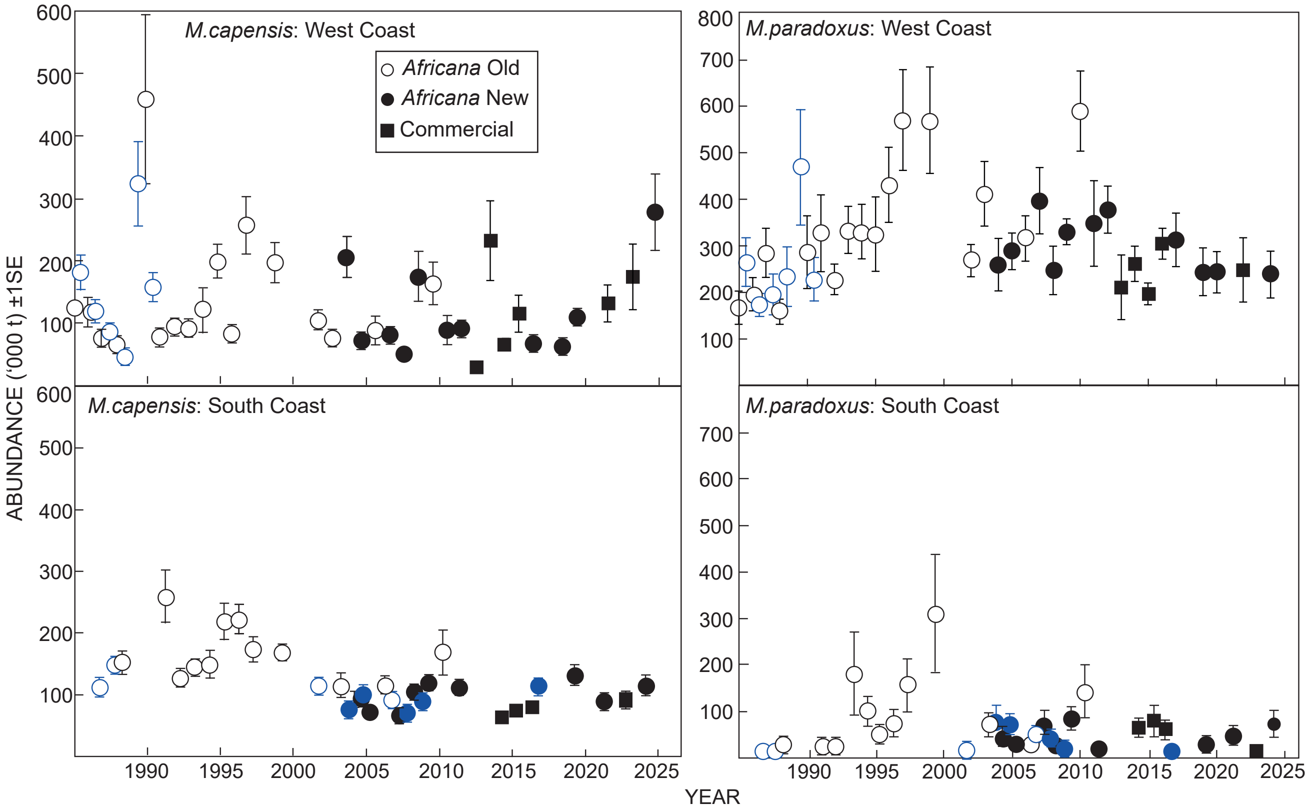


Figure 12: Hake abundance estimates ('000 t ± 1 SE) derived from fishery-independent swept area demersal surveys. Estimates are illustrated by species and coast for the various vessel-gear combinations. Summer (West Coast) and Autumn (South Coast) surveys are indicated with black symbols, while Winter (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

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 gender (hake, chondrichthyans and cephalopods), 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 subsamples of commercially important species (hake, kingklip, monkfish, Agulhas sole and chokka squid). 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 seabed). 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 hake assessments by the application of conversion factors estimated from experiments. Another relatively 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 from 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 South Coast surveys were conducted in 2012 and 2013. Ongoing technical problems

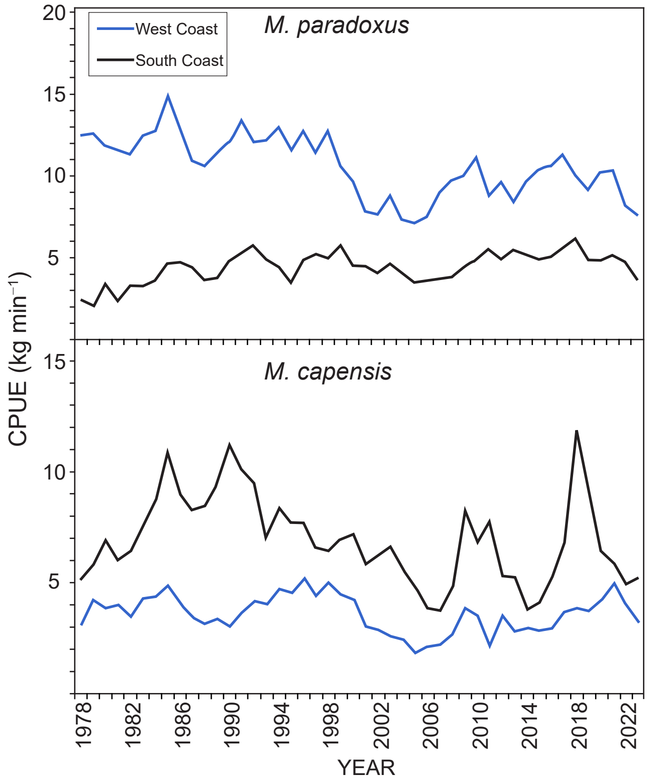


Figure 13: Coast and species-specific standardised indices of abundance (CPUE) for the deep-sea trawl sector. The CPUE indices are calculated using a GLM after application of the revised species-splitting algorithm to updated catch and effort data

with the FRS *Africana* have also prevented the completion of the autumn 2017 South Coast, summer 2018 West Coast, autumn 2018 South Coast, autumn 2020 South Coast, summer 2021 West Coast and autumn 2022 South Coast surveys, while the summer 2022 and 2023 West Coast surveys and the autumn 2023 South Coast survey were all conducted aboard MV *Compass Challenger*. The summer 2024 West Coast and autumn 2024 South Coast surveys were successfully completed in the FRS *Africana*.

Species- and coast-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 assessments to provide additional estimates of resource abundance and trends, as well as direct inputs to the OMP algorithm that calculates the annual hake TAC.

Assessments of the hake resources in recent years have typically followed a two-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 four-year schedule of OMP revision. The suite of operating models that is considered, referred to as the reference set, is designed to encompass major sources of uncertainty, and includes the feference case model that is considered to provide the most plausible measures of stock status and dynamics. A routine update of the reference case 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 South African reference case 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 South African 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 South African hake in isolation. Pending further research into the possibility and implications of a shared *M. paradoxus* resource, evaluations of the performance of the South African 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

A routine update of the reference set of operating models was conducted in 2024 using updated datasets that included commercial catch data extending to the end of 2023 and demersal survey abundance indices data that extended to May 2024. The update was conducted in circumstances where the offshore trawl CPUE indices of abundance were at relatively

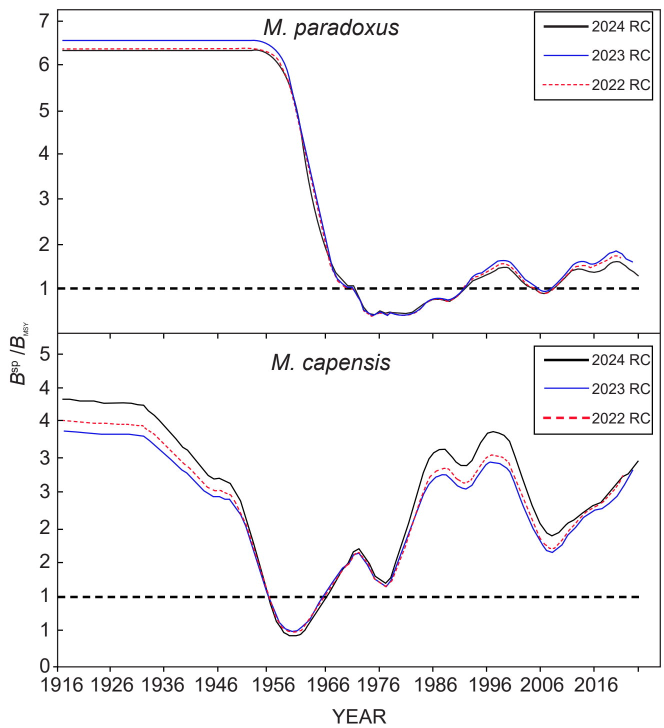


Figure 14: Trajectories of female spawning biomass (B^{sp}) relative to the biomass at maximum sustainable yield (B_{MSY}) estimated by the 2022, 2023 and 2024 updated reference case operating models

Table 2: Key parameter estimates derived from the 2024 update of the reference set (RS) of operating models as well as those from the 2023 reference case model (2023 RC). The 2024 reference set models encompassed three options for the central year of the shift from primarily *M. capensis* to *M. paradoxus* exploitation (1952, 1958 and 1963) and three options for the stock-recruit (S-R) function. The Beverton–Holt (B–H) stock-recruit options encompassed steepness parameters (*h*) set at either 0.7 or 0.9. Model RS02 (shaded) is viewed as the 2024 reference case model that provides the most plausible measures of stock status and dynamics.

	Model name	Central Year	S-R relationship	K^{sp}	B^{sp}_{MSY}	B^{sp}_{2024}	B^{tot}_{2024}	B^{sp}_{2023}/K^{sp}	B^{sp}_{2024}/K^{sp}	$B^{sp}_{2023}/B^{sp}_{MSY}$	$B^{sp}_{2024}/B^{sp}_{MSY}$	B^{sp}_{MSY}/K^{sp}	MSY
M. paradoxus	(0) 2023RC	1958	Ricker	470	72	-	-	0.24	-	1.59	-	0.15	135
	(1) RS01	1952		510	80	101	343	0.21	0.20	1.36	1.25	0.16	130
	(2) RS02 RC	1958	Ricker	497	79	101	342	0.22	0.20	1.39	1.29	0.16	130
	(3) RS03	1963		418	87	118	376	0.30	0.28	1.46	1.36	0.21	131
	(4) RS04	1952		981	140	177	441	0.20	0.18	1.38	1.26	0.14	117
	(5) RS05	1958	Beverton–Holt (*h*=0.9)	978	136	171	447	0.19	0.18	1.36	1.26	0.14	118
	(6) RS06	1963		959	129	201	529	0.22	0.21	1.65	1.56	0.13	121
	(7) RS07	1952		1404	340	420	927	0.31	0.30	1.29	1.24	0.24	114
	(8) RS08	1958	Beverton–Holt (*h*=0.7)	978	136	171	447	0.19	0.18	1.36	1.26	0.14	118
	(9) RS09	1963		1482	357	545	1181	0.38	0.37	1.58	1.53	0.24	120
M. capensis	(0) 2023 RC	1958	Ricker	237	70	NA	NA	0.83	NA	2.82	NA	0.30	83
	(1) RS01	1952		342	76	279	799	0.79	0.82	3.58	3.69	0.22	109
	(2) RS02 RC	1958	Ricker	227	59	175	530	0.74	0.77	2.84	2.95	0.26	84
	(3) RS03	1963		386	117	327	921	0.82	0.85	2.71	2.80	0.30	103
	(4) RS04	1952		1090	168	926	2491	0.82	0.85	5.35	5.52	0.15	162
	(5) RS05	1958	Beverton–Holt (*h*=0.9)	1062	164	897	2419	0.82	0.85	5.31	5.48	0.15	157
	(6) RS06	1963		1185	182	1021	2738	0.84	0.86	5.43	5.60	0.15	176
	(7) RS07	1952		411	110	66	267	0.15	0.16	0.55	0.60	0.27	49
	(8) RS08	1958	Beverton–Holt (*h*=0.7)	1363	352	1166	3110	0.83	0.86	3.22	3.31	0.26	147
	(9) RS09	1963		1685	435	1486	3935	0.86	0.88	3.32	3.42	0.26	181

K^{sp}	Pre-exploitation spawning biomass ('000 t)	B^{sp}_{2023}/K^{sp}	Spawning bio mass in 2023 relative to pre-exploitation biomass (depletion)
B^{sp}_{MSY}	Spawning biomass yielding MSY ('000 t)	B^{sp}_{2024}/K^{sp}	Spawning bio mass in 2024 relative to pre-exploitation biomass (depletion)
B^{sp}_{2024}	Spawning biomass in 2024 ('000 t)	$B^{sp}_{2023}/B^{sp}_{MSY}$	Spawning bio mass in 2023 relative to biomass yielding MSY
B^{tot}_{2024}	Total biomass in 2024 ('000 t)	$B^{sp}_{2024}/B^{sp}_{MSY}$	Spawning bio mass in 2024 relative to biomass yielding MSY
MSY	Total biomass in 2024 ('000 t)	B_{MSY}/K^{sp}	Bio mass yielding MSY relative to pre-exploitation biomass

low levels for both hake species on both coast (Figure 13), while the survey abundance estimates (Figure 12) for both species in 2024 were higher than those for 2023, and markedly so for *M. capensis* on the West Coast. Results of the updated reference set (Table 2) were generally consistent with the 2022 update that was used in the development of OMP-2022. Similarly, the results of the 2024 updated reference case ("RS02 RC" in Table 2 and "2024 RC" in Figure 14) are generally similar to those of the 2022 and 2023 updates ("2023 RC"), although the 2024 reference case suggests that both species are slightly more depleted than was suggested by the 2023 results. The 2024 estimates indicate a similar trend as previously estimated, where the *M. paradoxus* stock continues the slight downward trend which it has shown since 2020. This downward trajectory could still be considered reasonably compatible with abundance fluctuations evident for preceding years, but concern could be raised in future if indices continue to decline in the next few years. The *M. capensis* resource is estimated to be continuing an upward trajectory.

Application of the OMP-2022 TAC calculation algorithm and associated rules (see above) using the updated datasets yielded a value of 151 739 t, which has been adopted as the hake TAC for the 2025 fishing season (an increase of 4.1% from the 2024 TAC of 145 698 t).

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.
– 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.

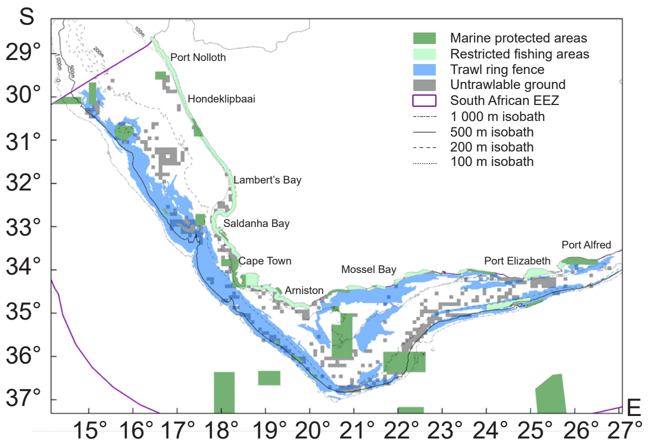


Figure 15: Spatial extent of the trawl ring fence area (no fishing by the hake trawl sectors is permitted outside of this designated area), restricted areas in which no fishing by any of the hake-directed trawl and longline sectors is permitted (as per permit conditions) and the locations of the current MPAs

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 catch 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 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" (Figure 15) 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 specified locations 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 encompass 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

Durholtz MD, Singh L, Fairweather TP, Leslie RW, van der Lingen CD, Bross CAR, Hutchings L, Rademeyer RA, Butterworth DS, Payne AIL. 2015. Fisheries, ecology and markets of South African hake. In: Arancibia H (ed.), *Hakes: biology and exploitation*. Oxford: John Wiley & Sons, Ltd.

Payne AIL.1989. Cape hakes. In: Payne, AIL, Crawford, RJM,

van Dalsen AP (eds), *Oceans of life off southern Africa*. Cape Town: Vlaeberg Publishers.
Rademeyer RA, Butterworth DS, Plagányi ÉE. 2008. Assessment of the South African hake resource taking its two-species nature into account. *African Journal of Marine Science* 30: 263–290.
Rademeyer RA, Butterworth DS, Plagányi ÉE. 2008. A history of recent basases of management and the development of a species-combined Operational Management Procedure for the South African hake. *African Journal of Marine Science* 30: 291–310.

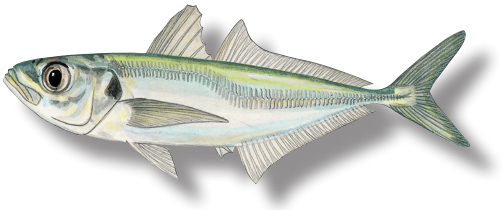
Useful statistics

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					800							800	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	58 744							58 744	58 800
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	65 805		1.000					66 805	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* Deep-sea WC	*M. paradoxus* Deep-sea SC	*M. paradoxus* Longline WC	*M. paradoxus* Longline SC	*M. paradoxus* TOTAL	*M. capensis* Deep-sea WC	*M. capensis* Deep-sea SC	*M. capensis* Inshore SC	*M. capensis* Longline WC	*M. capensis* Longline SC	*M. capensis* Handline SC	*M. capensis* TOTAL	TOTAL (both species)
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	113183	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	15 695	2 394	1 527	89 075	10 193	4 124	5 965	3 086	3 024	275	26 667	115 742
2011	131 780	75 697	18 580	2 522	140	96 939	15 639	4 240	6 437	3 521	3 047	186	33 070	130 009
2012	144 671	80 978	16 687	4 358	306	102 329	12 986	4 614	3 423	2 570	1 737	8	25 338	127 667
2013	156 075	75 005	29 155	6 056	60	110 276	8 965	4 503	2 920	2 606	1 308	0	20 302	130 578
2014	155 280	74 619	40 308	6 879	8	121 814	9 970	6 159	2 965	2 123	315	1	21 533	143 347
2015	147 500	79 639	30 858	5 205	23	115 725	13 431	3 924	3 082	3 025	69	1	23 532	139 257
2016	147 500	93 408	19 799	3 697	1	116 905	15 091	2 922	4 182	5 745	3	1	27 944	144 849
2017	140 125	72 406	30 878	5 300	25	108 609	15 646	4 468	2 813	2 813	126	4	25 870	134 479
2018	133 119	65 657	29 022	5 217	90	99 986	12 537	11 811	3 985	2 646	487	24	31 490	131 476
2019	146 431	75 446	21 979	5 328	34	102 787	14 127	8 840	4 743	3 623	299	9	31 641	134 428
2020	146 431	101 030	10 809	5 847	47	117 733	15 916	2 990	4 576	2 348	321	4	26 155	143 888
2021	139 109	95 635	12 317	5 892	18	113 862	22 276	8 098	5 439	2 932	194	10	38 949	152 811
2022	132 154	75 277	13 691	4 970	19	93 957	13 734	3 736	5 402	2 933	80	1	25 886	119 843
2023	138 760	71 756	14 747	5 049	7	91 559	12 774	3 610	3 700	2 366	33	7	22 490	114 049

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 16). 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

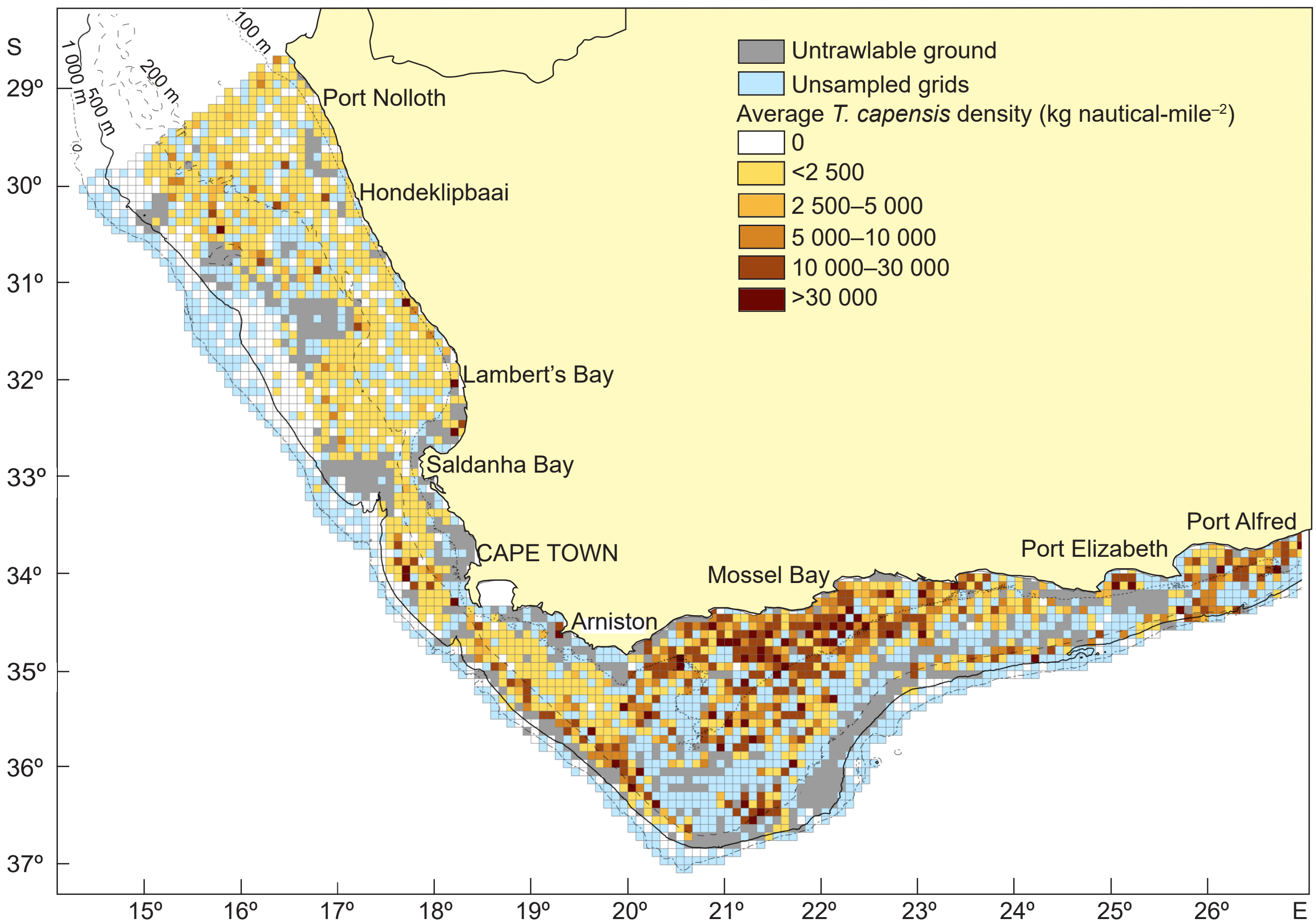


Figure 16: Distribution of Cape horse mackerel *Trachurus capensis* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

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 17). 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.

The semi-pelagic nature of the species brings the resource into contact with three different fishing sectors: the near-surface pelagic purse-seine fleet that catches juveniles as incidental bycatch; the midwater trawl fleet that targets adult fish largely on the South Coast; and the hake trawl fleet that catches adults as incidental bycatch on both the West and South coasts. The midwater fleet currently comprises a single, large midwater trawler (the *Desert Diamond*) that targets horse mackerel only, and several smaller hake trawlers carrying both hake and horse mackerel Rights (the "Dual Rights vessels") that allow them to target horse mackerel opportunistically with midwater gear in addition to their normal hake fishing operations using demersal trawl gear. The *Desert Diamond* implements the Rights for a large proportion of the Right Holders in the sector under several joint venture agreements, and lands on average about 75% of the total trawl-caught horse mackerel catch.

History and management

Annual purse-seine catches of mainly adult horse mackerel on the West Coast peaked in the early 1950s at 118 000 t (Figure 17), then declined to 80 000 t in the late 1950s, 40 000 t in the mid-1960s and finally levelled off at approximately 3 000 t between the early 1970s and late 1980s. The large surface schools of adult horse mackerel that were targeted by the purse-seine fleet in earlier years have subsequently disappeared from the South African West Coast. During the 1990s, purse-seine bycatches (largely comprised of juvenile fish) again showed an increasing trend, reaching 26 000 t in 1998. The increasing pelagic bycatches prompted modelling of the likely effects of large bycatches of pelagic juvenile horse mackerel on the midwater trawl fishery for adults, resulting in the introduction in 2000 of a precautionary upper catch limit (PUCL) of 5 000 t for purse-seine catches, separate from the adult horse mackerel precautionary maximum catch limit (PMCL) that was already in place. The annual purse-seine bycatch of juvenile horse mackerel has averaged 3 300 t since 2000, although a peak bycatch of almost 11 000 t was recorded in 2011 because of unusually large numbers of juvenile horse mackerel near the coast during that year. 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

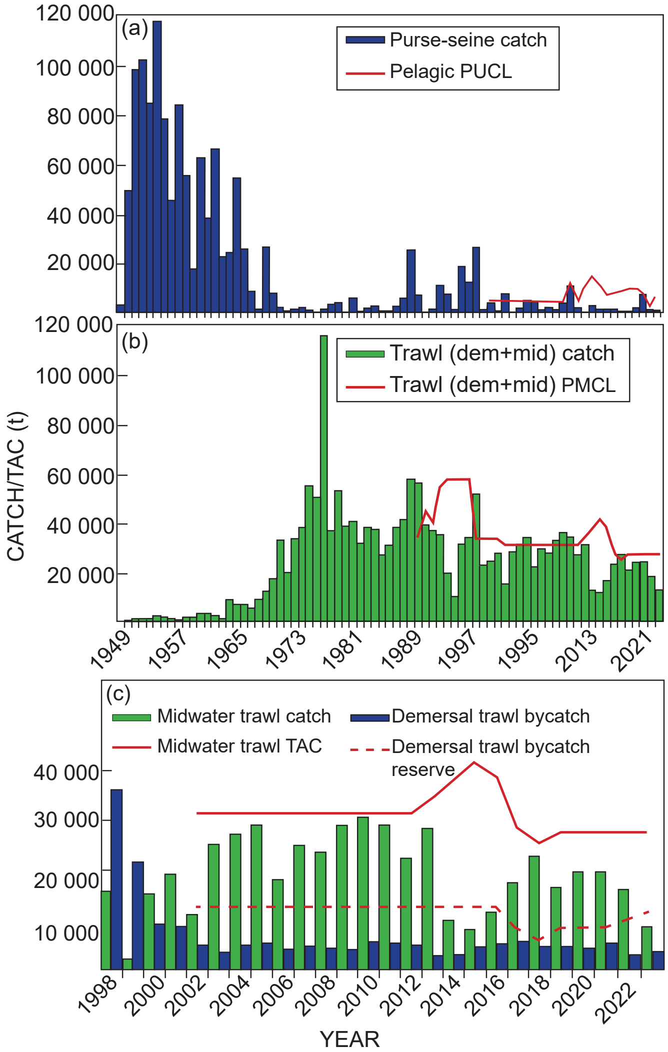


Figure 17: Catches and catch limits of Cape horse mackerel. (a) Pelagic purse-seine catches 1949–2023 and the precautionary upper catch limit (PUCL) first imposed on the fishery in 2000. (b) Trawl (demersal and midwater combined) catches 1949–2023 and the precautionary maximum catch limit first imposed in 1990. Catches cannot be reliably separated by sector (demersal versus midwater) or fleet (local versus foreign) prior to 1998. (c) Trawl catches 1998–2023 (all by South African vessels) split into the demersal and midwatertrawl components. The midwater trawl TAC (solid line) and demersal trawl bycatch reserve (dashed line) are also shown

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 (Figure 17), which has fluctuated between 8 000 t and 31 000 t since the 2000 fishing season.

Prior to 1999, precautionary catch limits set for the horse mackerel trawl fishery were based on results of first surplus production and then yield-per-recruit assessment approaches. A comprehensive age structured production model (ASPM) approach was developed during 1999 and has subsequently been used with updated datasets to provide a basis for scientific advice on management of the fishery. In 2011, it was recognised that the resource could perhaps be more efficiently utilised through implementing an operational management procedure (OMP) approach. This incorporated a provisional increase in the total allowable catch (TAC) for the directed midwater fishery, subject to CPUE not dropping too low, to allow for the possibility that resource abundance had been underestimated in absolute terms. It was also recognised that a more-flexible measure to regulate juvenile horse mackerel bycatch in the small pelagic purse-seine fishery was required to facilitate the operations of that sector in years of high horse mackerel recruitment (as had been experienced in 2011). Work on these measures was completed in 2012, and the small pelagic purse-seine $PUCL_3$ harvest control rule and the adult horse mackerel OMP were implemented for the 2013–2015 fishing seasons.

Assessments of the horse mackerel resource and provision of scientific advice for its management over the past decade have been confronted by appreciable short-term variations in the standardised CPUE calculated from catch and effort data from the directed midwater trawler *Desert Diamond* (the primary index of horse mackerel abundance). The CPUE over the period 2014–2016 had declined to levels that were appreciably lower than the bounds projected by the horse mackerel OMP (Figure 18) and in these Exceptional Circumstances, it was recognised that the then horse mackerel OMP was no longer an appropriate basis for providing scientific advice for the management of the resource. The available data were insufficient to inform on whether the low CPUE reflected a decline in catchability or an increase in natural mortality. A precautionary approach was consequently adopted for 2016 that implemented the TAC indicated by the OMP as well as an effort limitation scheme that would avoid the necessity for a substantial reduction in the TAC and allowed for the possibility of maintaining reasonably large midwater catches if the 2014 CPUE reflected a downward fluctuation in catchability, rather than an increased natural mortality event. These measures were implemented, with some slight adjustments, for the 2017–2019 fishing seasons. The marked increase in the CPUE in 2018 to the highest level on record 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

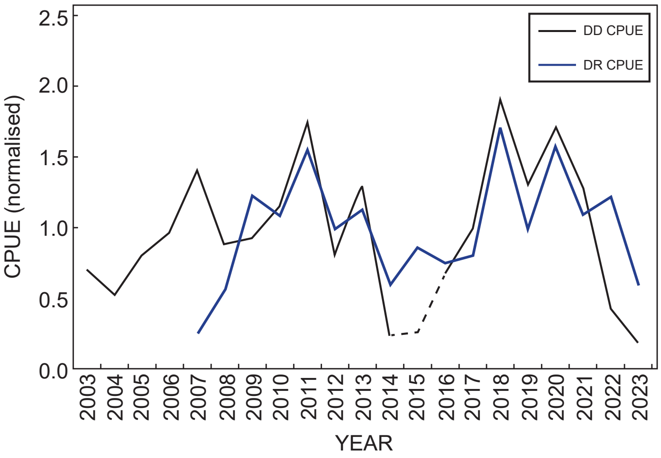


Figure 18: Annual standardised CPUE estimates for the midwater trawler *Desert Diamond* ("DD CPUE") over the period 2003–2023, and an alternative, nominal CPUE index derived from the Dual Rights vessels ("DR CPUE"). Note that both series of estimates have been normalised to their respective means to facilitate comparison of trends. Also note that due to the absence of scientific observers on the *Desert Diamond* in 2015 (and hence a lack of drag-level data required for the CPUE standardisation), the DD CPUE value for 2015 is an estimate derived from a comparison of standardised and crude nominal (catch per trip) CPUE estimates for that year

should not be considered further. Assessments conducted over the period 2019–2022 consequently assumed that the low 2014–2016 CPUE was a result of reduced catchability and yielded results that provided no compelling reason to alter the midwater trawl TAC imposed for the previous fishing seasons. Further, the 2021 assessments suggested that there was little basis to retain the more stringent effort restriction that had been imposed on the fishery to address the increased mortality hypothesis, and the effort limitation measure was consequently lifted.

The 2023 assessment update was conducted in circumstances where the 2022 *Desert Diamond* CPUE was at a level almost as low as that observed in 2014 (Figure 18), while the other abundance indices had either increased slightly from 2021 (the Dual Rights nominal index, Figure 18) or declined slightly from the previous level (the autumn South Coast demersal survey, Figure 19). Two model variants that assumed that the low CPUE reflected either an extra mortality event or a period of reduced catchability for the *Desert Diamond* were again explored (additional to the base case model that assumes that the low 2014 CPUE was due to reduced catchability). The results of all model runs indicated that the resource was above B_{MSY}, and projections of future resource status under constant catch scenarios of 20 000 and 30 000 t per annum predicted that the resource would not decline to below B_{MSY} under these scenarios (although the increased mortality model was obviously more pessimistic than the other two models). These results, considered together with the observation that the negative indicator of the *Desert Diamond* CPUE in 2022 was not apparent in the CPUE of the Dual Rights vessels and only to a small extent in the survey abundance indexes, led to a recommendation to maintain the midwater TAC for 2024 at the same level as that for 2023 (27 670 t).

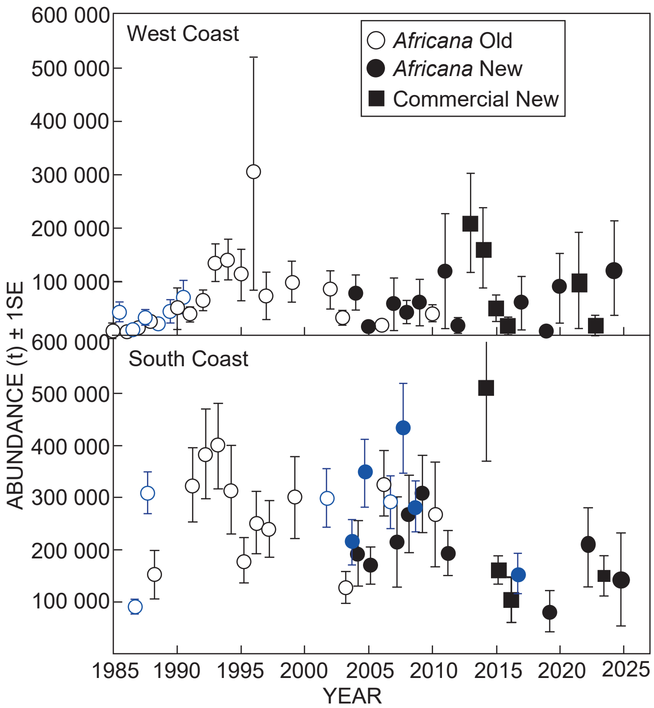


Figure 19: Cape horse mackerel abundance estimates (t) derived from fishery-independent swept area demersal surveys. Estimates are illustrated by coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West Coast) 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

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 South Coast (Figure 19). 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 trawl surveys. Analysis of the hydro-acoustic 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 been developed from commercial midwater trawl catch and effort data (and specifically data from the large midwater trawler *Desert Diamond*). The 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. The recent use of a bycatch mitigation device by the *Desert Diamond* has also been factored into the standardisation process to account for the possible impact of this gear adjustment on horse mackerel catch rates by the vessel. A nominal CPUE index computed from horse mackerel catch and effort data from the dual rights fleet has also been used in recent analyses of horse mackerel dynamics.

The causes of the large fluctuations in the *Desert Diamond* CPUE index in recent years is an aspect that requires further investigation. That similar fluctuations in fishery-dependent abundance indices of Agulhas sole, chokka squid and shallow-water have been observed over the same time suggests that a large-scale environmental anomaly may have prevailed on the South African South Coast over the 2013–2016 period. Scientific evaluation of this hypothesis is required.

Current status

Although the 2023 *Desert Diamond* CPUE was again at a low level comparable to that observed in 2014 (Figure 18), the 2024 assessment update assumed that this reflects a reduction in fishing catchability for the *Desert Diamond* rather than an increased mortality event. The assessment model was run using commercial catch and effort data as well as South Coast survey abundance indices updated to the end of 2023. The updated base case model estimated current depletion (current spawning biomass B_{sp} relative to pre-exploitation biomass K_{sp}) to be 61%. Considering that B_{MSY} is estimated to be about 0.24 K_{sp}, the resource remains in a very healthy state (Table 3). Projections of future constant catches for the midwater fleet at 20 000 and 30 000 t per annum indicate no immediate concerns in terms of future spawning biomass. Given these results, maintaining the mid-water TAC for 2025 at the same level as that for 2024 was appropriate, and the portion of the adult horse mackerel TAC allocated to directed midwater trawling was set at 27 670 t for the 2024 fishing season.

Ecosystem interactions

In addition to the dedicated midwater trawler *Desert Diamond*, the midwater trawl fleet currently also comprises several hake-directed demersal trawl vessels that are permitted to carry midwater gear in addition to the standard demersal trawl gear (the so-called “Dual Rights” vessels). These vessels must comply with the restrictions imposed on the demersal hake trawl fishery that are aimed at reducing 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

Table 3: Results of the 2024 assessment update compared to those of the 2022 and 2023 updates. Note that the 2022 and 2023 base case models ("2022 BC" and "2023 BC") assume a period of reduced catchability by the fishing vessel *Desert Diamond* (DD) over the period 2014–2016 to explain the low CPUE during that time. The "2023 V2" and "2024" models also assume a period of low catchability from 2022 onwards, again to explain the low CPUE in recent years

	2022 BC	2023 BC	2023 V2	2024
K^{sp} ('000 t)	755	752	752	752
B^{sp}_{MSY} ('000 t)	188	183	183	183
B^{sp}_{MSY} / K^{sp}	0.24	0.24	0.24	0.24
MSY ('000 t)	56	55	56	55
B^{sp}_{2022} ('000 t)	539	460	480	468
B^{sp}_{2023} ('000 t)	-	458	481	454
B^{sp}_{2024} ('000 t)	-	-	-	462
B^{sp}_{2022} / K^{sp}	0.695	0.612	0.638	0.623
B^{sp}_{2023} / K^{sp}	-	0.608	0.6	0.603
B^{sp}_{2024} / K^{sp}	-	-	-	0.614

horse mackerel as incidental bycatch) are required by permit conditions to deploy bird scaring ("tori") lines and refrain from discharging offal while trawling in order to minimise seabird mortalities.

The *Desert Diamond* uses a large midwater net that also catches several non-target species, including marine mammals, sunfish and various large pelagic shark species. These incidental catches have raised 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 such cases reflect more serious impacts than the long-term averages would suggest. In the interim, a comprehensive set of management measures aimed at reducing incidental bycatch has been implemented. These measures include a suite of catch limits and move-on rules. The vessel has also voluntarily supported the deployment of two scientific observers on all trips conducted by the vessel in South African waters to further advance the research on, and management of, bycatch by the vessel.

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 but have not, as yet, been successful.

Further reading

Barange M, Pillar SC, Hampton I. 1998. Distribution patterns, stock size and life-history strategies of Cape horse mackerel *Trachurus trachurus capensis*, based on bottom trawl and acoustic surveys. *South African Journal of Marine Science* 19: 433–447

Johnston SJ, Butterworth DSB. 2019. Yet further 2019 horse mackerel assessments and projections. FISHERIES/2019/OCT/SWG-DEM/43. Department of Forestry, Fisheries and the Environment, Cape Town

Johnston SJ, Butterworth DSB. 2024. Updated 2024 horse mackerel assessments and projections FISHERIES/2024/OCT/SWG-DEM/12. Department of Forestry, Fisheries and the Environment, Cape Town.

Johnston SJ. 2024. Calculation of the horse mackerel demersal by-catch reserve for 2025. FISHERIES/2024/OCT/SWG-DEM/12add. Department of Forestry, Fisheries and the Environment, Cape Town.

Kerstan M, Leslie RW. 1994. Horse mackerel on the Agulhas bank - summary of current knowledge. *South African Journal of Science* 90: 173–178.

McLaverty KJ. 2012. A re-evaluation of the life history strategy of Cape horse mackerel, *Trachurus capensis* in the southern Benguela. MSc thesis, University of Cape Town, South Africa. Available at https://open.uct.ac.za/handle/11427/12101.

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; dem. res. = demersal trawl bycatch reserve; mid. = midwater; pel. = pelagic

Year	Catch (t)	
	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	0 959
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
1986	500	31 378

Year	Catch (t)				Catch limits (t)			
	Purse-seine	Dem.	Mid.	Trawl (Dem.+Mid.)	Pel. PUCL	Mid. TAC	Dem. Res	Trawl PMCL
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	50 615
2015	2 041	4 747	7 976	12 723	12 233	41 927	12 500	54 427
2016	1 601	5 230	11 613	16 843	7 268	38 658	12 500	51 158
2017	1 415	5 703	17 545	23 249	8 372	28 200	8 004	36 204
2018	948	4 528	22 775	27 302	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	2 158	4 301	19 710	24 011	9 989	27 670	8 455	36 125
2021	7 864	5 183	19 681	24 864	8 762	27 670	8 455	36 125
2022	824	3 220	16 073	19 293	1 905	27 670	10 783	38 453
2023	524	4 409	8 750	13 159	6 200	27 670	12 397	40 067
2024					13 559	27 670	8 295	35 965

Kingklip

Photograph courtesy of Rob Leslie

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

Introduction

Kingklip *Genypterus capensis* (Figure 20) 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 may extend even farther eastwards). Kingklip are found at depths between 50 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 farther 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 20: 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 22), 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 22) 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

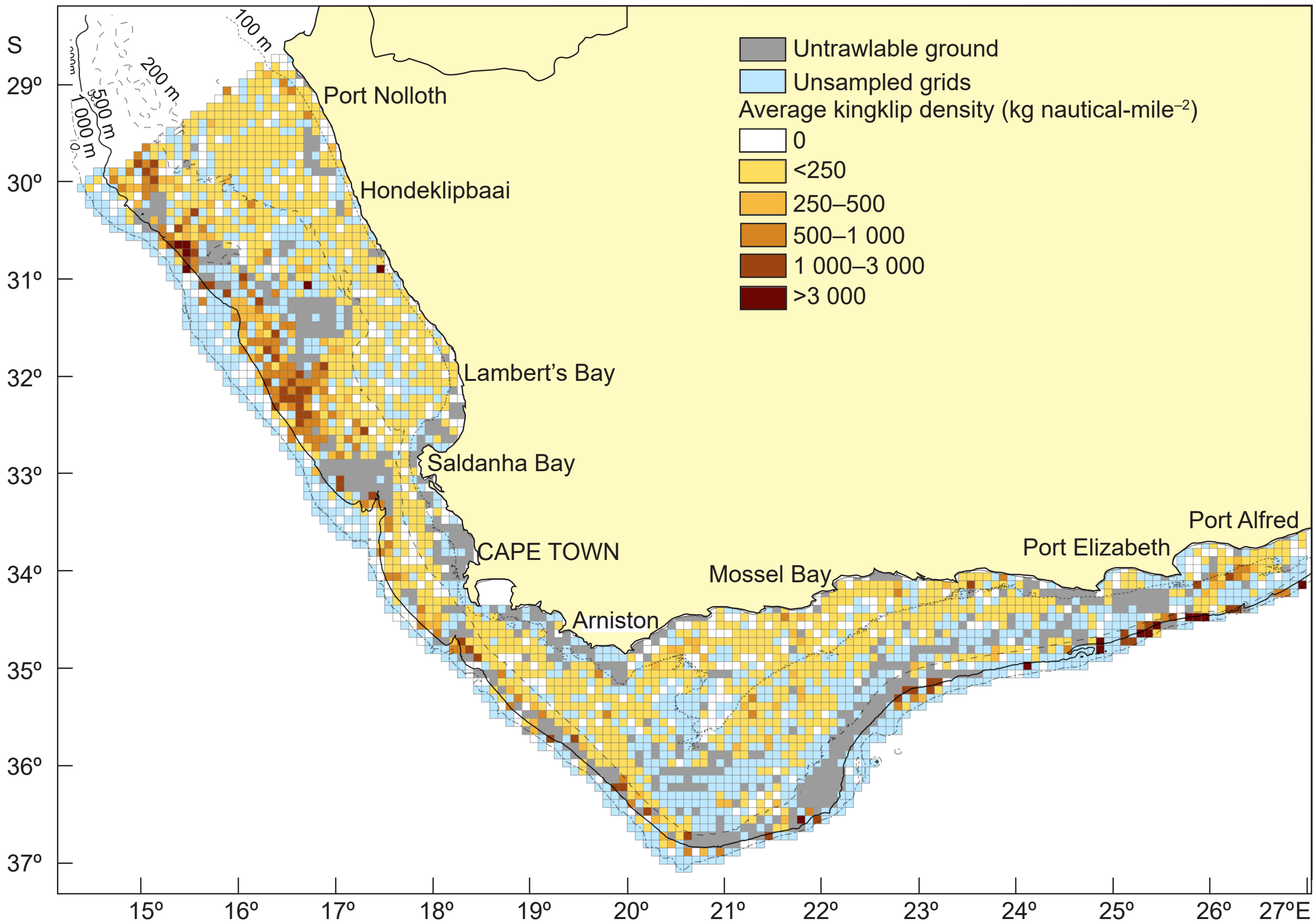


Figure 21: Distribution of kingklip *Genypterus capensis* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

the Department interacting closely with the relevant fishing associations.

The results of the first assessment of the kingklip resource 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 22). 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 West and South Coast stocks 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-fished. 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. No further adjustments to the PUCL were implemented for the 2018 and 2019 fishing seasons. Efforts to find and digitise these additional historical data had not advanced to the point where an ASPM 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.

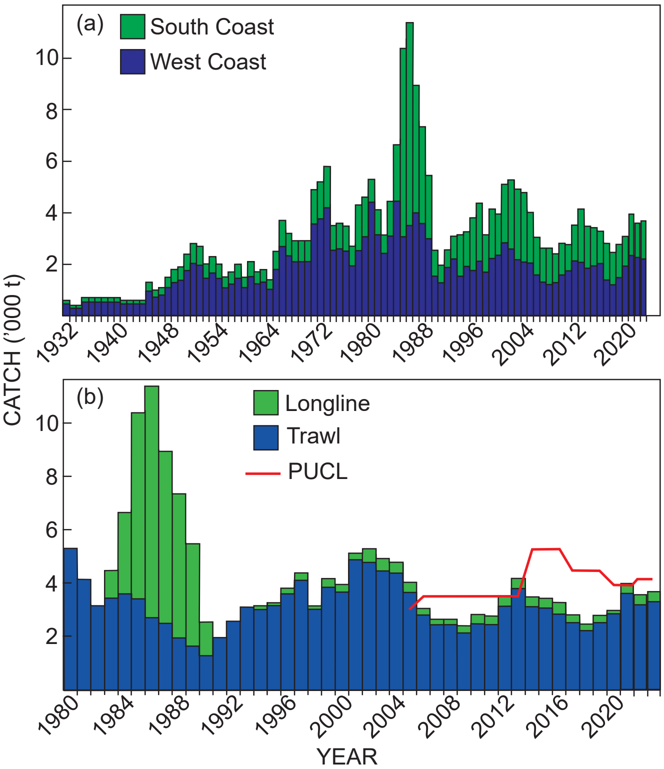


Figure 22: (a) Annual catches (t) of kingklip *Genypterus capensis* on the West and South coasts for the period 1932–2023. (b) Annual catches per fishing sector for the period 1980–2023 (catches prior to 1983 were all made by the trawl fishery), and the precautionary upper catch limit (PUCL) that was introduced in 2005

The results of the update were used to recommend a PUCL of 3 905 t for the 2020 and 2021 fishing seasons, given that a biennial schedule of assessment updates had been adopted by the Department, with a "*status quo*" situation prevailing in every other year. The updated results from the routine RY assessment update conducted in 2021 were used to set the PUCL at 4 047 t for the 2022 and 2023 fishing seasons.

Research and monitoring

Abundance estimates for kingklip (Figure 23) 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

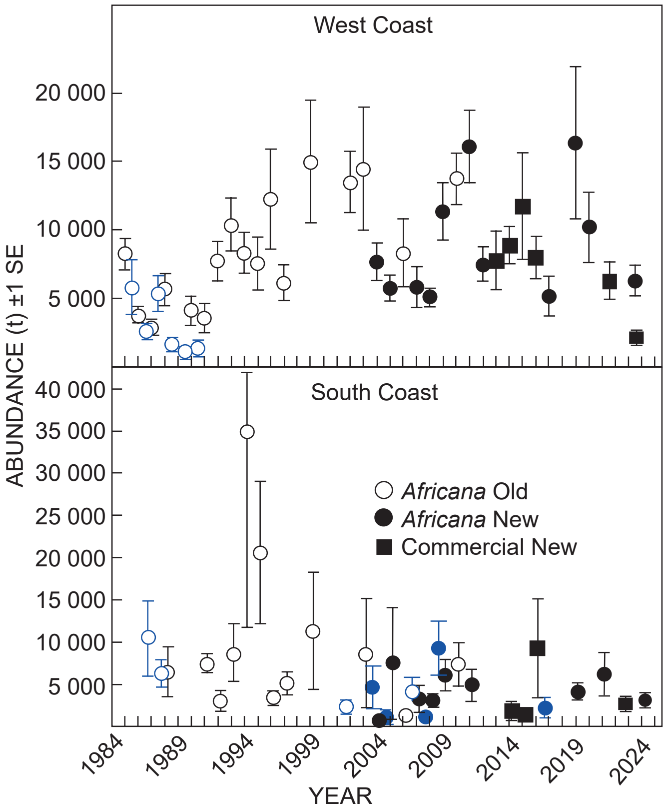


Figure 23: Kingklip abundance estimates (t ± 1 SE) derived from fishery-independent swept area demersal surveys. Estimates are illustrated by coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West Coast) 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. Also note that estimates across the vessel-gear combinations cannot be directly compared due to differences in catchability. *Africana* = research vessel FRS *Africana*, Commercial = commercial fishing

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 research using a genome-wide single nucleotide polymorph (SNP) approach applied to samples collected throughout South African and Namibian waters supported the two-stock hypothesis in South African waters, and identified a third kingklip stock in northern Namibia.

Current status

The 2023 update of the kingklip RY analysis used commercial catch data extending to the end of 2022 and survey abundance estimates to the end of 2023. The results of the 2023 analysis suggest that the abundance of kingklip on the South Coast has decreased by about 0.9% per annum over the last five years, whereas the West Coast component of the resource

Table 4: Posterior means and medians with 95% probability intervals (PI) for kingklip replacement yield by coast obtained from the updated assessment. Estimates obtained from the 2023 analysis are compared to those obtained in the previous (2021) analysis. Note that for the South Coast estimates, values are also provided for a repeat of the 2021 analysis that used the corrected input data

	South Coast			West Coast	
	2021 analysis	2021 analysis corrected	2023 analysis	2021 analysis	2023 analysis
Mean	1 409	1 125	1 164	2 898	2 719
Median	1 430	1 152	1 188	2 871	2 694
25th percentile	1 316	972	1 032	2 731	2 559
95% PI	(1 065; 1	(638; 1 481)	(721; 1 481)	(2 521; 3 430)	(2 357; 3 227)

has increased in abundance by about 1.3% per annum over those same five years (Figure 23). Median estimates of kingklip replacement yield obtained from the 2023 analysis (Table 4) were 2 694 t for the West Coast and 1 188 t for the South Coast. Given the simple nature of the RY analysis, a precautionary approach has been adopted and catch limits are set at the 25th percentile of the posterior distribution, which would result in an overall catch limit for 2024 of 3 591 t (1 032 t and 2 559 t for the South and West coasts respectively, Table 4).

During the 2023 update, it was established that an error in the input data of the preceding (2021) assessment (an incorrect value for the spring 2016 survey abundance estimate was used) had resulted in the South Coast component of the PUCL recommended at that time being 344 t larger than would have been the case if the correct data had been used. When considering the results of the 2023 assessment update, it was recognised that implementing the South Coast component of the PUCL indicated by the 2023 assessment update (1 032 t) for 2024 would represent a relatively large reduction (284 t) from the 1 316 t set for 2022 and 2023 using the results of the 2021 assessment (Table 4). Further noting that these circumstances were a result of the error in the input data, a phased approach to the reduction was adopted to alleviate possible negative impacts on fishing operations in 2024. It was consequently recommended at that time that 50% of the reduction in the South Coast component of the PUCL (i.e. a 142-t reduction from 1 316 t to 1 174 t) should be implemented for 2024, with the balance then being implemented for 2025 (i.e. a further 142-t reduction to 1 032 t). This measure resulted in the kingklip PUCL for 2024 being set at 3 733 t (comprising 2 559 t for the West Coast component and 1 174 t for the South Coast component), with a further reduction for 2025 to 3 591 t (comprising the 2 559-t West Coast component and the 1 032-t South Coast component).

The duration of the South Coast seasonal closure (the so-called “kingklip box”) remains at three months and encompasses the period 1 September–30 November, but this is regularly reviewed. The “kingklip box” closure is applied to the hake trawl and hake longline sectors.

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

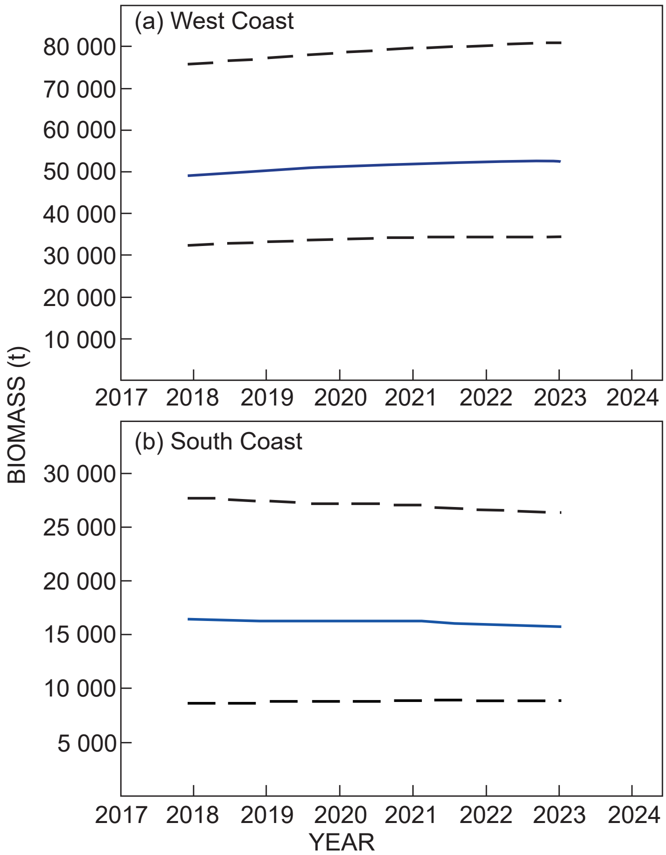
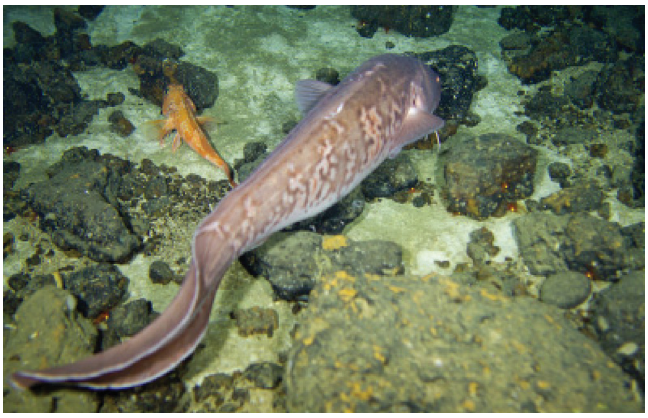


Figure 23: Bayesian posterior medians of abundance over the last five years for the (a) West Coast and (b) South Coast kingklip resource off South Africa. 95% probability interval envelopes are shown as dashed lines

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) also apply to kingklip.

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.
Olivar MP, Sabatés A. 1989. Early life history and spawning of *Genypterus capensis* (Smith, 1849) in the southern Benguela system. *South African Journal of Marine Science* 8: 173–181.
Payne AIL. 1986. Observations on some conspicuous parasites of the southern African kingklip *Genypterus capensis*. *South African Journal of Marine Science* 4: 163–168.
Schulze MJ, von der Heyden S, Japp D, Singh L, Durholtz D, Kapula VK, Ndjaula HON, Henriques R 2020. Supporting fisheries management with genomic tools: a case study of kingklip (*Genypterus capensis*) off Southern Africa. *Frontiers in Marine Science* 7: article 557146.

Useful statistics

Annual catches (t) 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
1977	1 953	737	2 690

	Catch (t) - trawl			Catch (t) - longline			
Year	WC	SC	Total	WC	SC	Total	PUCL
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	1 498	1 429	2 927	414	21	434	5 264
2017	1 099	1 430	2 529	297	2	299	4 450
2018	1 025	1 333	2 358	270	2	272	4 450
2019	1 265	1 293	2 558	253	14	267	4 450
2020	1 668	1 129	2 797	235	12	247	3 905
2021	2 034	1 551	3 585	369	11	380	3 905
2022	1 977	1 261	3 238	335	17	352	4 047
2023	1 927	1 414	3 341	331	4	335	4 047

KwaZulu-Natal crustacean-trawl fishery

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

Introduction

The KwaZulu-Natal prawn-trawl fishery historically consisted of two distinct components: a shallow-water fishery (operating at depths of 5–40 m) located on the Thukela Bank and at St Lucia, covering an area of approximately 500 km^2, and a deep-water fishery (operating at depths of 100–600 m) between Cape Vidal in the north and Amanzimtoti in the south, along the shelf-edge and upper continental slope (Figure 24). The shallow-water trawl fishery predominantly targeted white prawns *Penaeus indicus*, which accounted for 80% of the historic prawn catch, along with 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.

In contrast, the deep-water trawl fishery targets longer-lived species, such as pink prawns *Haliporoides triarthrus*, red prawns *Aristaeomorpha foliacea*, langoustines *Metanephrops mozambicus*, deep-water rock lobster *Palinurus delagoae*, and red crab *Chaceon macphersoni*. These species are longer-lived and do not have an estuarine juvenile stage.

Between 50 than 75% (by mass) of the total catch of the crustacean-trawl fishery 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

The KZN prawn-trawl fishery formally commenced in the mid-1970s following a period of sporadic trawling, and reached a peak in terms of vessels in the mid-1980s. Although a relatively small fishery, it was valued at R32 million in 2017, with vessels primarily operating out of Durban. Landed catches totalled approximately 500 t annually in the 1980s but has fluctuated strongly between approximately 200 and over 500 t since then. Regular collection of statistics only began in 1988.

The fishery is managed through effort-control, with regulations limiting the number of vessels allowed to operate in both the shallow- and deep-water fisheries. 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 fishery has stopped owing to the promulgation of the uThukela MPA in 2019 (Figure 24) and cannot be resumed anymore in this area, such considerations are no longer necessary. The main objective now is the setting of sustainable total allowable effort (TAE) levels for the deep-water 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, historical catch and effort data were used as input for a preliminary stock assessment based on the Schaefer surplus production model. Initially, the landing (discharge) data were examined for suitability; however, these were excluded because it was not feasible to disaggregate effort data (number of trawling days based on dates of the trip) into shallow- and deep-water fisheries based on the information recorded in the landing records. 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

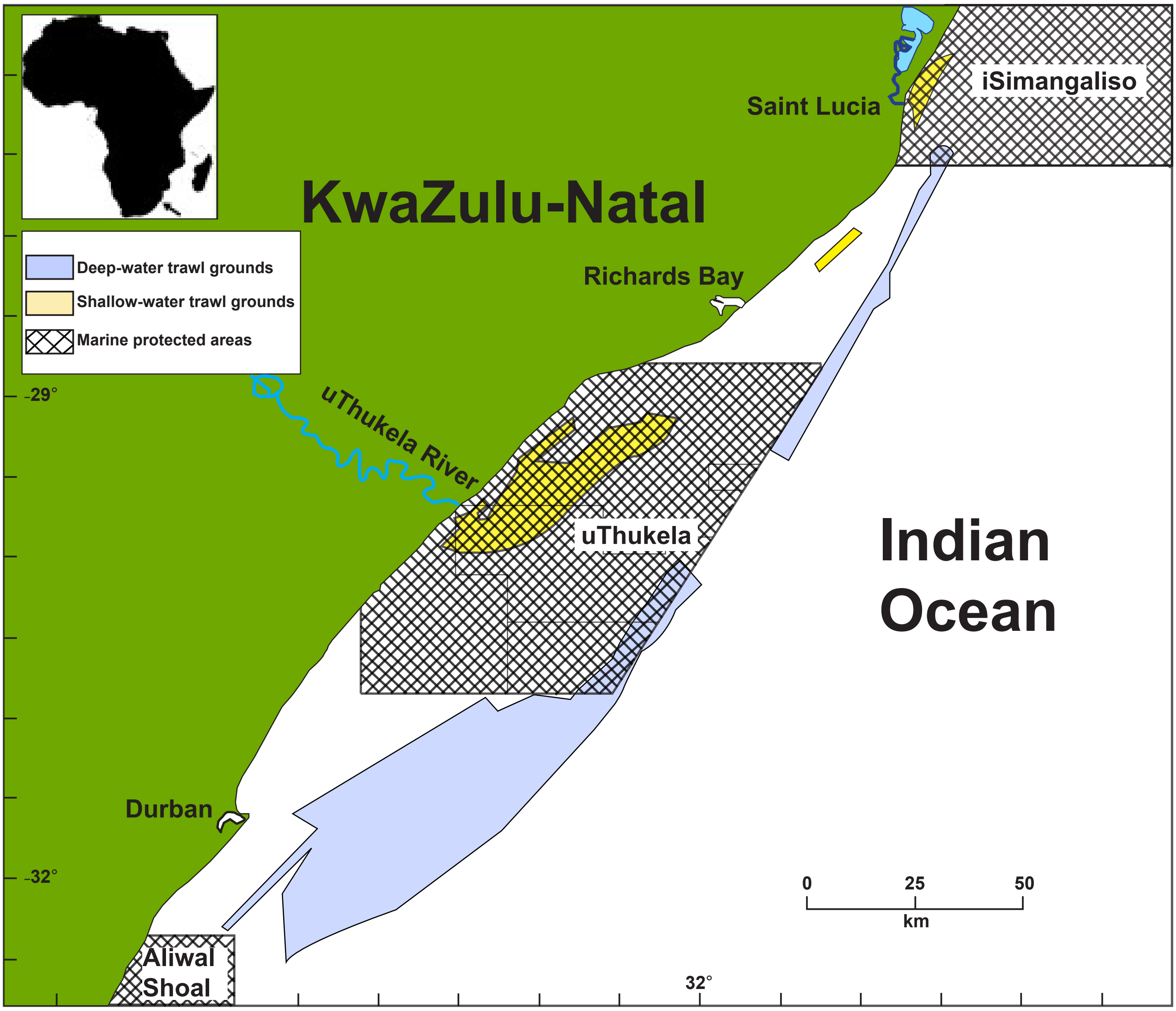


Figure 24: Trawl grounds of the KwaZulu-Natal crustacean-trawl fishery as established from trawl data since 2000, including areas that are now unavailable to the fishery due to MPA declarations

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 were applied to the catch and catch per unit effort (CPUE) data for the KwaZulu-Natal crustacean-trawl fishery in 2009. These 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.

To date, no comprehensive stock assessment has been conducted for this fishery. 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 recent years, fishing effort in the deep-water part of the KwaZulu-Natal crustacean-trawl fishery has more or less continuously increased, resulting in substantially higher landings. As a result, total CPUE and CPUE time-series for the main target species have been declining since 2018. However, in the last two years, most CPUE time-series have stopped this trend (see below). The deep-water resource remains under heavy fishing pressure and, until thorough stock assessment

Table 5: Total landings of the KwaZulu-Natal crustacean-trawl fishery in the various species groups

		Total catch (t)						
		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
2022	5	0	42.3	85.9	76.4	15.6	97.4	317.7
2023	5	0	78.6	84.2	71.1	9.6	97.2	340.7

is conducted, the status of this resource remains uncertain. There remains a critical need for improved data collection and systematic research on the biology of prawn species and bycatch species to inform sustainable management.

Historically, catches of shallow-water prawns strongly reflected annual recruitment from estuaries, and a predictive model 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. Low catches since 2008 have been 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 and very limited opening in 2020 and 2021, but these were brief and insufficient to support recruitment of juvenile prawns from the estuary to the Thukela Bank. In the short periods following the opening of the estuary, no fishing effort was directed in the shallow-water areas (<100 m depth). The area is now largely within the iSimangaliso and uThukela MPAs (Figure 24) 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 25).

Trends in catches in the deep-water fishery reflect both the abundance and changes in fishing practices, such as selective targeting of specific depths or substrates to optimise species composition for highest economic value. Over the past decade, landings fluctuated between about 220 and 565 t, averaging around 350 t (including retained bycatch of fish and cephalopods). In 2023, the landed catch increased by 7% to 341 t, from 318 t in 2022 (Table 5, Figure 25). This increase was mainly due to an 86% rise in the deep-water prawn landings, while landings of langoustine (84 t), red crab (71 t) and retained bycatch (97 t) remained relatively stable (Table 5). Landings of deep-water rock lobsters declined by 39% to about 10 t compared with 2022. For reasons mentioned above, no landings of shallow-water prawns have been recorded in recent years.

The total fishing effort in the deep-water fishery remained relatively constant from 2012 to 2014 (at about 1 100 drags per year) but gradually increased to 1 879 drags in 2018. In 2019, the effort declined again to 1 460 drags, likely as a result of only three vessels fishing (down from four in 2018). The decreased effort in 2019 partly explains the decreased landings of all deep-water species compared with the record year of 2018. From 2020 to 2022, the number of active vessels increased to five, the highest number in 14 years, driven by the displacement of vessels from Mozambique. The number of drags increased to a record of 3 603 in 2021. In 2022, the effort declined again but was still high at 2 357 drags. In 2023, only four vessels were active, resulting in further reductions in effort to 1 699 drags and 9 026 trawl hours, a 45% decrease in trawl hours compared to the record high of 16 500 in 2021. However, the effort in 2023 remained higher than in 2019, the year before the steep increase of effort. Although the reduced nominal effort in 2022 and 2023 likely contributed to the substantial decreases in total catches in both years, they were still high compared with 2021. As in previous years, this reflects effort creep stemming from the sustained use of larger vessels since 2020, which has not been the case previously. Nominal CPUE trends for the main target species (except red crab) declined until 2022 (Figure 26), likely influenced by the high fishing effort. The absence of one vessel and reduction in drags and trawl hours in 2023 appear to have halted the steep decline in CPUE observed in previous years (Figure 26). Current CPUE values for three of the four target species are considerably below their historical peaks, notwithstanding effort creep since the early 2000s, including increased use of technologies like track plotters and other changes. Given the high effort levels and concomitant decline in CPUE trends from 2020 to 2022, management actions may be required in future to arrest or reverse these trends by imposing effort limitations.

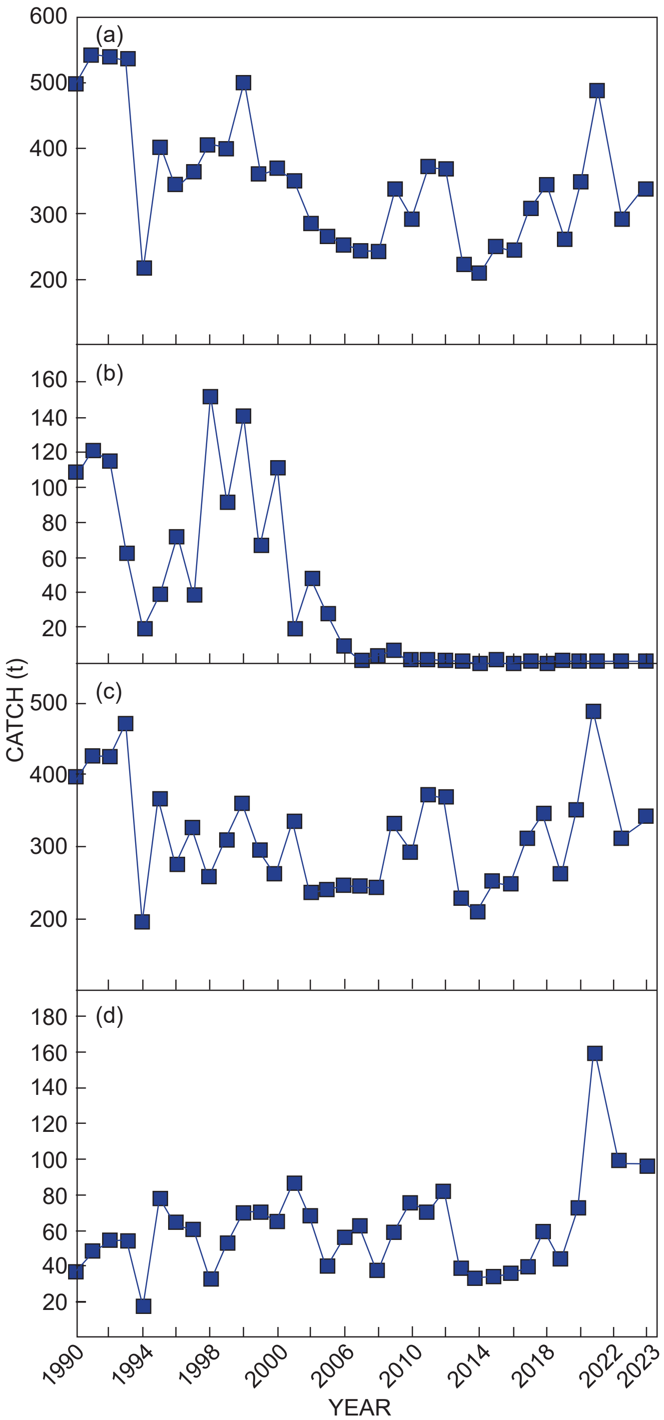


Figure 25: Total annual catches of (a) the entire fishery, (b) the shallow-water fishery, (c) the deep-water fishery and (d) landed bycatch in the KwaZulu-Natal crustacean-trawl fishery for the period 1990 to 2023

Between 50 and 75% (by mass) of the total catch is discarded at sea because it has little commercial value. This includes certain species of cephalopods, bony fish, sharks and rays, and lower-value crustaceans. However, a substantial amount of bycatch is landed. Bycatch mitigation is a major challenge and an aim of the management of this resource. Historically, the shallow-water fishing season on the Thukela Bank was restricted to March–August to reduce bycatch of linefish species, but this restriction is no longer required since the area is now closed to fishing. There is ongoing research on the bycatch composition of the deep-water fishery but more information on the biology of bycatch is needed to develop further mitigation strategies. The amount (Table 5; Figure 25) and composition (Figure 27) of landed bycatch shows marked seasonal fluctuation. Of the 97 t of bycatch landed in 2023, approximately 60% were fish species and 24% molluscs. Almost 65% 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 two cephalopod species: Angel octopus *Velodona togata* and Indian squid *Uroteuthis (Photololigo) duvaucelii*, and the cuttlefish genus Sepia.

Ecosystem interactions

The KwaZulu-Natal crustacean-trawl fishery is associated with high amounts of bycatch, though issues related to bycatch in shallow-water grounds have diminished since no fishing effort is directed there anymore. These shallow-water areas act as nurseries for various fish species, contributing to previous bycatch concerns. To monitor and analyse the large amount of non-retained bycatch of the deep-water fishery, additional measures are necessary. It is therefore

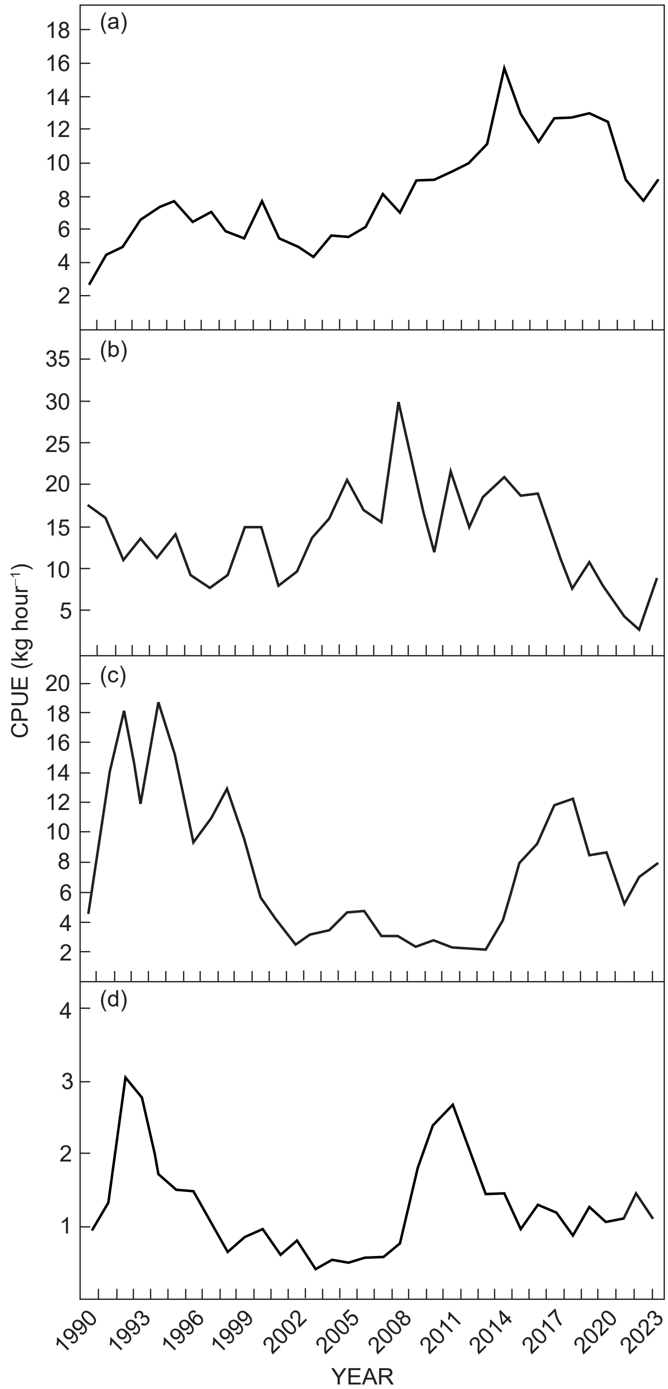


Figure 26: Abundance trends according to nominal CPUE of (a) langoustine, (b) pink prawns, (c) red crabs and (d) deep-water lobsters for the period of 1990 to 2023

essential to re-instate the observer program that existed until 2012. Furthermore, it is necessary to improve monitoring and recording of bycatch by the industry. Possible measures could include more specific drag sheets and electronic monitoring by on-board cameras. Results from these measures should be used to mitigate and possibly reduce the high bycatch in the fishery.

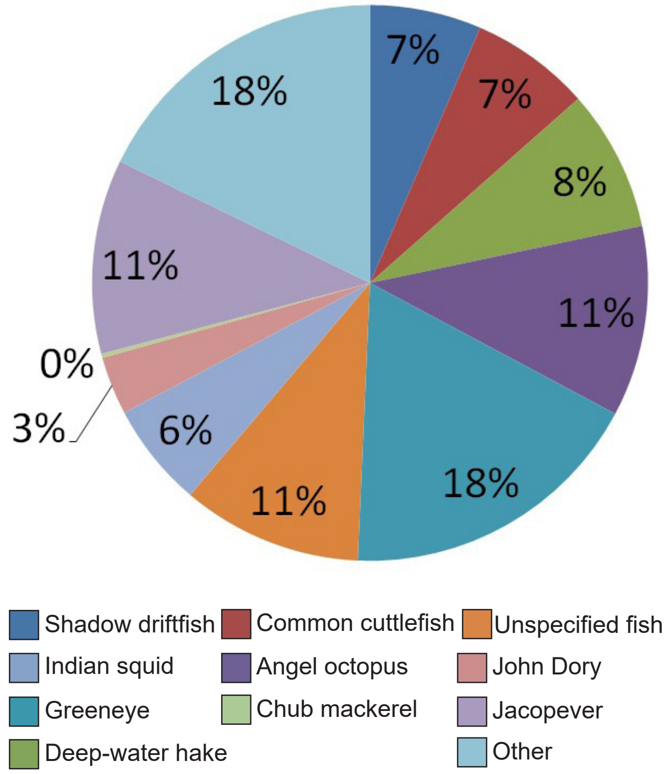


Figure 27: Species composition (by mass) of landed bycatch of the KwaZulu-Natal crustacean-trawl fishery for the 2023 fishing season

Climate change also has potential impacts on the fishery, though these are not yet well-understood. Changes in sea temperature, current patterns, and the overall marine ecosystem could alter the distribution and abundance of crustacean species, affecting the sustainability of the fishery. Monitoring these shifts and implementing adaptive management strategies will be important to ensure the long-term viability of the fishery and its ecosystem interactions.

Further reading

Everett BI, Fennessy ST, van den Heever N. 2021. Using hotspot analysis to track changes in the crustacean fishery off KwaZulu-Natal, South Africa. *Regional Studies in Marine Science* 41: article 101553

Fennessy ST. 1994. The impact of commercial prawn trawlers on linefish catches off the North Coast of Natal. *South African Journal of Marine Science* 14: 263–279.

Fennessy ST. 1994. Incidental capture of elasmobranchs by commercial prawn trawlers on the Tugela Bank, Natal, South Africa. *South African Journal of Marine Science* 14: 287–296.

Fennessy ST. 1995. Relative abundances of non-commercial crustaceans in the bycatch of Tugela Bank prawn trawlers off KwaZulu-Natal, South Africa. *Lammergeyer* 43: 1–5.

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.

Fennessy ST, Groeneveld JC. 1997. A review of the offshore trawl fishery for crustaceans on the east coast of South Africa. *Fisheries Management and Ecology* 4: 135–147.

Useful statistics

Total landings of the KwaZulu-Natal crustacean-trawl fishery in the various species groups

		Total catch (t)						
		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		
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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
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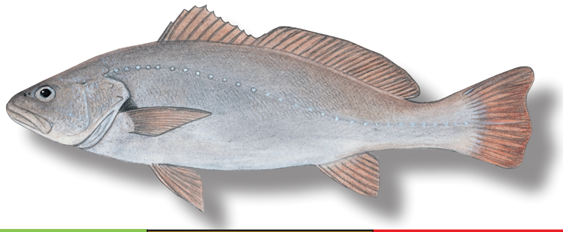
2019	7	0	68.5	78.0	55.1	8.2	40.5	252.2
2020	7	0	66.6	114.5	70.6	7.7	62.7	324.7
2021	7	0	74.2	149.8	87.2	18.5	158.9	488.9
2022	5	0	42.3	85.9	76.4	15.6	97.4	317.7
2023	5	0	78.6	84.2	71.1	9.6	97.2	340.7

Linefish



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
		Snoek Cape bream	Yellowtail Slinger Carpenter	Silver kob Santer	Dusky kob Red steenbras Dageraad
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	**Moratorium**
		Snoek Cape bream	Slinger Santer Carpenter Yellowtail Sliver kob	Dusky kob Red steenbras Dageraad	Seventy-four

Introduction

The use of individual fishing lines with baited hooks—linefishing—in South Africa constitutes the most-widespread fishing activity in the country, with the highest number of participants and species caught. Together, the linefish cluster, the three sectors of the linefishery (commercial, recreational and small-scale), catch around 200 of South Africa's 2 200 marine fish species, and commercial catches of more than one metric tonne per annum have been recorded for 120 species. Species caught 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 boat-based commercial component of the linefishery include temperate, reef-associated seabreams (e.g. carpenter *Argyrozona argyrozona*, Cape (hottentot) seabream *Pachymetopon blochii*, santer *Cheimerius nufar* and slinger *Chrysoblephus puniceus*), coastal migrants (e.g. geelbek *Atractoscion aequidens* and silver kob *Argyrosomus inodorus*) and nomads (e.g. snoek *Thyrsites atun* and yellowtail *Seriola lalandi*). More than 80% of the current linefish catch is derived from the aforementioned eight species, but other species such as Roman *Chrysoblephus laticeps*, Englishman, mackerel and tuna species, as well as soupfin sharks and houndsharks, are of considerable importance in certain areas or during certain times of the year. 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. There is an overlap with the demersal trawl sector on the South Coast and with the tuna pole and netfish sectors on the West Coast, and recently the formalisation of the small-scale fishery has seen the introduction of another boat-based sector that targets the same species as the commercial linefishery with similar vessels under similar permit conditions. These interactions, across the linefish cluster and with other fisheries, make linefish management extremely complex.

The commercial traditional linefishing sector is exclusively boat-based and confined to small (4–10 m), mostly trailered, skiboat-type vessels that can be launched from slipways or even beaches around the coast, albeit that old, displacement vessels are still in use in some of the small harbours. The allocated effort in this fishery has been stable at 455 vessels since 2006, but the dynamics in this fishery have changed over recent decades with a tendency to larger, more-efficient boats and a reduction of sea-days and catch. Recreational fishing in South Africa is diverse and occurs around the entire coast, in estuaries, from the shore and from boats, and from a thriving charter-boat and gamefish tourism industry to subsistence-type fishing to supplement food. The recreational fishery is managed by output restrictions, such as size- and bag limits, closed areas and seasons. Few reliable estimates of recreational fishing impact and participation are available, but there is general agreement that it 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 small craft, outboard motor, fishing tackle and bait trades. For some areas and species the catch from this sector could be equivalent to or even exceed that reported by the commercial sector. Recently, the small-scale sector has begun its formal implementation, and fishing Rights that include shore- and boat-based linefishing have been given to co-operatives around the country. While the shore-based component of this sector emulates recreational fishing in terms of target species, the boat-based component could be regarded as a subset of the traditional linefishery as it operates with similar gear, similar craft, and in the same areas as the commercial fishery, albeit with (on average) smaller vessels. The impact of this fishery has not been quantified, but, similar to the recreational fishery, it is thought to be considerable.

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 a 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, but in reality species-specific management regulations have not changed since 2014.

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 (Figure 28; 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 after the appeals process, the fishing effort equivalent to 378 standard vessels—a standard vessel being a vessel with 7 crew—was allocated in the traditional commercial linefishery to keep effort available for the small-scale fishery.

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 limits 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.

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 collect- ed size frequencies per species from the boat-based fishery at access points around the country. The collection of size frequencies was repeated prior to the latest assessment to obtain updated information for the main target species.

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

Table 6: Annual total allowable effort (TAE) and activated commercial linefish and small-scale effort per management zone from 2006 to 2023. SV=standard vessel units. A standard vessel unit has the fishing power equivalent to an average linefish boat with seven crew. Note that the actual number of vessels might be higher. Question marks denote figures that were not available for this analysis

Zone	Zone boundaries	Global TAE (SV)	Commercial traditional linefish allocation (SV)	Commercial traditional linefish activated effort (SV)	Small-scale fishery activated effort (SV)	Total activated effort (SV)
A	Orange River-Cape Infanta	350	281	228	179	407
B	Cape Infanta-Port St Johns	64	52	38	?	>38
C	Port St Johns Mozambique	51	45	37	?	>37
Total		455	378	303	?	482

is estimated to be at only 1.3% of pristine spawner biomass. As fishing effort along this part of the coast is likely to increase due to the formalisation of the small-scale fishery, there is an urgent need to resample and reassess these species.

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. To-date more than 7 000 hours of footage from this method is available through the Marine Remote Imagery Platform (MARIP) initiative of SAIAB, including considerable amounts of data from species under moratorium such as seventy-four *Polysteganus undulosus* and partial moratorium such as red steenbras *Petrus ruprestris*. In the absence of data from fisheries, this method might be the only option to get stock status information for moratorium species, if dedicated surveys are not feasible. Several initiatives are afoot to unlock the potential of this massive dataset, with the help of computer vision AI and automated species identification.

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.

The type of stock assessment applied is determined by the nature and quality of data available. For the linefish species, commercial catch data are available from the boat-based component and from some of the other commercial fisheries that land linefishes in larger quantities. Drawing on the enormous body of data contained in the NMLS, a method to standardise catch-per-unit-effort (CPUE) data that accounts for targeting in the multispecies linefish sector has been developed. This method can be used to create an index of relative abundance for most commonly caught linefish species, which reaches back 40 years. For linefish species that are also trawled, another abundance index has been developed based on the annual demersal trawl survey data from the FRS *Africana*. Specifically, we used a spatiotemporal generalized mixed effect model (GLMM) implemented in the R package 'sdmTMB' (Anderson et al. 2024).

Based on the catch information and the abundance indices a comprehensive Bayesian state-space surplus production model framework (JABBA: Just Another Bayesian Biomass Assessment) and its extension (JABBA-Select) was applied to seven of the most important species, namely slinger, carpenter, hottentot seabream, snoek, yellowtail, santer and silver kob as well as two shark species, smoothhound *Mustelus mustelus* and soupfin *Galeorhinus galeus* (for recent catches see Table 7). JABBA-Select also takes into account the life-history information of the species and the selectivity, as the name suggests.

In situations where comprehensive stock assessment methods are not applicable, alternative methods must be used. This is the case for species that have substantial unknown catches in other fisheries that cannot be tracked over time with any certainty. Here, a recently developed risk assessment method (JARA: Just Another Bayesian Risk Assessment) offers an alternative, where abundance time-series and information on generation length is used to assess species and to categorise them probabilistically according to the IUCN Red List framework in terms of extinction risk.

When no time-series data are available, for example for small-scale or recreational fisheries, length-based analysis presents the only option to assess the stocks, but this method is only useful when fishing effort has been relatively stable for some time, as is the case for the South African linefisheries. Spawning potential ratio (SPR), a metric derived from spawner-biomass-per-recruit analysis, has previously been applied to several linefish species. To understand why certain species are predisposed to depletion, stock-status estimates

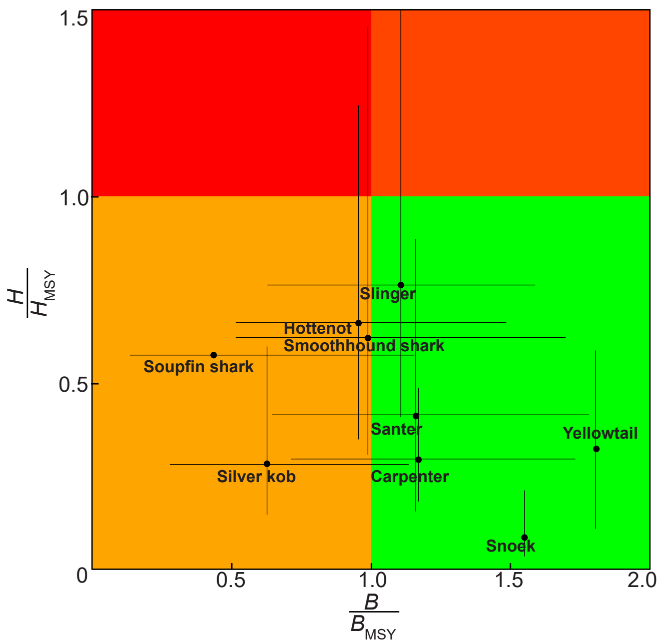


Figure 28: Kobe phase plot summarising the stock status estimates of fishing mortality relative to *F* and biomass relative to *B* for linefish species. Only results from stock assessments conducted by the Linefish Scientific Working Group (LSWG) in 2024 are included

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.

Current status

The results of stock assessments conducted in 2024 indicate that the drastic reduction of fishing effort from 2003 onwards resulted in the partial recovery of most of the main target species such as the slinger, Cape bream and carpenter (Figure 28; Table 6). However, other important stocks such as silver kob, soupfin shark and santer are still overfished. Overall catches in the linefishery continue to decline in favour of other fisheries such as the trawl fishery and the tuna pole-line fishery and the freshly implemented small-scale fishery. There is considerable inter-fishery conflict around species which are 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).

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 can 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 can damage 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.

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. Notably, numerous species that are important to shore- and estuarine-based subsistence fishing, such as dusky kob, are considered collapsed. Although conservation awareness among recreational anglers has somewhat increased in recent years, the proliferation of drone fishing had, until its ban, a detrimental effect on some of the most vulnerable species of teleosts and sharks as it allowed for selective targeting and fishing at shore distances too far to cast. That said, competitive organised angling has started to pivot towards ‘catch and release’ and competitive angling formats are constantly adapting to minimise fish mortalities. Still, 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, fatigue and hook damage.

Climate change

The small-scale and commercial sectors of the linefishery are the sectors 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 also likely 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.

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.

Further reading

Duncan MI, Bates AE, James NC, Potts WM. 2019. Exploitation may influence the climate resilience of fish populations through removing high performance metabolic phenotypes. *Scientific Re-ports* 9: article 11437.

Haupt M, Winker H, Parker D, Kerwath SE. 2020. Are South African linefishes recovering and what makes them prone to overexploitation? *African Journal of Marine Science* 42: 261–273.

Kerwath SE, Winker H, Götz A, Attwood CG. 2013. Marine protected area improves yield without disadvantaging fishers. *Nature Communications* 4: article 2347.

Kerwath SE, Parker D, Winker H, Potts W, Mann BQ, Wilke C, Attwood CG. 2019. Tracking the decline of the world's largest seabream against policy adjustments. *Marine Ecology Progress Series* 610:163–173.

Murray TS, Duncan MI, Winkler AC, Childs A-R, Mann BQ, Potts WM (eds). 2020. *Linefish resilience in the Anthropocene: the proceedings of the 5th Southern African Marine Linefish Symposium, Mpekweni Beach Resort, South Africa, 8–11 July 2019*. Makhanda, South Africa: Rhodes University.

Parker D, Coetzee JC, Winker H, van der Lingen CD. 2020. Accounting for linefish dependency in the management of South African small pelagic fisheries. *African Journal of Marine Science* 42: 183–194.

Parker D, Kerwath S, Næsje T, Arendse C, Keulder-Stenevik F, Hutchings K, Clark B, Winker H, Cowley PDP, Attwood CG. 2017. When plenty is not enough: an assessment of the white stumpnose (*Rhabdosargus globiceps*) fishery of Saldanha Bay, South Africa. *African Journal of Marine Science* 39: 153–166.

Parker D, Winker H, Attwood CG, Kerwath SE. 2016. Dark times for dageraad *Chrysoblephus cristiceps*: evidence for stock collapse. *African Journal of Marine Science* 38: 341–349.

Table 7: Annual catch (t) of eight important linefish species and two shark species caught in the linefishery for the period 1985–2023

Year	Carpenter	Geelbek	Hottentot	Kob	Slinger	Snoek	Santer	Yellowtail	Soupfin shark	Smoothhound shark
1985	587.94	152.28	399.18	751.89	312.28	1 063.17	73.27	324.16	44.75	0.00
1986	768.11	262.38	810.57	1 008.00	267.60	3 142.85	99.17	816.58	57.55	0.00
1987	831.41	435.78	914.72	951.06	245.82	5 642.06	99.13	809.38	140.23	0.00
1988	877.44	481.76	953.27	911.05	131.70	4 919.49	56.81	721.65	72.84	0.18
1989	774.62	809.53	739.45	1 048.68	198.82	4 038.98	60.09	867.65	103.10	0.04
1990	1 227.71	512.72	541.93	1 269.96	262.32	7 892.50	85.87	585.06	102.96	0.05
1991	1 210.33	456.92	522.20	1 041.23	248.58	6 556.27	89.44	542.44	140.34	0.00
1992	873.42	530.06	496.39	899.31	304.95	5 692.25	113.99	591.49	248.94	0.00
1993	695.14	609.88	614.49	933.59	298.20	2 948.11	123.53	888.11	292.16	0.01
1994	637.78	468.35	815.08	673.77	217.13	7 759.49	81.95	867.91	227.27	0.03
1995	757.57	396.41	252.02	710.83	234.68	9 617.64	85.22	800.91	141.88	0.09
1996	878.52	384.37	276.43	707.61	179.07	7 063.03	80.46	496.89	74.87	0.36
1997	840.86	524.08	321.60	735.34	128.17	6 623.10	67.60	487.91	80.62	0.19
1998	518.21	683.59	407.74	665.37	114.41	7 871.72	64.46	565.10	53.03	1.23
1999	573.75	466.76	269.83	513.10	160.35	8 348.16	59.89	338.89	76.54	0.59
2000	441.43	893.91	234.11	546.58	185.68	6 542.54	74.58	320.45	86.20	2.14
2001	284.67	394.52	109.39	415.52	139.12	6 838.55	69.17	327.30	21.15	1.60
2002	231.24	315.44	79.25	391.98	101.25	3 836.52	48.11	242.32	19.88	2.34
2003	177.05	512.58	105.98	272.16	87.78	4 532.15	48.29	328.81	25.51	1.00
2004	228.29	671.59	253.53	360.25	184.13	7 277.75	86.73	883.31	31.93	8.12
2005	183.78	580.14	167.80	323.62	168.84	4 787.07	84.10	739.40	59.60	3.27
2006	159.00	419.07	87.01	400.02	191.74	3 529.01	79.41	310.12	59.20	3.57
2007	265.05	447.74	127.89	420.74	157.11	2 765.10	84.40	478.49	163.49	9.32
2008	226.14	403.16	120.36	357.69	193.51	5 222.60	81.74	313.47	185.94	21.20
2009	282.17	494.88	183.62	441.97	186.06	6 321.70	65.53	329.98	124.32	29.23
2010	262.56	407.64	144.36	419.16	180.16	6 360.12	68.51	170.63	89.41	25.21
2011	362.68	286.17	216.25	312.44	213.82	6 205.43	61.98	203.72	49.99	16.81
2012	300.13	337.15	160.12	220.61	239.56	6 808.78	81.62	382.26	56.72	31.74
2013	480.95	263.32	173.16	156.60	199.50	6 690.41	84.14	712.11	72.56	16.16
2014	522.40	211.76	191.92	144.35	200.85	3 863.01	73.78	986.83	91.86	14.94
2015	521.87	243.58	142.77	123.04	186.00	2 103.86	69.34	608.65	59.72	11.45
2016	713.39	249.76	210.99	138.32	210.62	1 680.84	66.05	475.34	111.63	15.93
2017	819.74	148.22	187.99	99.62	215.38	1 888.38	72.17	360.56	44.97	12.33
2018	728.13	214.09	215.49	213.26	173.64	2 094.90	68.86	654.28	68.17	19.53
2019	604.45	131.76	188.17	227.23	215.35	1 878.71	78.14	439.03	60.43	10.68
2020	543.64	159.96	224.68	317.90	183.06	2 439.87	66.01	552.33	36.70	12.98
2021	441.20	87.71	151.47	175.79	186.33	2 746.65	64.41	239.51	31.46	10.59
2022	430.99	140.80	178.96	132.76	176.86	2 229.44	49.60	488.69	46.03	16.21
2023	384.25	159.94	244.15	149.86	128.82	1 244.40	43.94	521.55	32.57	11.24

Useful statistics

Annual catch (t) of eight important linefish species and two shark species caught in the linefishery for the period 1985–2023

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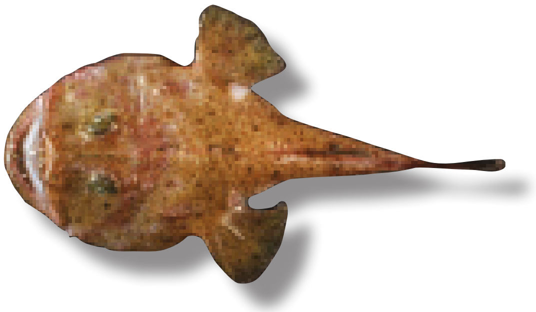
Monkfish



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 characterised 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 seabed and often burrow under the surface sediment while awaiting potential prey (Figure 29). 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

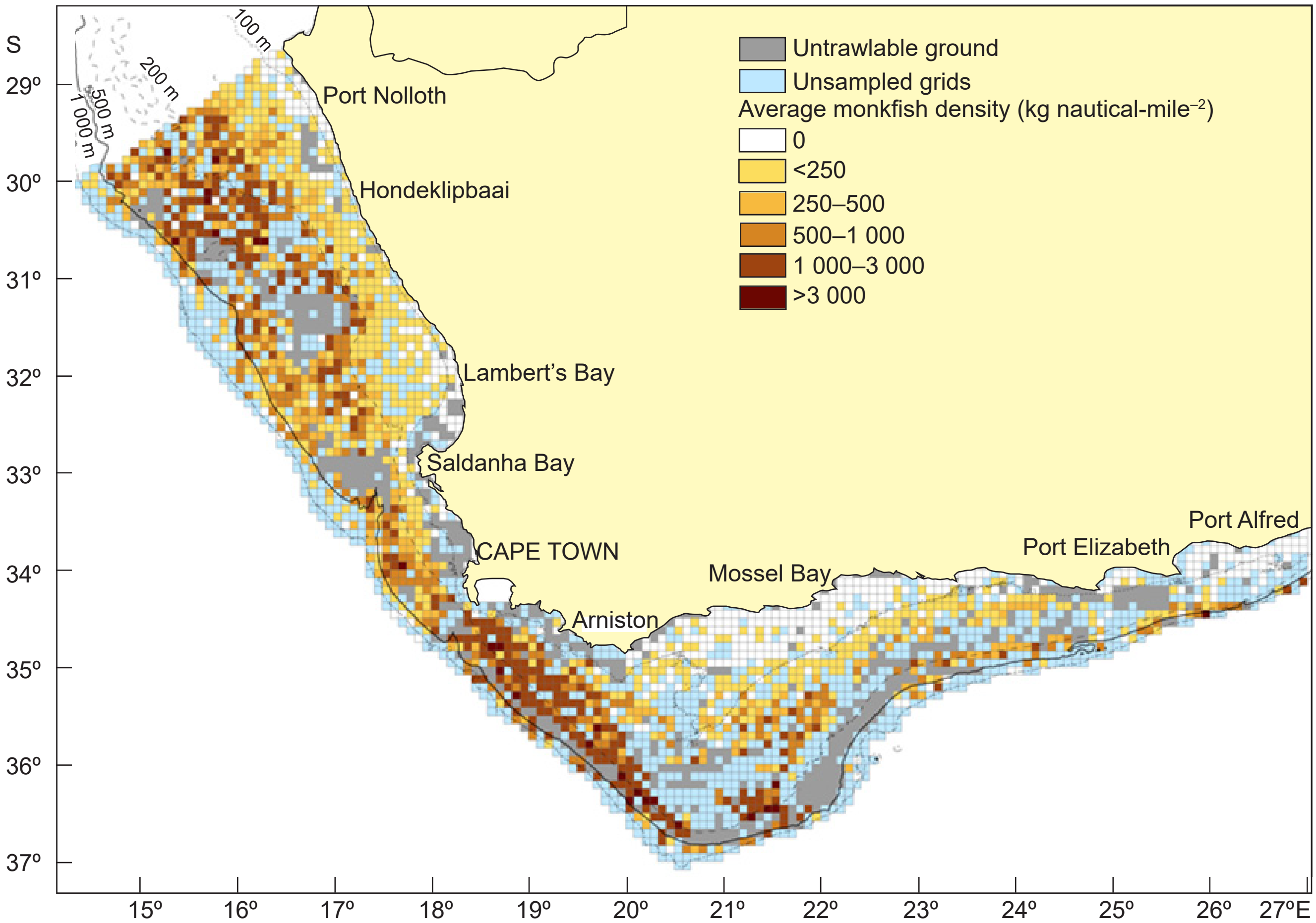


Figure 29: Distribution of Cape monkfish *Lophius vomerinus* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

about 50 m to 1 000 m (Figure 29) and larger individuals tend to be found deeper and farther 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 (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 4 500 t over the period from 1974 to 1994, increasing to a peak of over 10 000 t in 2001 and subsequently decreasing to an average of about 7 200 t since 2006 (Figure 30).

Prior to 2005, exploitation of the monkfish resource was unregulated. The increased catches raised concerns of possible 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 (ASPM) to evaluate resource status and productivity 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 suggested 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

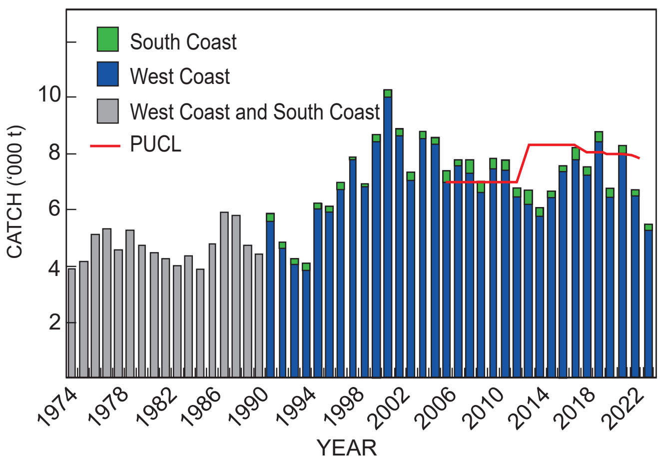


Figure 30: Annual catches (t) of Cape monkfish made by the hake trawl fishery for the period 1974–2023, and the precautionary upper catch limit (PUCL) that was introduced in 2006. Catches prior to 1991 cannot be split by coast. WC = West Coast, SC = South Coast

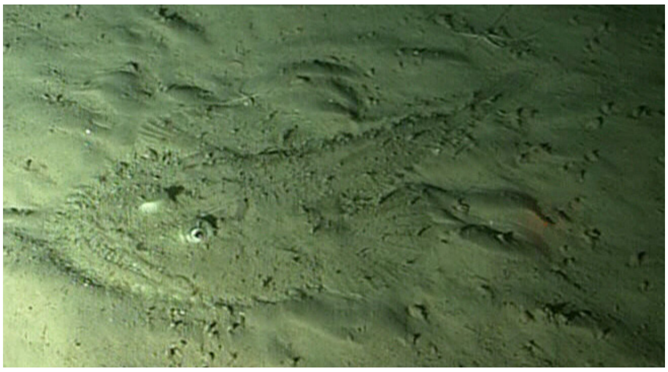


Figure 31: A monkfish in its natural habitat. Photograph courtesy of SAEON

PUCL in 2006 was set at a level of 7 000 t per annum and maintained at this level until 2013. However, this was generally exceeded during the early years of its implementation (Figure 31), largely due to difficulties associated with real-time monitoring and management. Co-management procedures have been developed and implemented over time and catches after 2011 have, with two exceptions, generally been below the PUCL (Figure 30). A biennial schedule of assessment updates for monkfish has been adopted by the Department, with a “*status quo*” situation prevailing in every other year. The RY analysis is consequently updated every two years and has resulted in PUCLs that have fluctuated between 7 972 t and 8 300 t per annum over the period 2013–2021.

While the 2021 assessment results were used to set the PUCLs for 2022 and 2023 at 7 780 t (with the intention of updating the assessment in 2023), concerns were raised during 2022 regarding an appropriate management response to the 2021 catch of monkfish, which had exceeded the PUCL set for that year by 287 t (about 3.6%). While it was recognised that this slight over-catch was largely a result of the 15% rollover of the hake TAC that was permitted by the Department for 2021 for the alleviation of the negative impacts of the COVID19 pandemic on hake catches during 2020, it was considered useful to conduct an unscheduled update of the monkfish replacement yield estimates to provide a scientific basis for possibly adjusting the monkfish PUCL for 2023 if appropriate. The results of the analysis indicated that the monkfish PUCL should be reduced by 95 t to 7 780 t for the 2023 fishing season. It was also decided that provided the catches of monkfish made during 2022 did not exceed the PUCL set for that year (7 875 t), a “*status quo*” PUCL should be implemented for 2024 (i.e. 7 780 t) and that the next update of the monkfish assessment should be conducted during 2024. The monkfish catch for 2022 was 6 323 t, providing no basis to deviate from the decision to maintain the PUCL for 2024 at 7 780 t.

Research and monitoring

Abundance estimates for monkfish (Figure 32) 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

Table 8: Maximum likelihood estimates of coast-specific replacement yield (RY, t) for the South African monkfish resource for different assumed values of survey catchability (*q*) from the 2024 updated assessment. The associated log likelihood (-ln*L*), asymptotic normal 95% confidence intervals (95% CI, upper and lower) and the CV (%) corresponding to each estimate are also shown

q	West Coast				South Coast			
	-ln*L*	RY(t)	CV(%)	95%CI	-ln*L*	RY(t)	CV(%)	95%CI
0.7	-20.56	7 391	2.8	6 999, 7 805	-13.9	418	30.9	224, 598
1,0	-20.59	7 281	1.9	7 014, 7 559	-13.7	401	21.0	266, 527
1,3	-20.19	7 213	1.5	7 011, 7 422	-13.5	391	15.9	288, 488

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.

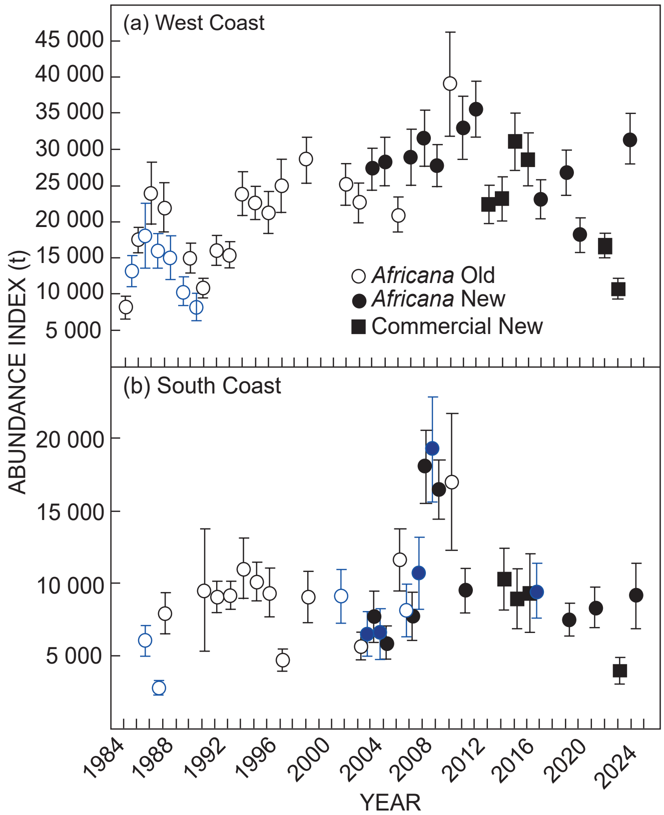


Figure 32: Monkfish abundance estimates (t ± 1 SE) derived from fishery-independent swept area demersal surveys. Estimates are illustrated by coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West Coast) 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 FRS *Africana*, Commercial = commercial fishing vessel

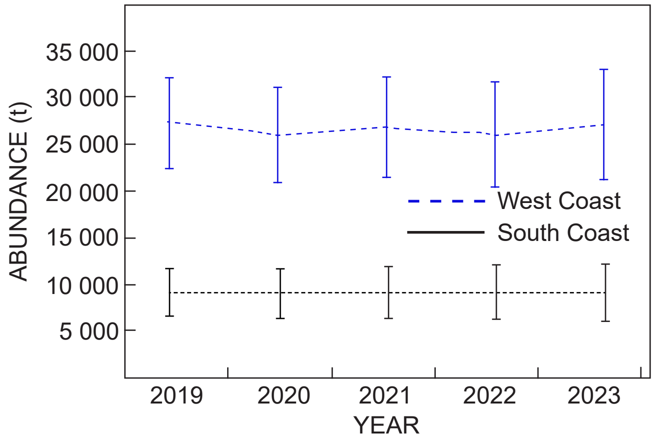


Figure 33: Point estimates of abundance and associated 95% confidence intervals per coast for monkfish for the most recent five years derived from maximum likelihood estimation.

Current status

The monkfish assessment was updated during 2024, again using a coast-disaggregated RY approach applied to survey and commercial catch data extending to the end of 2023. The resulting RY estimates (Table 8) ranged from 7 213 to 7 391 t on the West Coast and 391 to 418 t on the South Coast, depending on the survey catchability (*q*) assumptions that were considered. The base case model (*q* = 1.0) indicated that coast-specific estimates of biomass have remained relatively stable over the past five years (Figure 33), with the 2023 estimate for the West Coast being slightly higher than that for the previous year. To remain consistent with the approach that has been used previously to formulate scientific advice (i.e. using the RY estimates from the *q* = 1 model runs), the PUCL for 2025 and 2026 was set at 7 638 t (comprising a West Coast component of 7 281 t and a South Coast component of 357 t). This is a reduction of 142 t (1.83 %) from the 7 780 t that was set for the 2023 and 2024 fishing seasons. The next update of the monkfish assessment is scheduled for 2026.

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

Badenhorst A, Smale MJ. 1991. The distribution and abundance of seven commercial trawlfish from the Cape south coast of South Africa, 1986–1990. *South African Journal of Marine Science* 11: 377–393.

Booth T. 2004. South African monkfish (*Lophius vomerinus*) stock assessment. Report No. WG/05/04/D:A:07. Marine and Coastal Management, Cape Town, South Africa.

Glazer J, Durholtz D, Fairweather TP. 2017. An assessment of the South African Monkfish resource, *Lophius vomerinus*. Report No. FISHERIES/2017/SEP/SWG-DEM/36. Department of Agriculture, Forestry and Fisheries, Cape Town.

Leslie RW, Grant WS. 1990. Lack of congruence between genetic and morphological stock structure of the southern African anglerfish *Lophius vomerinus*. *South African Journal of Marine Science* 9: 379–398.

Walmsley SA, Leslie RW, Sauer WHH. 2005. The biology and distribution of the monkfish *Lophius vomerinus* off South Africa. *African Journal of Marine Science* 27: 157–168.

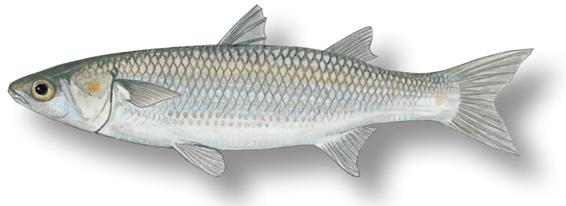
Yemane D, Durholtz D, Fairweather T, Glazer J. 2024. Updated assessment of monkfish (*Lophius vomerinus*) off the south and west coasts of South Africa. Report No. FISHERIES/2024/OCT/SWG-DEM/28rev. Department of Forestry, Fisheries and the Environment, Cape Town.

Useful statistics

Annual catches (t) of monkfish made by the hake trawl fishery for the period 1974–2023, and the precautionary upper catch limit (PUCL) that was introduced in 2006. Catches prior to 1991 cannot be split 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	7 976	314	8 290	7 972
					2022	6 323	388	6 712	7 875
					2023	5 238	316	5 554	7 780

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 are the fisheries for harders (or mullet) *Chelon richardsonii*, 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 intersectoral conflict arises due to real and perceived impacts on linefish resources from associated bycatch. Excessive effort 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* 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 fishers 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, less than half of which was reported. 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 houndshark *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, and declining catches due to overfishing. Consequently, from 2001 onwards, rights were allocated to those reliant on the fishery, and the number of legal beach-seine operations was reduced from around 200 to 28 and gillnet operations from just over 1 500 to 162.

Prior to this reduction in effort, size-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 size 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 size, i.e. before they were 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 size of harders in Saldhana Bay and Langebaan Lagoon, respectively, and the collapse of that population or stock (see ‘Current status’, below). The 2015 fishing rights allocation process (FRAP2015) and the implementation of small-scale fisheries were intended to see these fishers formally incorporated into the beach-seine and gillnet fisheries 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 length frequency, 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, however, not been possible to repeat this survey since 1995 due to the high cost.

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

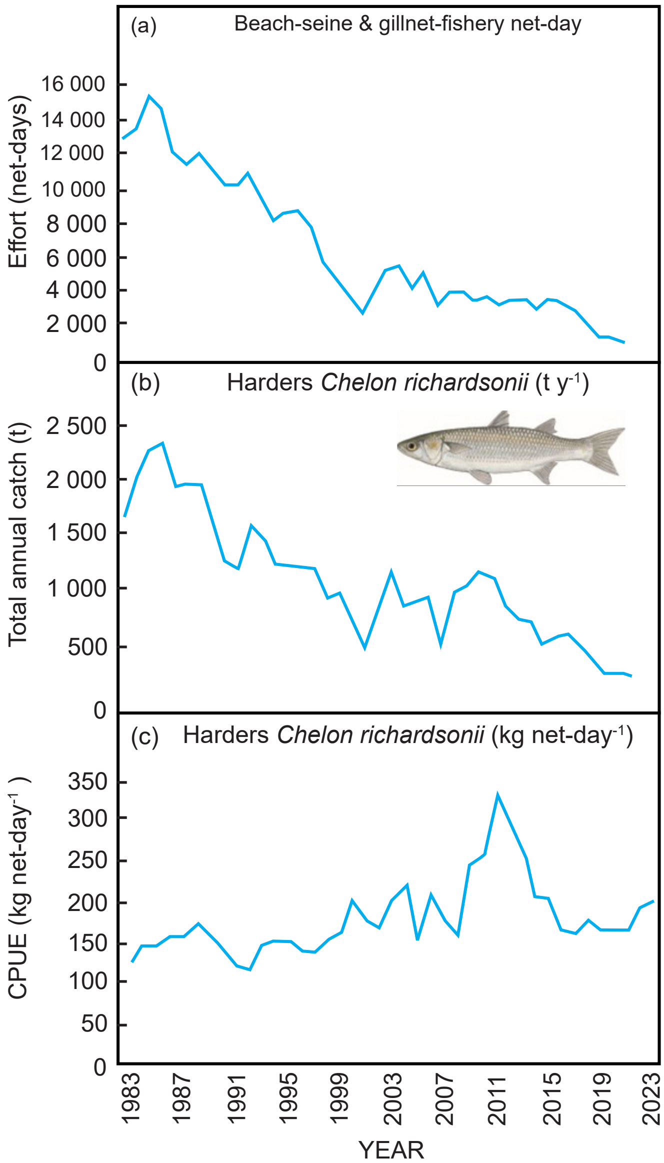


Figure 34: Reported (a) beach-seine and gillnet effort (net-days); (b) total annual catch (t); and (c) CPUE (kg net-day^{-1}) from 1983 to 2023. Catches corrected for 14% under-reporting

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 size frequency information, which allows comparison between areas with different levels of fishing effort, is validated by size-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 size.

Current status

Overall, the last 40 years have seen a substantial decline in effort and landed catch (Figure 34). Reported effort declined from > 14 000 net-days in 1983 to < 2 000 net-days in 2023, although some of the latter may be due to aggregating of daily catch and effort into weeks and months in catch returns. Total reported catch has declined from >2 500 t to <500 t over the same time-period, while reported effort dropped by 90%, and CPUE (kg net-day^{-1}) increased by only 50%. Prior to the reduction in effort implemented after 2001, size 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 size of fish caught (Figure 35). 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 of less than one year old and well below minimum legal size, i.e. before they were recruited into the linefishery and before they were able to reproduce and thus contribute to replenishment of the linefish stocks.

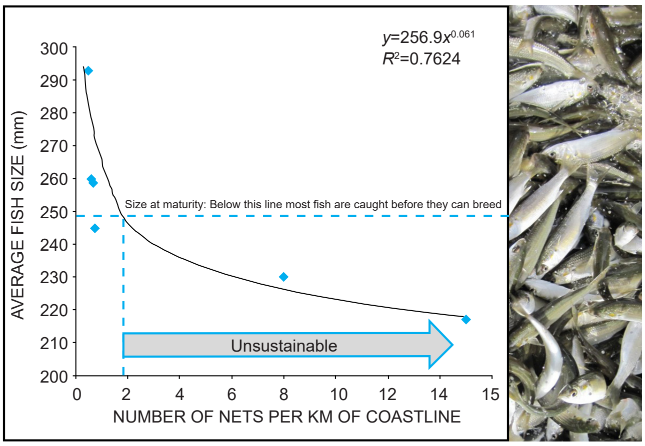


Figure 35: The relationship between harder *Chelon richardsonii* fish size and fishing effort (the number of gillnets per kilometre of coastline)

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 size of harders and bycatch species such as elf *Pomatomus saltatrix*. An increase in the numbers and mean size 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.

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 substantial drop in CPUE (>40%) and a 15–20% decline in the average size of harders caught (Figure 36).

Consequently, an assessment of the Saldanha and Langebaan harder gillnet fishery was conducted in 2019. The per-recruit assessment applied utilised 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 of 36.5 mm over time (Figure 36). The standardised CPUE of harders for the period 2008–2016 declined, indicating a reduction in relative abundance of C. richardsonii of approximately 30% over this time (Figure 37). A spawner-biomass-per-recruit model revealed that the stock is heavily depleted and at only 24% of estimated pristine spawner biomass or breeding potential (Figure 38), 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 total length 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 a severe 1-in-100-year drought, which considerably reduced juvenile recruitment into estuaries and ultimately into fisheries, over the last six years. This had a

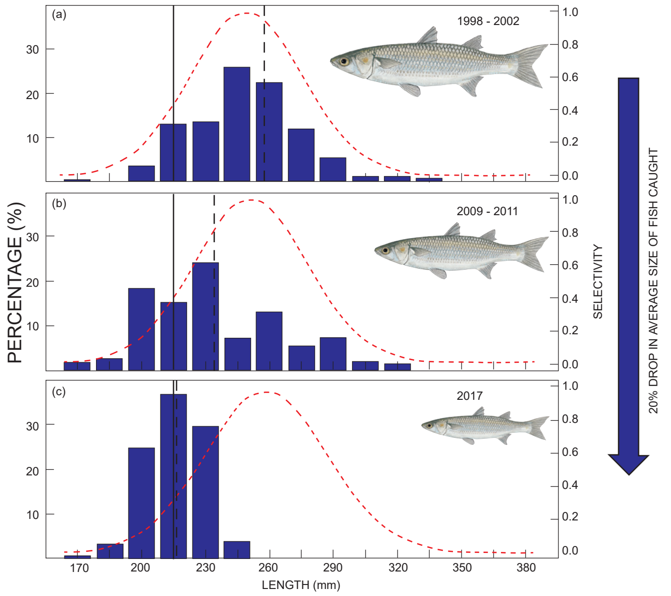


Figure 36: Length-frequency distributions of *Chelon richardsonii* caught in Saldanha and Langebaan by the commercial gillnet fishery fleet for three different time-periods. The solid vertical line represents length-at-50% maturity (215 mm total length [TL]) and the dotted vertical line is the mean TL 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 size in each of the time-series

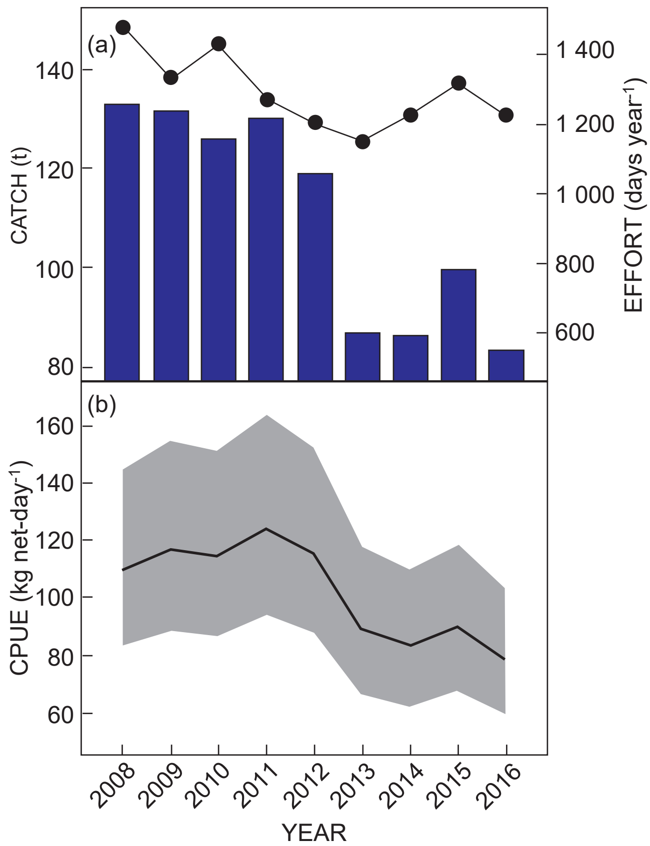


Figure 37: (a) The annual total catch (t) (shaded bars) and fishing effort (days year^{-1}) (line) of *Chelon richardsonii* by the commercial net fishery in Saldanha Bay and Langebaan, and (b) the standardised CPUE (kg trip^{-1}) estimates (±95% CI) of the commercial *Chelon richardsonii* net fishery in Saldanha Bay and Langebaan derived from mandatory catch records between 2008 and 2016. After Horton et al. (2019)

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

Environmental drivers 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 that are subject to low fishing pressure are skewed towards females and may be as high 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 to maturity at the same fast rate during the first year, whereupon female growth slows considerably and that of males becomes negligible. Females attain larger size-at-age in all regions and habitats. South Coast female fish are larger than West Coast ones and estuarine 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 responses to the environment and fishing. Females grow larger than males and continue to grow after maturity to maximise

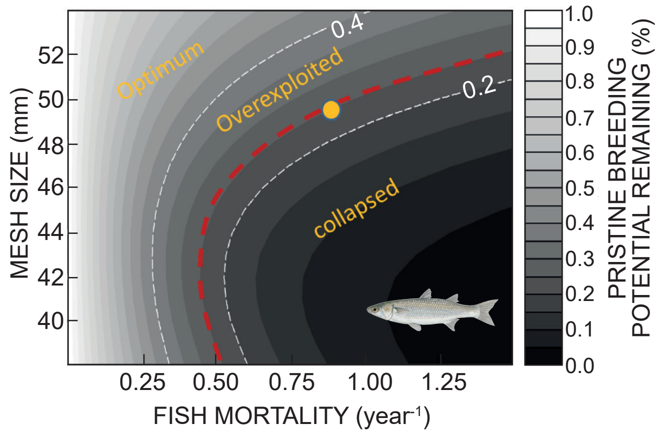


Figure 38: An isopleth illustrating the response of the percentage of spawner-biomass-per-recruit (SBR) to unexploited levels (SB_0) of *Chelon richardsonii* according to varying levels of fishing mortality (F, year^{-1}) and different combinations of mesh sizes (mm). Critical reference depletion points (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)

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 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 less than 10% of their pristine level and are likely to decline to less than 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.

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 harders 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 a wetland of international importance. Extended drought and over-abstraction of freshwater inflow has resulted in unprecedented low water levels, fish kills and loss of bird life. 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 fish kill event, salinity was markedly elevated in the estuary. 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, 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 more than 22% of estuarine nursery area for harders on the West Coast, of which the stock implications have yet to be determined.

Figure 39: Acidification of Verlorenvlei Estuarine Lake resulted in 100% mortality of all fish and invertebrates and flocculation of ferrous precipitate.

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 penguins *Spheniscus demersus* around Dassen and Robben Islands prompted management intervention in the late 1990s. Gillnet fishers were setting their nets across penguin approaches to the islands because of the guano slicks on which harders feed. Consequently, in 2001, gillnet exclusion zones were implemented that prohibit gillnets being set within 1–2 km of each island.

High bird incidental 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 incidental mortality issue has been the recent proliferation of very cheap "single-use" gillnets in KwaZulu-Natal southwards to the Wild Coast. The resultant upsurge in illegal gillnets has been accompanied by an increase in bird, reptile and mammal incidental catch and retention of these species for food and for the African and Asian traditional medicine trade.

The high incidence of dead penguins in confiscated and retrieved ghost-fishing illegal gillnets is a concern. The illegal gillnets are aimed at catching sharks and linefish and hotspots include coastal islands. Globally, penguins are rated as the birds most vulnerable to gillnet mortalities. Data are limited due to the illegal nature of the gillnet fishery so penguin mortalities in gillnets relative to predation and other drivers of penguin mortality are being simulated using foraging tracks derived from penguin telemetry data.

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 caught as bycatch to depredation of catches by sevengill cowsharks *Notorynchus cepedianus* and bronze whalers *Carcharhinus brachyurus*. Despite claims to the contrary, white shark *Carcharodon carcharias* are not attracted to beach-seine activity in False Bay, and this activity therefore does not pose a safety risk to beach-goers. Analysis of more than 11 000 catch records suggest that these white 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 their target species (e.g. yellowtail *Seriola lalandii*) in Fish Hoek Bay.

Stonewall fishtraps

Stonewall fish traps or "visvywers" were once an integral part of the "netfishery" on the Cape South Coast (Figure 40). Visvywers were perhaps first built by aboriginal peoples, but no links have been found between the catch composition in nearby middens and those in visvywers, nor is there any evidence for construction of these traps by aboriginal peoples. It is thought that traps built by these peoples were likely to have been according to need and would have been likely to have been small. Peak construction of the large visvywers occurred in colonial times with most visvywers constructed after 1880 and 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 shores on the Cape South Coast. Demand soon exceeded available area and trap construction spread to sandy beaches. These latter traps, which were constructed of materials such as railway tracks, steel cables and concrete have all but disappeared. The most productive traps were fished until 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 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 when falling tides commence during dark, thus entrapping more fish, and dawn harvesting times are 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 9). The fishery is characterised by low catches punctuated by 1-in-50 large 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

Figure 40: Historical “visvywers” or stonewall fish-traps in the Still Bay MPA

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, archaeological feature of the Still Bay MPA, but a potential large linefish bycatch of more than 500 t suggests against re-establishing the fishery on the Cape South Coast.

Table 9: Catch composition of the Still Bay stone-wall fish traps over 13 dark-moon springtides

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

Further reading

Horton M, Parker D, Kerwath S, Lamberth SJ, Winkler H, Hutchings K. 2019. Age, growth and per-recruit stock-assessment of Chelon richardsonii in Saldanha Bay and Langebaan, South Africa. *African Journal of Marine Science* 41: 313–324.

Hutchings K, Lamberth SJ. 2002. Catch and effort estimates for the gillnet and beach-seine fisheries in the Western Cape, South Africa. South African Journal of Marine Science 24: 205–225.

Hutchings K, Lamberth SJ. 2002. Socio-economic characteristics of gillnet and beach-seine net fishers in the Western Cape, South Africa. *South African Journal of Marine Science* 24: 243–262.

Hutchings K, Lamberth SJ. 2003. The likely impacts of an eastward expansion of the inshore gill-net fishery in the Western Cape, South Africa: implications for management. *Marine and Freshwater Research* 54: 39–56.

Hutchings K, Clark BM, Atkinson LJ, Attwood CG. 2008. Evidence of recovery of the linefishery in the Berg River Estuary, Western Cape, South Africa, subsequent to closure of commercial gillnetting. *African Journal of Marine Science* 30: 507–517.

Kelly C, Foden W, Midgley G, Porter S, Lamberth S, van der Lingen C, Atkinson LJ, Robinson J. 2019. Chapter 6: Climate Change. In: Sink KJ, van der Bank MG, Majiedt PA, Harris LR, Atkinson LJ, Kirkman SP, Karenyi N (eds), South African National Biodiversity Assessment 2018: Technical report, volume 4:marine realm. Pretoria. South Africa: South African National Biodiversity Institute. Available at http://hdl.handle.net/20.500.12143/6372.

Lamberth SJ, Whitfield AK. 2013. Harder (Chelon richardsonii). In: Mann BQ. (ed), *Southern African marine linefish species profiles*. Special Publication No. 9: Durban: Oceanographic Research Institute. pp 125–127.

van Niekerk L, Adams JB, Lamberth SJ, MacKay F, Taljaard S, Turpie JK, Weerts S, Raimondo DC. (eds). 2019. South African National Biodiversity Assessment 2018 :Technical report, volume 3: estuarine realm. CSIR report number CSIR/SPLA/EM/EXP/2019/0062/A. SANBI report number SANBI/NAT/NBA2018/2019/Vol3/A. Pretoria: South African National Biodiversity Institute. Available at http://hdl.handle.net/20.500.12143/6373

Useful statistics

Catch composition of the Still Bay stone-wall fish traps over 13 dark-moon springtides

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Cape stumpnose	0.16	0.15	1.04
Other	8.98	2.10	58.95
Total	14 038	2 711	1 352

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 eight people) held concessions to harvest oysters and employed

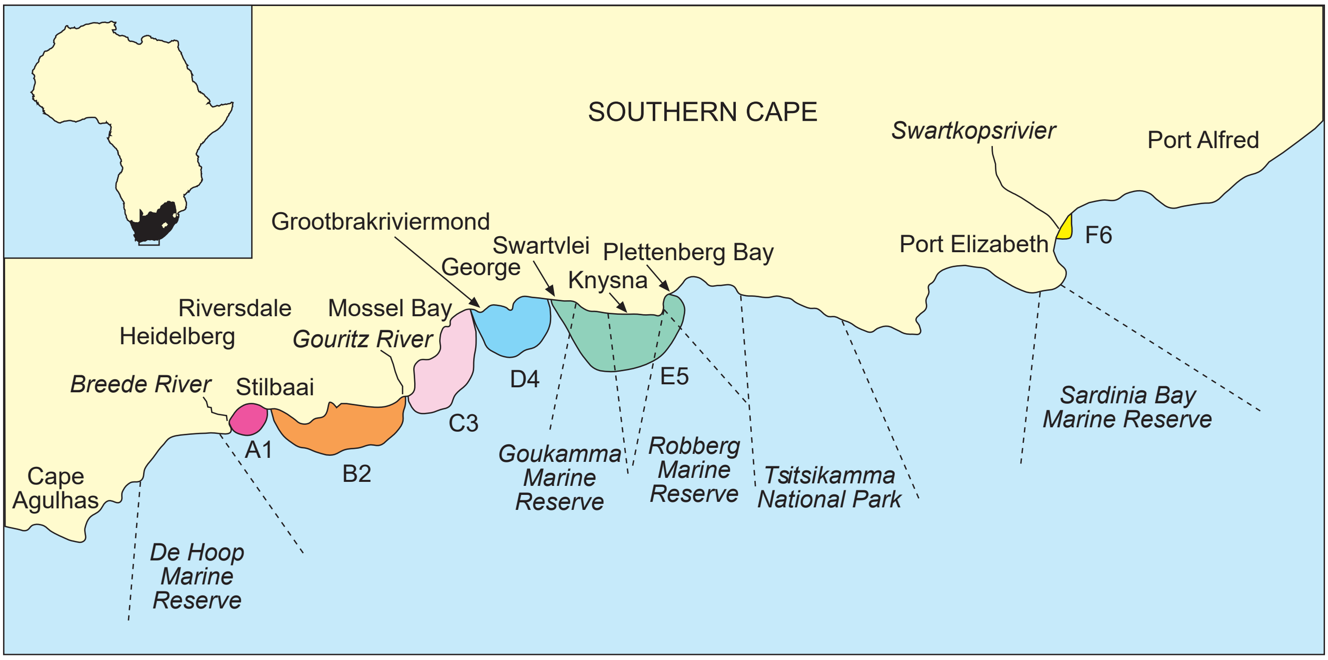


Figure 41: Spatial divisions of the oyster fishery in Port Elizabeth and the Southern Cape. The colour-coded areas indicate dedicated oyster-collection zones

large 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 strategy four areas were officially recognised: the Southern Cape, Port Elizabeth, KZN North and KZN South (Figures 41 and 42). Regional differences regarding regulations and harvesting patterns were retained. Management strategies for each of the areas vary. The Southern Cape fishery is managed by using a TAE, whereby the total number of right holders are limited per area in each of the four sub areas. In the Port Elizabeth a single right holder may only collect beach cast oyster. KZN North and South are managed by TAC, only allowing a total catch per day per person of 180 oysters. These two areas are further managed utilising a rotational system, whereby each of the four subareas per area are rotationally utilised. Hence, each subarea is fished for one fishing season and then left fallow for three seasons, in order to recuperate (see Steyn et. al. 2023 in further reading).

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

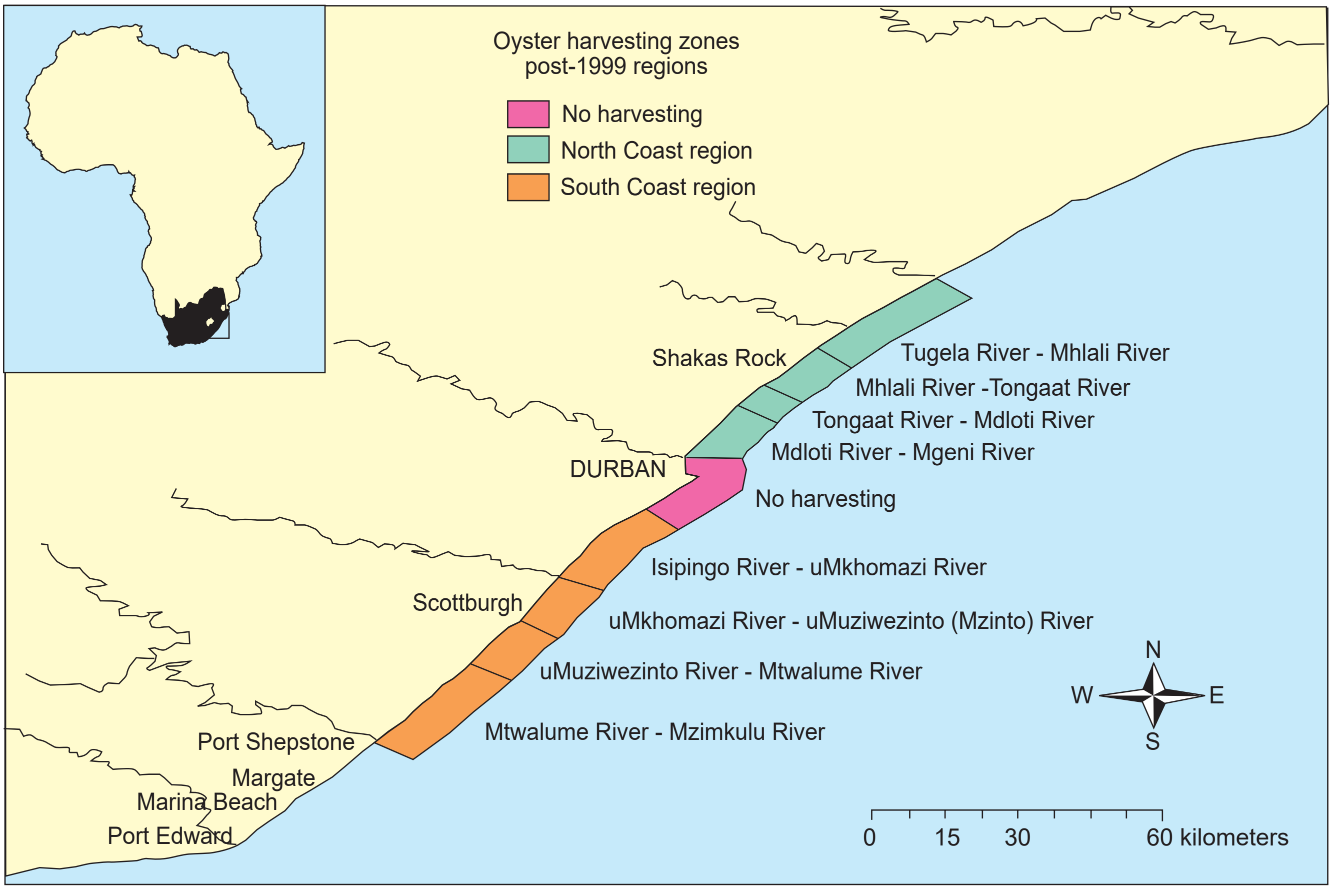


Figure 42: Spatial divisions of the oyster fishery in KwaZulu-Natal (re-zoning of South Coast included)

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 variable accessibility made accurate sampling of this resource, in the intertidal zone, exceedingly difficult. Fishery independent surveys in the Southern Cape are underway, however, in order to assess population fluctuations, with a report expected in 2030. Priority was 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.

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 43). 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 43). 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

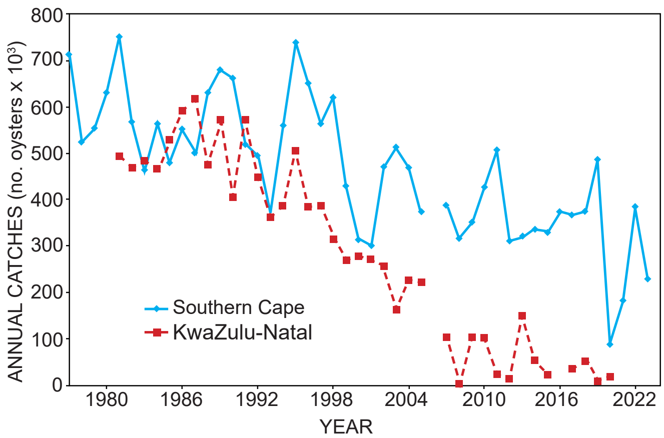


Figure 43: Total number of oysters harvested commercially per annum from 1977 to 2023. Note: No data for 2016 and 2021–2023 had been submitted for KZN

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 have been escalating 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 44) and are considered unsuitable for the purposes of stock assessment. Similarly

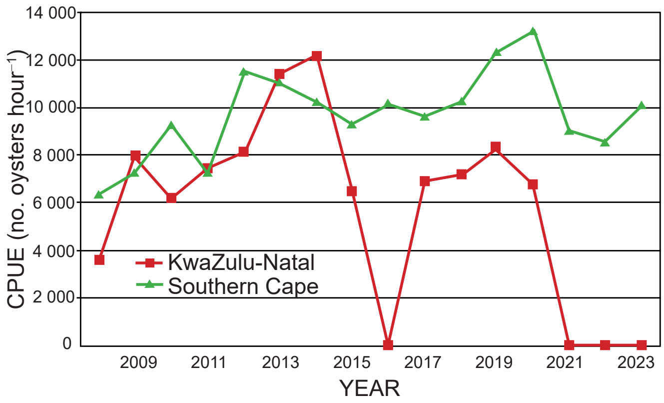


Figure 44: CPUE data calculated from catch data (see Figure 43) for oysters harvested commercially per annum from 2008 to 2023. No data for 2016 and 2021–2023 had been submitted for KZN

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 43), partly due to substandard data submissions and the effect of the Covid-19 pandemic, CPUE fluctuated between 68 and 83 oysters per hour (Figure 44). No KZN catch 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, with no data received for 2023. The status of this resource thus remains uncertain, but fishery-independent surveys are underway in the commercially harvested areas, to obtain a better understanding of fluctuations in exploited oyster populations.

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, because of destructive and unsustainable resource extraction and coastal degradation. This loss has had serious ecosystem consequences because of the oyster's role as an ecosystem engineer. 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* within estuaries, and because this is an alien species, harvesting it would be highly targeted and with no bycatch; hence a commercial fishery for this species could become feasible.

Further reading

Beck MW, Brumbaugh RD, Airoldi L, Carranza A, Coen LD, Crawford C, Dereo O, Edgar GJ, Hancock B, Kay MC, Lenihan HS, Luckenbach MW, Toropova CL, Zhang G, Guo X. 2011. Oyster reefs at risk and recommendations for conservation, restoration and management. *BioSciences* 61: 107–116.

de Bruyn PA, Moloney CL, Schleyer MH. 2009. Application of age-structured production models to assess oyster *Striostrea margaritacea* populations managed by rotational harvesting in KwaZulu-Natal, South Africa. *ICES Journal of Marine Science* 66: 408–419.

Haupt TM, Griffiths CL, Robinson TB, Tonin AFG, De Bruyn PA. 2010. History and status of oyster exploitation and culture in South Africa. *Journal of Shellfish Research* 29: 151–159.

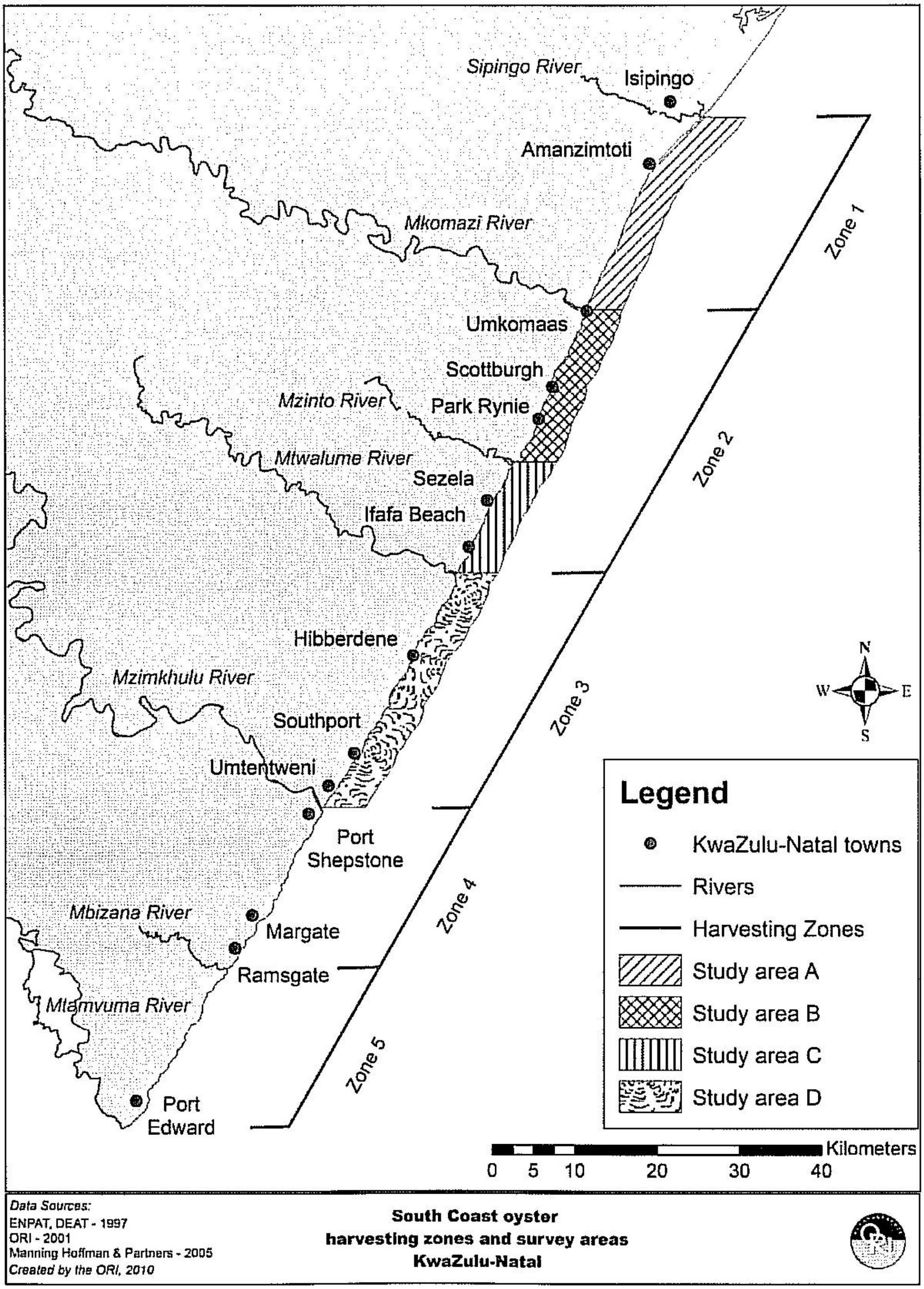
King NG, Wilmes SB, Smyth D, Tinker J, Robins PE, Thorpe J, Jones L, Malham SK. 2020. Climate change accelerates range expansion of the invasive non-native species, the Pacific oyster, *Crassostrea gigas*. *ICES Journal of Marine Science* 78: 70–81.

Keightley J, von der Heyden S, Jackson S. 2015. Introduced Pacific oysters *Crassostrea gigas* in South Africa: demographic change, genetic diversity and body condition. *African Journal of Marine Science* 37: 89–98.

McAfee D, Connell SD. 2021. The global fall and rise of oyster reefs. *Frontiers in Ecology and the Environment* 19: 118–125

Robinson TB, Griffiths CL, Tonin A, Bloomer P, Hare MP. 2005. Naturalized populations of oysters *Crassostrea gigas* along the South African coast: distribution, abundance and population structure. *Journal of Shellfish Research* 24: 443–450.

Table 10: KwaZulu-Natal South Coast oyster study areas A to D which correspond to the newly proposed oyster management zones



Patagonian toothfish

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

Introduction

Patagonian toothfish *Dissostichus eleginoides* (Figure 45) 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 ºC. 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 40º S and 55º 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. Various mitigation measures aimed at reducing the impacts of cetacean depredation have been tested by the fishing industry with varying success.

Figure 45: 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 46). Another shift in the gear employed began with the introduction in 2008 of a modified longline gear, the trotline, which appreciably decreased the loss of catch to marine mammal depredation and displayed an improved retention of large fish. Use of this gear subsequently increased to the extent that

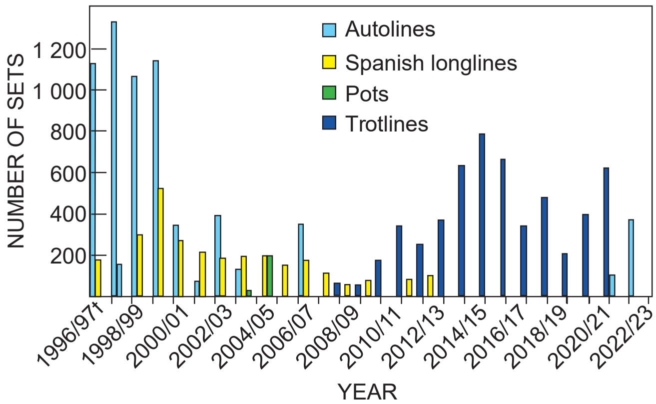


Figure 46: Number of (legal) sets deployed per fishing season in the Prince Edward Islands EEZ. Data are shown for pot lines and for three different longline gear configurations deployed in the fishery over time. † Note that data for the 1996/97 season include fishing during the months of October and November 1996

no Spanish longline gear was used after the 2012/13 fishing season (Figure 46). Both active vessels were withdrawn from the fishery during the 2021/22 season, and a shift back to the use of autoline gear occurred when a different vessel was introduced to the fishery in 2022. These gear changes have complicated the assessment 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 2011/12 season and continued through to the end of the 2012/13 fishing season, but no such experiment to undertake a similar calibration between the trotline and the new autoline gear has been possible to date. Currently, autolines 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 group of illegal vessels that ranged throughout the Southern Ocean. The estimated IUU catch during those initial two years is estimated to have been 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 and inadequate surveillance in the PEI-EEZ. Consequently, assessments of the Patagonian toothfish resource in the PEI-EEZ 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.

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 (see Table 13). 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. An OMP is essentially a combination of pre-specified methods of data collection and analysis, coupled with a set of simulation-tested decision rules that specify exactly how the regulatory mechanism is to be computed each year. In the case of Patagonian toothfish in the PEI-EEZ, the regulatory mechanism is a TAC, the value of which is calculated from stock-specific monitoring data (commercial CPUE indices of abundance and indices related to abundance derived from mark-recapture data). Implicit in this OMP approach is a schedule for OMP revision (every 4 years) to account for updated datasets and possible changes in resource and/or fishery dynamics, as well perhaps as updated management objectives.

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), and 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.
– 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 to the 2024/25 fishing seasons (see Table 13).

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 program was initiated in 2006. Vessels are required to tag and release one fish per tonne of catch (in line 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 2004, 4 632 fish have been tagged, of which 295 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.

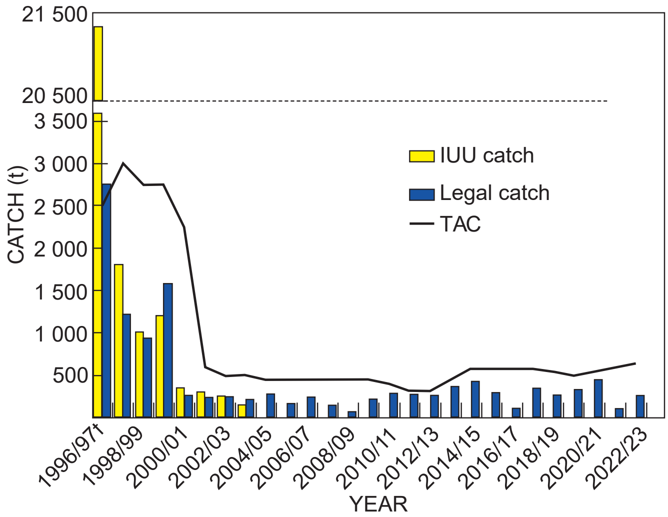


Figure 47: Catches (t) of Patagonian toothfish estimated to have been taken from the Prince Edward Islands EEZ. Catches are split into those from the legal fishery and estimates of illegal (IUU) catches. † Note that data for the 1996/1997 season include legal catches during the months of October and November 1996

Season	Released	Recaptured
2004/2005	175	4
2005/2006	179	4
2006/2007	120	8
2007/2008	140	12
2008/2009	74	1
2009/2010	131	22
2010/2011	206	15
2011/2012	162	12
2012/2013	254	30
2013/2014	380	59
2014/2015	473	47
2015/2016	345	17
2016/2017	115	8
2017/2018	363	20
2018/2019	285	9
2019/2020	366	15
2020/2021	502	6
2021/2022	100	3
2022/2023	262	3
Total	4 632	285

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

Current status

A routine update of the toothfish reference case 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. In keeping with this schedule, a routine update of the reference case assessment was conducted in October 2024 using updated catch (Figure 47), CPUE, catch-at-length and tagging data (Table 11) that extended to the end of the 2022/23 fishing season. Two runs of the reference case assessment were performed, assuming that either the trotline or the longline model parameters are applicable to the recent autoline gear data. The differences in the results amongst the reference case models of 2022, 2023 and 2024 (whether assuming trotline or longline parameters to model autoline data) were relatively small. With the further year's data available, the results showed a slightly better status for the resource (Table 12) and an increase in abundance for 2022 and 2023 compared to the preceding few years (Figure 48). The results indicated that the resource remains above B_{MSY}.

Figure 48: Spawning biomass trajectories estimated by the 2022, 2023 and 2024 reference case assessment updates. Estimates are shown in both absolute terms (upper panel) and relative to the spawning biomass yielding maximum sustainable yield (lower panel)

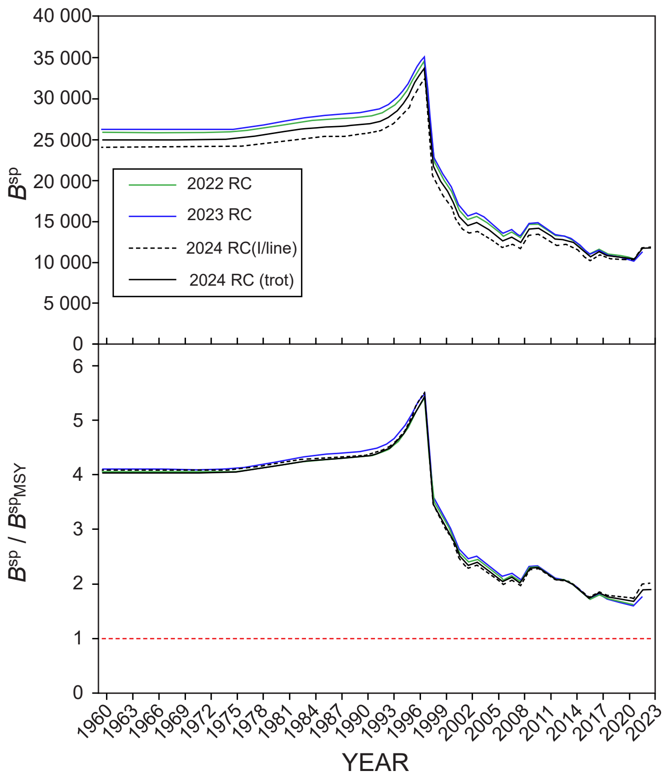


Table 12: Results from the 2022, 2023 and 2024 updates of the Patagonian toothfish reference case operating model. Note that two model variants were evaluated during the 2024 update that assumed either trotline ("RC 2024 [trot]") or Spanish longline ("RC 2024 [l/line]") parameters when fitting to the data from the recent autoline deployments

Parameter	Description	RC 2022	RC 2023	RC 2024 (trot)	RC 2024 (l/line)
K^{sp}	Pre-exploitation spawning biomass (t)	25 886	26 185	25 004	24 075
MSY	Maximum sustainable yield (t)	1 102	1 112	1 068	1 032
B_{MSY}	Spawning biomass yielding MSY (t)	6 401	6 465	6 195	5 993
B^{sp}_{2020} / K^{sp}	Depletion in 2020	0,414	0.401	0	0
B^{sp}_{2021} / K^{sp}	Depletion in 2021	0,403	0.39	0	0
B^{sp}_{2022} / K^{sp}	Depletion in 2022	–	0.431	0	0
B^{sp}_{2023} / K^{sp}	Depletion in 2023			0	0
B^{sp}_{2020} / B_{MSY}	Spawning biomass in 2020 relative to B_{MSY}	1.674	1.626	2	2
B^{sp}_{2021} / B_{MSY}	Spawning biomass in 2021 relative to B_{MSY}	1.632	1.581	2	2
B^{sp}_{2022} / B_{MSY}	Spawning biomass in 2022 relative to B_{MSY}	–	1.747	1 898	1 971
B^{sp}_{2023} / B_{MSY}	Spawning biomass in 2023 relative to B_{MSY}	–	–	1 894	1 985

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 that 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 aimed primarily at protection of biodiversity.

Further reading

Brandão A, Butterworth DS. 2021. The 2020 Operational Management Procedure for the toothfish (*Dissostichus eleginoides*) resource in the Prince Edward Islands vicinity. FISHERIES/2021/JUN/SWG-DEM/09. Department of Forestry, Fisheries and the Environment, Cape Town.

Brandão A, Butterworth DS. 2021. Updated GLMM standardised trotline CPUE series for the toothfish resource in the Prince Edward Islands EEZ to include data up to the 2020 season. FISHERIES/2021/OCT/SWG-DEM/22. Department of Forestry, Fisheries and the Environment, Cape Town.

Table 13: History of scientific advice for the management of the Prince Edward Islands Patagonian toothfish fishery. (Note that the TAC values listed are those that were implemented. In only one instance [2013/14] did the TAC implemented differ [being slightly more conservative] from the scientific advice.)

Season	TAC(t)	Basis/comments
1996/97	2 500	Experimental fishery initiated–5 permits allocated 500 t each
1997/98	3 000	TAC in to promote increase presence in PEI to deter IUU fishing
1998/99	2 750	Resource indicators (CPUE) suggested sustainable catch levels has been reduced by IUU fishing and a TAC reduction was necessary
1999/00	2 750	*Status quo*
2000/01	2 250	Further CPUE decline
2001/02	600	2001 ASPM assessment (CPUE and catch data only) indicated severe resource depletion and that catch should be restricted to a maximum of 400 t per annum. TAC set at 600 t, however, to maintain a presence in PEI and deter. IUU fishing
2002/03	500	2002 ASPM (included CPUE, catch and CAL data) -inconsistencies in estimates of resource status between the CPUE index and when greater weight was placed on the length-based information. Advice was for a *status quo* (600 t TAC) given these difficulties. TAC set at 500 t as a compromise between 400 t recommended by CCAMLR Scientific Committee and the 600 t *status quo* to promote presence in PEI (deter IUU fishing)
2003/04	500	2003 ASPM assessment - inconsistencies between CPUE and length-based information persisted, causing difficulties in scientific advice on appropriate catch limit. *Status quo* TAC set. Work begins on ascertaining whether or not an OMP would be a useful approach.
2004/05	450	2004 ASPM assessment - inconsistencies between CPUE and length-based information persisted, causing difficulties in scientific advice on appropriate catch limit. Precautionary TAC reduction in absence of scientifically defensible estimate of appropriate catch limit. Work on developing an OMP continues.
2005/06	450	2005 ASPM assessment - inconsistencies between CPUE and length-based information persisted, causing difficulties in scientific advice on appropriate catch limit. *Status quo* TAC set. Work on developing an OMP continues.
2006/07	450	2006 ASPM assessment - inconsistencies between CPUE and length-based information persisted, causing difficulties in scientific advice on appropriate catch limit. *Status quo* TAC set. Work on developing an OMP continues.
2007/08	450	2007 ASPM assessment - inconsistencies between CPUE and length-based information persisted, causing difficulties in scientific advice on appropriate catch limit. *Status quo* TAC set. Work on developing an OMP continues.
2008/09	450	No assessment - *status quo* TAC set. Work on developing an OMP continues.
2009/10	450	Work on an OMP completed, but the OMP was not adopted due to concerns that it was too conservative (assumed levels of cetacean depredation and IUU fishing that were to high, resulting in TAC recommendations that were lower than necessary). *Status quo* TAC set.
2010/11	450	Application of the OMP indicated a TAC of 250 t, but this was recognised as too low to allow for economically viable fishing by all Right Holders (second vessl introduced into the fishery in late 2010). Uncertainly regarding assumptions of cetacean depredation and IUU levels, coupled with appreciable under-catches in previous years (only one Right Holder operating) suggested that a maximum 400 t TAC was scientifically defensible.
2011/12	320	2011 ASPM assessment - complications arising from gear change in the fishery (Spanish longline to trotline). CPUE indicated a decline in abundance of between 16 and 34%, suggesting that a 20% reduction in the TAC should be recommended. Research strategy implemented (paired longline and trotline sets) to address CPUE limitations.
2012/13	320	2012 ASPM assessment – further decline in CPUE, but limited data availability for trotline CPUE standardisation introduced considerable uncertainty. *Status quo* recommendation pending improved data availability. Research strategy continued.
2013/14	450	2013 ASPM assessment - sufficient data collected from the research strategy to enable development of a reliable standardised CPUE index. Assessment suggested resource depletion between 43 and 87%. Pojections indicated a catch of 500 t per annum over the long-term would be sustainable, but decision was 450 t (precautionary measure).
2014/15	575	2014 ASPM assessment – included tag-recapture data for the first time as well as an improved method of estimating cetacean depredation levels, and improved spatial resolution of CPUE standardisation. Indicated that catches could be increased, but various concerns (model fits to recent longline CPUE data and over-optimistic estimates of future recruitment) indicated a phased increase would be appropriate.
2015/16	575	2015 ASPM assessment – similar results to previous assessment, but concerns regarding model fit to recent longline CPUE data, coupled with a decline in trotline CPUE suggested an increase in TAC should be deferred pending availability of CPUE data for the 2016 season.
2016/17	575	2016 ASPM assessment – slightly more positive estimates of depletion than previously, but spawning biomass still decreasing. Although trotline CPUE had increased slightly in 2015, previous concerns regarding model fits to the data remained. Recommended that an increase in the TAC be deferred pending a consistent increase in trotline CPUE and ideally within an OMP framework.
2017/18	575	2017 ASPM assessment – OMP not developed yet and trotline CPUE showed an appreciable decline leading to a more pessimistic estimate of resource status. Recommendation to maintain TAC at 575 t, but recognised that a reduction may be required for 2018/19 if the trotline CPUE continues to decline.
2018/19	543	2018 ASPM assessment – OMP development still in progress. Assessment used a new basis to estimate extent of cetacean depredation. Continued decline in trotline CPUE and estimates of depletion were generally lower < 40%) than the previous assessment. Reduction in the TAC was consequently recommended.
2019/20	502.3	2019 assessment – OMP development still in progress. Assessment now includes cetacean depredation on trotlines. Although CPUE had increased slightly, projections indicated a reduction in TAC should be considered. Projections using future recruitment equal to the average observed over past few years more pessimistic than those using stochastic future recruitment. Precautionary approach adopted and a slightly ad hoc 7.5% TAC reduction was recommended.
2020/21	542.9	Toothfish OMP-2020 developed and adopted. The OMP modifies the TAC each year in synchrony with trends in resource abundance indices (CPUE and tag recapture data) and applies a TAC smoothing factor. Inter-annual changes in the TAC are restricted to ± 10% (except in circumstances where resource indices fall below specified threshold levels). Application of the TAC computation formula to data extending to the end of the 2018/19 fishing season yielded a TAC recommendation of 524.9 t.
2021/22	548.5	Application of the OMP-2020 computation formula to data extending to the end of the 2019/20 fishing season yielded a TAC recommendation of 548.5 t.
2022/23	573.2	Application of the OMP-2020 computation formula to data extending to the end of the 2020/21 fishing season yielded a TAC recommendation of 573.2 t.
2023/24	599	Application of the OMP-2020 computation formula to data extending to the end of the 2021/22 fishing season yielded a TAC recommendation of 599 t.

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	Autoline			
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
2021/22			66.5	31.0		97.5	573
2022/23				260.8		260.8	599

† Note that data for the 1996/97 season include 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** Non-kelps	**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 Concession Areas (Figure 49). 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. Only South African persons or companies may apply for access to a seaweed resource. The process of evaluating and awarding the resources is known as the Fisheries Rights Allocation Process (FRAP). Successful applicants are known as Concessionaires and once a Concessionaire activates their Right to harvest a group of seaweeds, through applying for and subsequently receiving their permit, they are referred to as a Right Holder. These permits are renewable annually.

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 April of year 1 to 31 March 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 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 14).

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

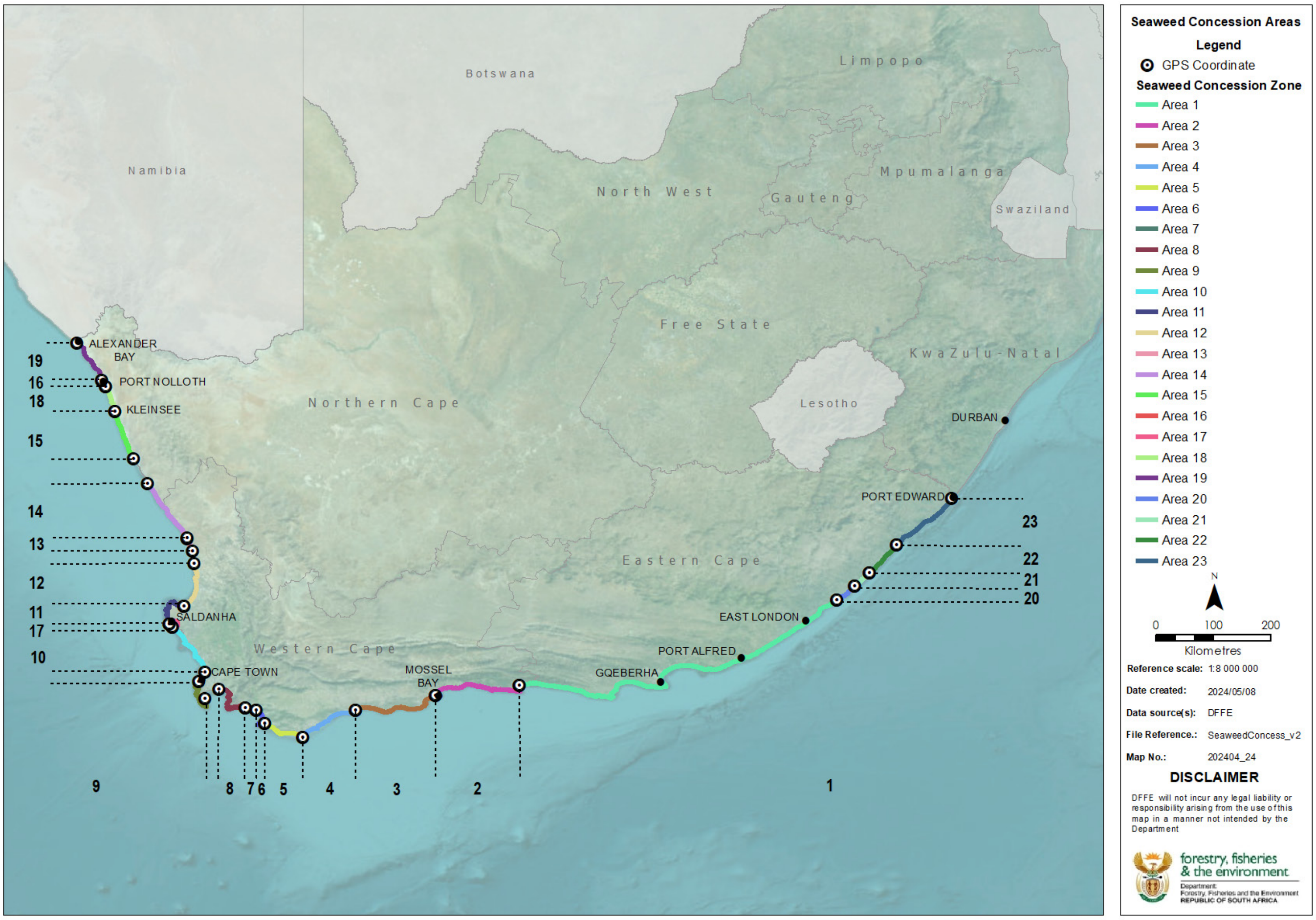


Figure 49: Map of seaweed Concession Areas in South Africa.

feed. In 2022 a total of 2 989 t of fresh kelp fronds were supplied to farmers. Demand for kelp as feed is currently centred 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 Concession Areas 1, 20, 21, 22 and 23; Figure 49), where they have been harvested from intertidal areas since the mid-1950s. Yields come almost entirely from Area 1. Harvested weights have been steadily decreasing from an average of about 100 t dry weight annually to 46.5 t dry weight in 2022. 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 also 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 Concession 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 2008.

Other resources

Other seaweeds have been harvested commercially on occasion, including *Porphyra*, *Ulva*, *Gigartina* species and *Mazzaela*. 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. 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.

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 *Gelidium 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 2022.

Yields of dry beach-cast kelp totalled 336 t in 2022 (Table 14). A further 114 t wet weight of fresh beach-cast kelp was supplied to abalone farms, together with 2 989 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 Concession Areas (Areas 5, 8, 15 and 16) to the small-scale fisheries sector in 2016, kelp harvesting in these areas was 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 2 331 t of fresh kelp in 2022. 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.

Gelidium

All harvested *Gelidium* were collected from Area 1, with *G. pristoides* now comprising almost all of 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 2022 catches from Area 1 (46.5 t dry weight) were the lowest ever recorded, mainly because of reduced demand. Inspections and measurements done in February and Octoberber 2022 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.

Table 14: Annual yields of commercial seaweeds in South Africa, 2008–2022, 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 (kg wet weight)	Kelp beach cast (kg wet weight)	Kelp fronds harvest (kg wet weight)	Growth enhancer (kg wet weight)	*Gelidium* (kg wet weight)
2008	120 247	550 496	542 9279	809 862	120 247
2009	115 502	606 709	510 9311	1 232 760	115 502
2010	103 903	696 811	554 2210	1 264 739	103 903
2011	102 240	435 768	624 4773	1 617 975	102 240
2012	117 149	1 063 233	748 8485	1 788 881	117 149
2013	106 382	564 919	583 7889	2 127 728	106 382
2014	75 900	775 625	479 9966	1 610 023	75 900
2015	95 200	389 202	422 3114	1 930 654	95 200
2016	102 500	411 820	414 4777	2 166 293	102 500
2017	102 802	482 082	331 7837	3 001 611	102 802
2018	89 253	540 490	535 6049	1 886 691	89 253
2019	476 013	287 221	420 9634	1 029 731	67 376
2020	131 119	246 420	356 0901	1 250 555	61 243
2021	50 020	297 713	318 2354	1 645 097	58 095
2022	114 000	336 000	2 989 000	2 331 000	46 500
Total	1 902 230	7 684 509	71 435 579	25 693 600	1 364 292

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* was 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 Concession 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 it can now be found 70 km further east at De Hoop Nature Reserve. The kelp bed there is now well-established and fairly significant. 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 have not shown any similar distributional changes.

Table 15: Maximum sustainable yield (MSY) 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. 9a is the Soetwater sub-area of Concession Area 9; 9b is the Platboom/Maclear sub-area of Concession Area 9

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

Further reading

Anderson RJ, Simons RH, Jarman NG, Levitt GJ. 1991. *Gelidium pristoides* in South Africa. *Hydrobiologia* 221: 55–66.

Anderson RJ, Bolton JJ, Molloy FJ, Rotmann KW. 2003. Commercial seaweeds in southern Africa. In: Chapman ARO, Anderson RJ, Vreeland VJ, Davison IR (eds), *Proceedings of the 17th International Seaweed Symposium, 28 January–02 February 2001, Cape Town*. Oxford, UK: Oxford University Press. pp 1–12.

Anderson RJ, Rand A, Rothman MD, Bolton JJ. 2007. Mapping and quantifying the South African kelp resource. *African Journal of Marine Science* 29: 369–378.

Blamey LK, Shannon, LJ, Bolton JJ, Crawford RJ, Dufois F, Evers-King H, Griffiths CL, Hutchings L, Jarre A, Rouault M, Watermeyer KE. 2015. Ecosystem change in the southern Benguela and the underlying processes. *Journal of Marine Systems* 144: 9–29.

Bolton JJ, Anderson RJ, Smit AJ, Rothman MD. 2012. South African kelp moving eastwards: the discovery of *Ecklonia maxima* (Osbeck) Papenfuss at De Hoop Nature Reserve on the south coast of South Africa. *African Journal of Marine Science* 34: 147–151.

Reimers B. 2012. Historical changes on rocky shores in the Western Cape, as revealed by repeat photography. MSc thesis, University of Cape Town, South Africa.

Rothman MD, Anderson RJ, Boothroyd CJT, Kemp FA, Bolton JJ. 2008. The gracilarioids in South Africa: long-term monitoring of a declining resource. *Journal of Applied Phycology* 21: 47–53.

Levitt GJ, Anderson RJ, Boothroyd CJT, Kemp FA. 2002. The effects of kelp harvesting on kelp biomass, density, recruitment, and understorey community structure at Danger Point (Gansbaai) South Africa. *South African Journal of Marine Science* 24: 71–85.

Rothman MD, Anderson RJ, Kandjengo L, Bolton JJ. 2020. Trends in seaweed resource use and aquaculture in South Africa and Namibia over the last 30 years. *Botanica Marina* 63: 315–325.

Useful statistics

Annual yields of commercial seaweeds in South Africa, 2008–2022, by calendar year.

Year	Kelp fresh beach cast (kg wet weight)	Kelp beach cast (kg wet weight)	Kelp fronds harvest (kg wet weight)	Growth enhancer (kg wet weight)	*Gelidium* (kg wet weight)
2008	120 247	550 496	542 9279	809 862	120 247
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2011	102 240	435 768	624 4773	1 617 975	102 240
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2017	102 802	482 082	331 7837	3 001 611	102 802
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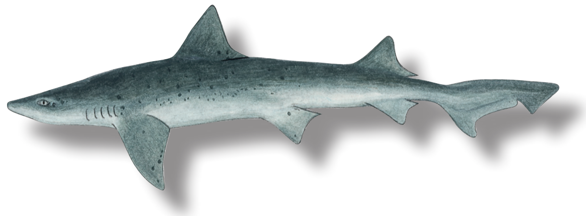
2020	131 119	246 420	356 0901	1 250 555	61 243
2021	50 020	297 713	318 2354	1 645 097	58 095
2022	114 000	336 000	2 989 000	2 331 000	46 500
Total	1 902 230	7 684 509	71 435 579	25 693 600	1 364 292

Sharks



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

Status only for chondrichthyans for which assessments are availabe. *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 16% 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 +200 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 16).

South Africa is a signatory of the FAO Code of Conduct for Responsible Fisheries. Under its framework an International

Table 16: Estimated dressed catches (t) of chondrichthyans of which more than 11 t were caught by South African fisheries from 2023. Current scientific name and authority follows Ebert and van Hees (2015). Fisheries abbreviations: DSL = demersal shark longline; PL = pelagic longline fishery; RecL = recreational linefish; LF = commercial linefish; BG = beach seine and gillnet fisheries; TF = offshore/inshore demersal trawl fisheries. IUCN Red List Status: LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered. *Species prohibited for retention. **Species generally released if alive. TF not reflecting release due to high mortality. # heavily depleted but currently not subjected to overfishing, ## depleted but currently not subject to overfishing

Scientific name	Common name	Estimated average annual catch 2010–2012 (t)	Estimated average annual catch 2013–2023 (t)	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	Yellow-spotted 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	Whitespottted smoothhound shark	1–100	1–100	TF,DSL, LF	LC –	LC 2020	–

Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) was developed in 1998, which encourages maritime 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 the 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.

The suite of demersal shark species 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 such as smoothhound and soupfin 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 demersal shark longline, large pelagic longline, beach-seine and gillnet fisheries.

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 (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 fluctuation in demand for shark trunks or "flake" internationally; however, reduced catches and effort in recent years may be directly related to declining stocks.

Rights in the demersal shark longline 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. 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 an average of 917 hooks. The fishery operates in waters generally shallower than 100 m. This fishery contributes to the total fishing mortality for eight species; bronze whaler shark *Carcharhinus brachyurus* (classed as Vulnerable [VU] on the IUCN Red List of Threated Species, 7.6 t average annual dressed catch between 2010 and 2023), dusky shark *C. obscurus* (Endangered [EN], <1 t average annual reported catch between 2010 and 2023), 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], 23.5 t), smoothhound shark (EN, 52.1 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) programme 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 programme for longline operations will be investigated from these data and from national surveys. This fishery was responsible for 6.1% of the average annual reported catch of sharks between 2010 and 2023.

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 2023 was 149.3 t with this sector responsible for 9.6% 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 and may be substantial for some species such as hammerhead sharks.

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 a few sharks are reported to species level in the fishery: St Joseph *Callorhinchus capensis* (300.8 t average annual reported catch between 2010 and 2023) and soupfin shark (25.2 t). The remaining estimated 65 species are lumped under the following categories: dog sharks (1.5 t average annual reported catch between 2010 and 2023), hound sharks (21.7 t), skates (132.7 t), copper (or bronze whaler) shark (<1 t), and unidentified sharks (9.8 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 2023.

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 (see Netfish section of this report). However, reporting rate of this legal fishery is consistently low at 20%. 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 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 between 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 hammerhead (reported as smooth hammerhead) and milk shark *Rhizoprionodon acutus* in the "shark nursery" of Richards Bay. Extinctions 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. The recent entry of the online shopping app Temu in South Africa has exacerbated the issue with extremely affordable small-mesh nets freely available without any control or restrictions. There is a pressing need for illegal operations to be eradicated and existing legal gillnetting to be phased out and replaced with 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 on 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 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 2023 was 739.2 t. 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 148.8 t in 2023.

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

Since the completion of the first NPOA-Sharks 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, 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 have 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 (2023) of the dressed-weight catch of chondrichthyans across all fisheries in South Africa decreased to 624.4 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 from 1 408.3 t in 2017 to 148.8 t in 2023. In 2023, the trawl fishery was responsible for 55% of total shark mortality in South Africa, followed by the large-pelagic longline fishery (24%), commercial linefishery (13%) and lastly the demersal shark longline fishery (2%). For chondrichthyans caught across multiple fisheries, reducing catches as necessitated by pessimistic stock assessment results becomes difficult to achieve.

Soupfin and smoothhound sharks for example are caught across three fisheries as shown in Figure 50. To inform discussions about future management recommendations for sharks caught in multiple fisheries, it is important to understand the impact of the directed demersal longline fishery relative to that of the trawl- and line fisheries. Overall, the commercial linefishery catches the largest proportion of soupfin, with an average of 63% of catches between 2010 and 2023, followed by the trawl fishery (21%) and the demersal shark longline fishery (16%).

Research and monitoring

There are ~200 chondrichthyan species that occur in southern Africa, with the number changing frequently due to taxonomic revisions and descriptions 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.

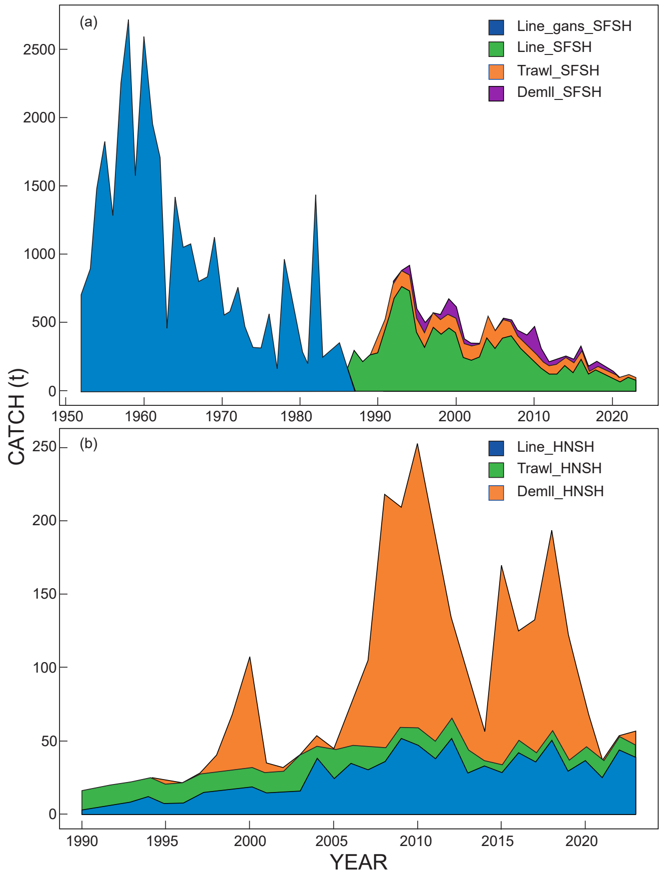


Figure 50(a&b): Time-series of (proportional) estimated catch in tonnes for soupfin sharks *Galeorhinus galeus* (1952–2020) showing the Gansbaai linefish historical data (Line_gans_SFSH), commercial linefish data (Line_SFSH), trawl catch data (Trawl_SFSH) and demersal shark longline catch data (Demll_SFSH)

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 exists for less than 15% of species, with much of this information being 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 spillover if nursery areas are contained within the MPAs. It is also likely that various existing MPAs also provide protection for various other 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, whitespotted wedgefish *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

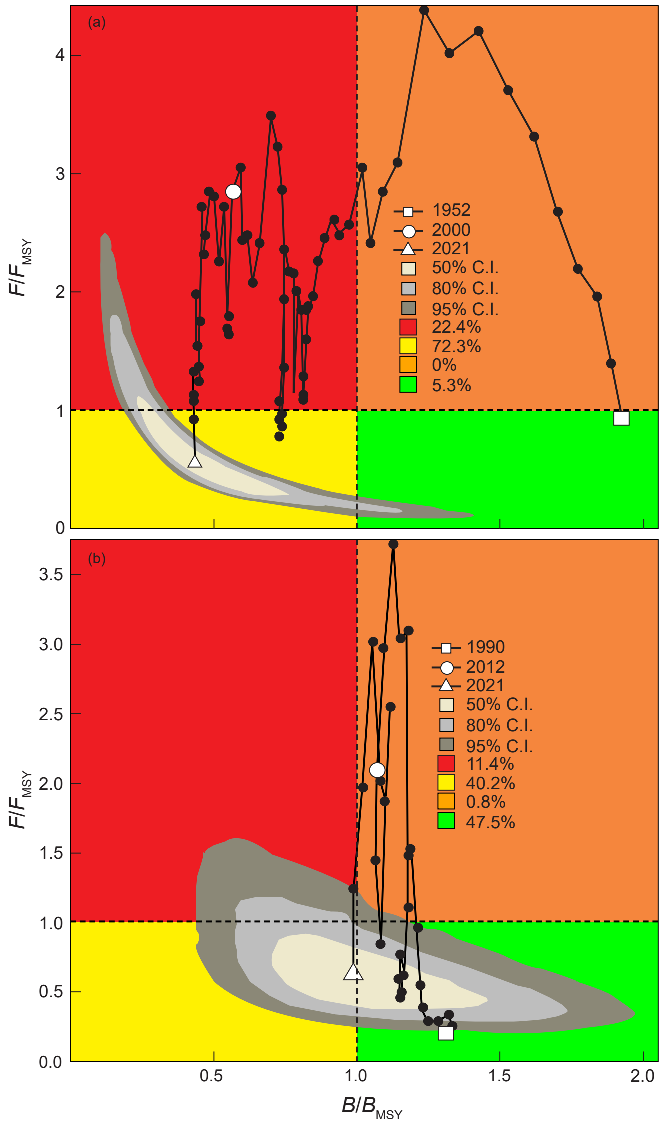


Figure 51: Kobe plots indicating the estimated trajectories (1952–2021) of B/B_{MSY} and F/F_{MSY} for all scenarios of the Bayesian state-space surplus production model JABBA assessment for soupfin sharks *Galeorhinus galeus*. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend. C.I. = confidence interval

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 indicate a high degree of residency. South Africa is a major contributor to mako shark catch in the IOTC area, but proportions of reported catch 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. 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 more precisely 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 and incorporating the de Hoop tag and-release research programme. This 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 four species of chondrichthyans have catches in excess of 100 t in terms of estimated average catch between 2013 and 2023, 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 most recent assessment for these species was concluded in 2024. The assessment input data included standardised abundance indices from fishery-independent demersal trawl surveys (1990–2021) 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 51a).

Recently updated assessments were more optimistic overall than the previous assessments in 2019, mostly attributable to a reduction in catch. For soupfin sharks, the base-case scenario indicated a 74% probability that it is currently not subjected to overfishing, but that the stock remains overexploited. Biomass in 2021, the terminal year of the time-series, was estimated at 13% of pristine stock. At the most recent total catch assessment (96 t), the projected trajectory is stable. Given these results, urgent steps are required to keep the fishing mortality for soupfin sharks below 100 t. The smoothhound shark biomass, on the other hand, is still above the biomass at maximum sustainable yield (Figure 51b) and at the most recent catch construction (56.6 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. 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. In 2024, a stock assessment of the shortfin mako shark in the IOTC area of competence was conducted using JABBA (Just Another

Bayesian Biomass Assessment). The results showed that in 2022, the shark population was at 45% (with a confidence range of 27-69%) of unfished (pristine) levels and below the levels that would support MSY (Maximum Sustainable Yield). Fishing pressure was too high, with mortality rates exceeding sustainable limits the 2022 catch 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, given the absence of a stock assessment and given 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 2023. Bayesian state-space surplus production model estimates were less optimistic than previous models and indicate that the stock is not overfished but that overfishing could be occurring.

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, currently increasing catches are 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 unfavourable 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 trade in this species.

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 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. Preliminary analysis of the EM programme suggests that it is suitable to obtain observer data from this fishery. In addition, this footage has been used to test the feasibility of using machine learning to augment the EM programme and reduce processing time.

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 recent 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 that had been fished 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 as a result of changes in climate are elevated CO_2 levels in the blood (causing acidosis, respiratory issues, etc.) 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.

Further reading

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.

Bosch AC, O'Neill B, Sigge GO, Kerwath SE, Hoffman LC. 2016. Heavy metals in marine fish meat and consumer health: a review. *Journal of the Science of Food and Agriculture* 96: 32–48.

Currie JC, Atkinson LJ, Sink KJ, Attwood CG. 2020. Long-term change of demersal fish assemblages on the inshore Agulhas Bank between 1904 and 2015. *Frontiers in Marine Science* 7: article 355.

Currie JC, Thorson JT, Sink KJ, Atkinson LJ, Fairweather TP, Winker H. 2019. A novel approach to assess distribution trends from fisheries survey data. *Fisheries Research*: 98–109.

DAFF (Department of Agriculture, Forestry and Fisheries). 2013. National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks). Rogge Bay [Cape Town]: DAFF.

da Silva C, Winker H, Parker D, Kerwath SE. 2019. Assessment of smoothhound shark *Mustelus mustelus* in South Africa. FISHERIES/LSWG/#04/2019. Cape Town: Department of Agriculture, Forestry and Fisheries.

da Silva C, Winker H, Parker D, Wilke C, Lamberth S, Kerwath SE. 2018. Update and review of the NPOA for Sharks South Africa. IOTC-2018-WPEB14-11_Rev1. 14th Working Party on Ecosystems and Bycatch, 10–14 September 2018, Cape Town, South Africa. Victoria, Seychelles: Indian Ocean Tuna Commission.

da Silva C, Booth A, Dudley S, Kerwath S, Lamberth S, Leslie R, Zweig T. 2015.The current status and management of South Africa's chondrichthyan fisheries. *African Journal of Marine Science* 37: 233–248.

da Silva C, Kerwath SE, Winker H, Lamberth SJ, Attwood CG, Wilke CG, Næsje TF. 2021. Testing the waters to find the 'goldilocks' zone: fine-scale movement of *Mustelus mustelus* in relation to environmental cues. *Marine and Freshwater Research* 73: 110–124.

de la Cruz Y. 2015. Conversion factors for dressed to total lengths and weights for two elasmobranch species, smoothhound shark, *Mustelus mustelus* and soupfin shark *Galeorhinus galeus*, within South African waters. BTech oceanography project, Cape Peninsula University of Technology, Cape Town.

Dulvy NK, Pacoureau N, Rigby CL, Pollom RA, Jabado RW, Ebert DA, Finucci B, Pollock CM, Cheok J, Derrick DH, Herman KB. 2021. Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. *Current Biology* 31: 4773–4787.

Dziergwa J, Singh S, Bridges CR, Kerwath SE, Enax J, Auerswald L. 2019. Acid-base adjustments and first evidence of denticle corrosion caused by ocean acidification conditions in a demersal shark species. *Scientific Reports* 9: article 18668.

Ebert DA, Wintner SP, Kyne PM. 2021. An annotated checklist of the chondrichthyans of South Africa. *Zootaxa* 4947: 1–127.

Ebert DA, van Hees KE. 2015. Beyond Jaws: rediscovering the 'lost sharks' of southern Africa. *African Journal of Marine Science* 37: 141–156.

Maduna SN, da Silva C, Wintner SP, Roodt-Wilding R, Bester-van der Merwe AE. 2016. When two oceans meet: regional population genetics of an exploited coastal shark, *Mustelus mustelus*. *Marine Ecology Progress Series* 544: 183–196.

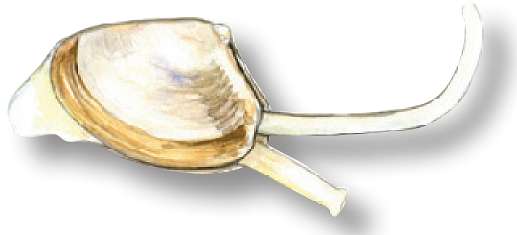
Pacoureau N, Rigby CL, Kyne PM, Sherley RB, Winker H, Carlson JK, Fordham SV, Barreto R, Fernando D, Francis MP, Jabado RW. 2021. Half a century of global decline in oceanic sharks and rays.*Nature* 589: 567–571.

Veríssimo A, Sampaio I, McDowell JR, Alexandrino P, Mucientes G, Queiroz N, da Silva C, Jones CS, Noble LR. 2017. World without borders—genetic population structure of a highly migratory marine predator, the blue shark (*Prionace glauca*). *Ecology and Evolution* 7: 4768-4781.

Winker H, Parker D, da Silva C, Kerwath SE. 2019. Assessment of soupfin shark *Galeorhinus galeus* in South Africa. FISHERIES/ LSWG/#05/2019. Cape Town: Department of Agriculture, Forestry and Fisheries.

WWF-TRAFFIC. 3D shark fins project. Available at *https://www.traffic.org/3d-replica-shark-fins/ 2022.*

Small invertebrates and new fisheries



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

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 52). 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

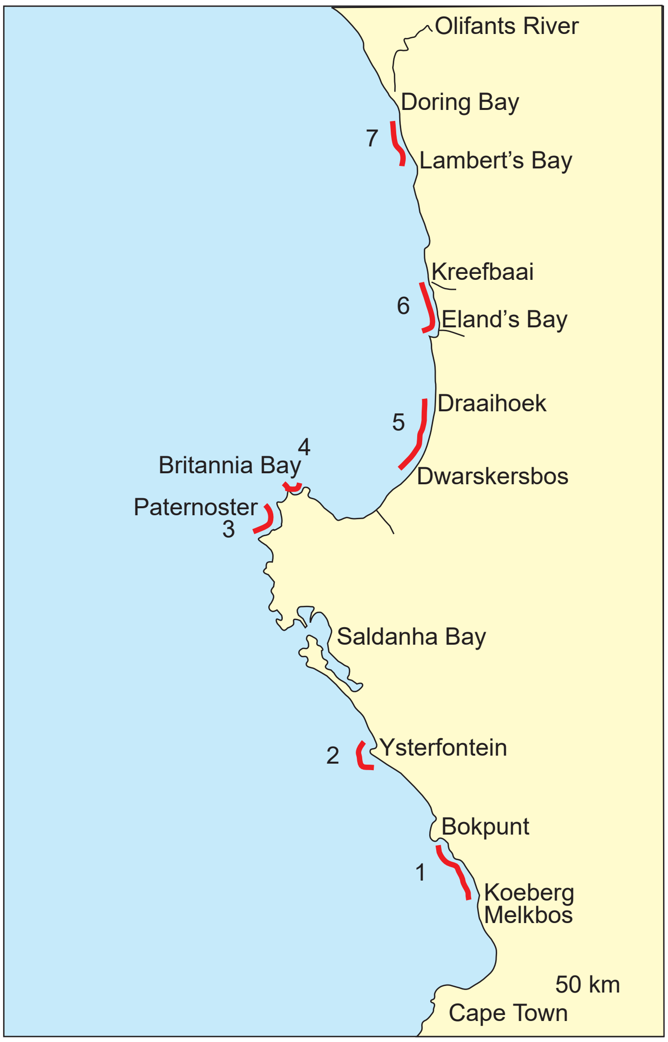


Figure 52: Areas allocated for commercial harvesting of white mussel *Donax serra* along the West Coast of South Africa

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.

In the decades preceding the 1990s, commercial catches declined continuously (Figure 53). 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 54). 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-19.

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 53). In addition, the development of a bait market in Namibia 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 1-2 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

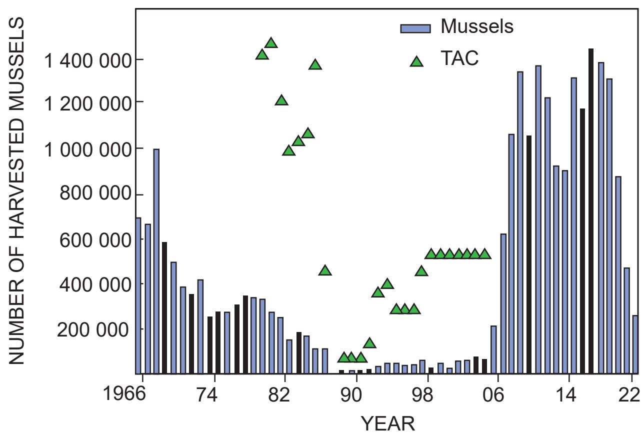


Figure 53: TAC and yield (total number) of white mussels harvested commercially per annum, 1966–2022

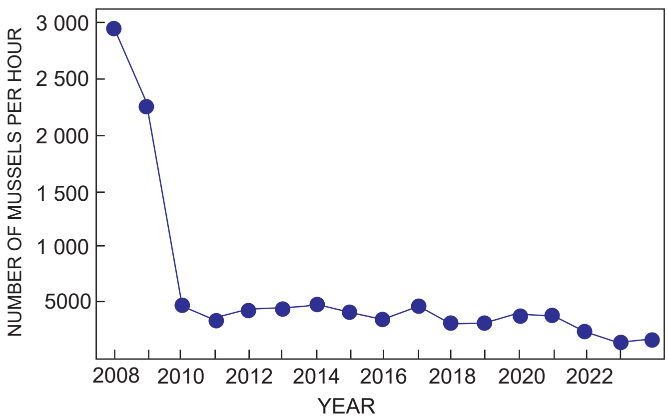


Figure 54: CPUE data calculated from catch data (see Figure 53) for mussels harvested commercially from 2006 to 2022

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 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 55). Lower

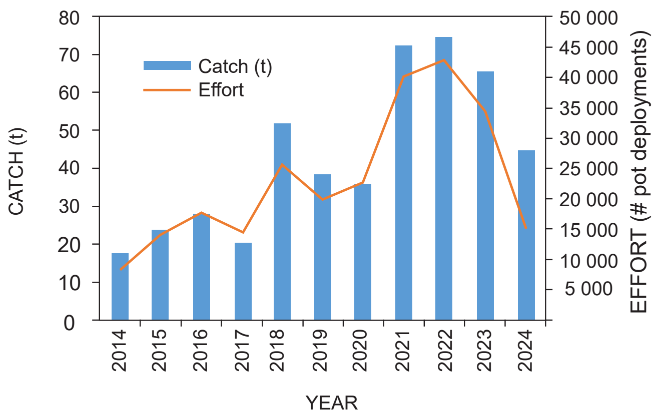


Figure 55: Total annual octopus catch (whole weight) and effort by the exploratory octopus fishery, 2014–2024 (catches for 2024 up to May only)

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 fished 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 ini-tiation of the fishery, but then declined rapidly before stabilising to levels of between 0.5 and 3.0 kg pot^{-1} (Figure 56a). 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}of 2.8 kg pot^{-1} for 2024 (Figure 56a). CPUE levels in False Bay show a clear seasonal pattern, being highest in summer and autumn and lowest in winter and spring (Figure 56b). 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.

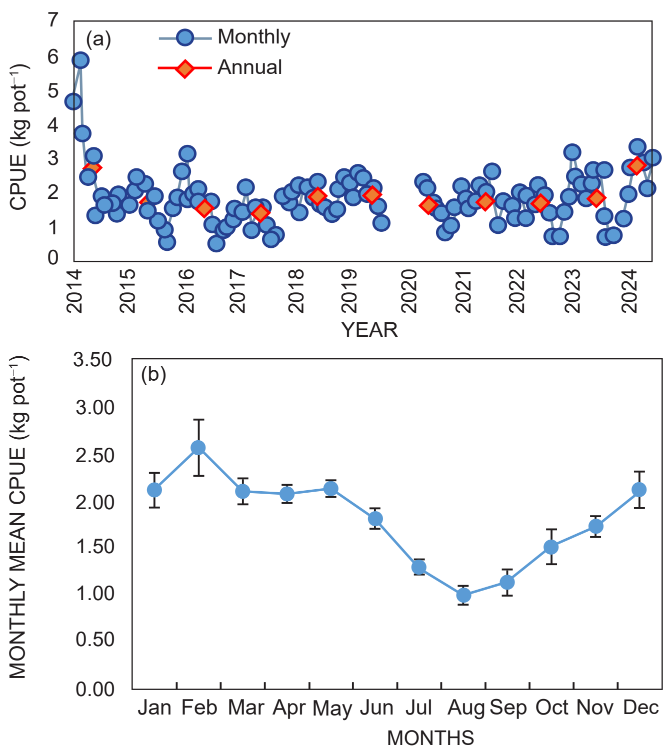


Figure 56: (a) Monthly (blue circles) and annual (orange diamonds) catch per unit effort (CPUE); and (b) average (± 1 standard error) monthly CPUE for octopus in False Bay, 2014–2024 (data for 2024 up to May only)

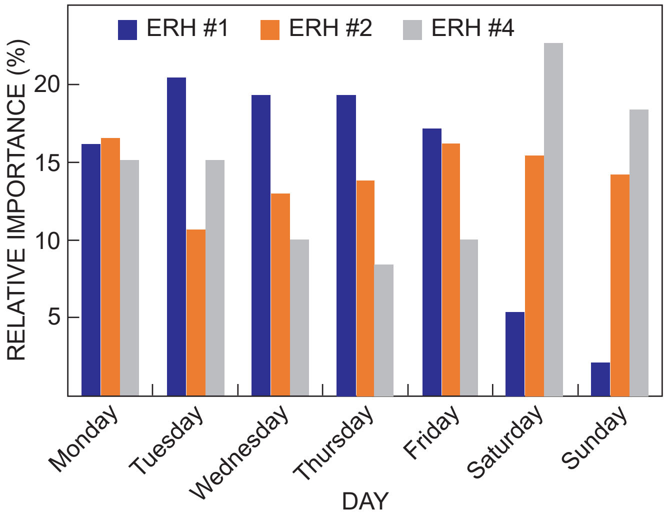


Figure 57: The relative importance (%) of each day of the week for fishing for East Coast round herring by three Exploratory Right Holders (ERHs). If fishing was spread equally throughout the week each day would have a value of 14.3%

East Coast round herring (KwaZulu-Natal)

East Coast round herring *Etrumeus wongratanai* 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 57). 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 after 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 17, and annual catch, effort and catch per unit effort (CPUE) levels are shown in Figure 58. 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 58a). 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 58a), and CPUE has declined from 7.1 and 11.6 kg trip^{-1} (equivalent to approximately 140 and 105 fish, 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 58b).

Table 17: 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 (#s; 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**

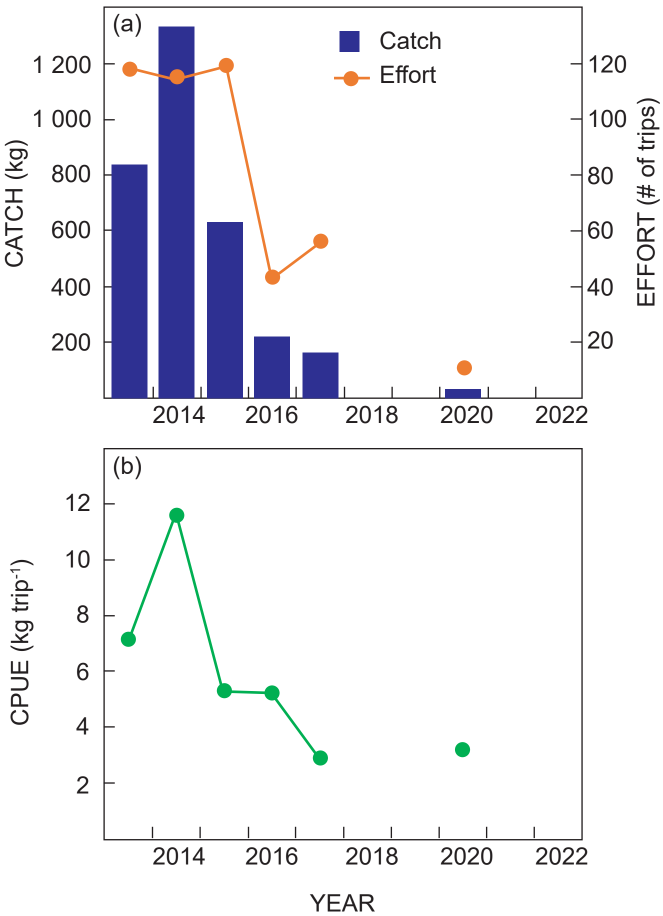


Figure 58: (a) Annual catch and effort and (b) catch per unit effort (CPUE), in the exploratory fishery for East Coast round herring, 2013 to 2022

The 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 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.

Further reading

Jerardino A, Navarro R, Galimberti M. 2014. Changing collecting strategies of the clam *Donax serra* Röding (Bivalvia: Donacidae) during the Pleistocene at Pinnacle Point, South Africa. *Journal of Human Evolution* 68: 58-67.

Mangold K. 1983. *Octopus vulgaris*. In: Boyle PR (ed.), *Cephalopod life cycles*, vol. 1. London: Academic Press. pp 335–364.

Oosthuizen A. 2004. Economic feasibility of an experimental octopus fishery in South Africa. *South African Journal of Science* 100: 595–602.

Oosthuizen A, Smale MJ. 2003. Population biology of *Octopus vulgaris* on the temperate south-east coast of South Africa. *Journal of the Marine Biological Association of the United Kingdom* 83: 535–541.

Sauer WH and 47 co-authors. 2021. World octopus fisheries. *Reviews in Fisheries Science and Aquaculture* 29: 279–429.

Smith CD. 1999. Population biology and ecology of octopus in the south-western Cape: a study towards the establishment of a small-scale octopus fishery. MSc thesis, University of Cape Town, South Africa.

Smith CD, Griffiths CL. 2002. Aspects of the population biology of *Octopus vulgaris* in False Bay, South Africa. *South African Journal of Marine Science* 24: 185–192.

Sonderblohm CP, Pereira J, Erzini K. 2014. Environmental and fishery-driven dynamics of the common octopus (*Octopus vulgaris*) based on time-series analyses from leeward Algarve, southern Portugal. *ICES Journal of Marine Science* 71: 2231–2241.

Vorsatz LD, van der Lingen CD, Gibbons MJ. 2015. Diet and gill morphology of the East Coast redeye round herring *Etrumeus wongratanai* off KwaZulu-Natal, South Africa. *African Journal of Marine Science* 37: 575–581.

Vorsatz LD, van der Lingen CD, Gibbons MJ. 2019. Observations on the biology and seasonal variation in feeding of the east coast round herring (*Etrumeus wongratanai*) (Clupeiformes) off Scottburgh, KwaZulu-Natal, South Africa. *Journal of Fish Biology* 94: 498–511.

Willer DF, Aldridge DC, Gough C, Kincaid K. 2023. Small-scale octopus fishery operations enable environmentally and socioeconomically sustainable sourcing of nutrients under climate change. *Nature Food* 4: 179–189.

Useful statistics

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 (#s; mass)
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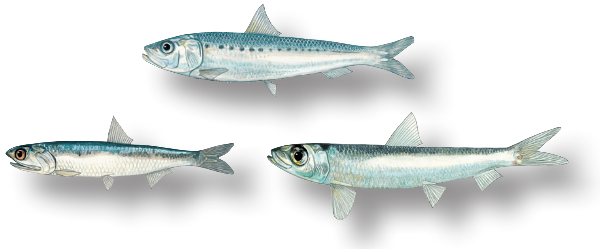
2022	No fishing	No data	No data
2013-2022	TOTALS	**464 / 1 651.5+**	**59 663 / 3 225.9**

Small pelagic fish (sardine, anchovy and round herring)



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

Introduction

Forage fish of the order Clupeiformes occur in continental shelf waters between Hondeklip Bay 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 encrasicolus*, sardine *Sardinops sagax* and West Coast round herring (or redeye) *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 West Coast 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 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. West Coast round herring catches have been reported since the mid-1960s but, prior to 2024, had never exceeded 100 000 t or dominated the pelagic landings, despite several attempts by the pelagic industry to increase catches of this species. However, due to the recent high abundance and availability of West Coast round herring, coupled with poor recruitment of anchovy, this species has become important to the South African small pelagic fishery, which now relies on round herring to boost production when anchovy catches are poor. The industry is also encouraged to optimise catches of West Coast round herring to preserve anchovy and sardine stocks when the biomasses of these are low.

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. These low sardine catches were insufficient for profitable operation of the major canning facilities and the bulk (>80%) of canned sardine products produced in South Africa during this time contained sardine that were sourced from Morocco and elsewhere. This enabled the industry to retain market share and to keep their workers employed. Sardine catches recovered from 14 800 t in 2020 to 29 000 t in 2023 with more than 70% of catches in 2021, 2022 and 2023 taken on the South Coast. Catches of sardine in 2024 exceeded 53 800 t with 50% landed on the West Coast and 50% landed on the South Coast but whereas these catches have improved the profitability of harvesting and processing sardine, most of the locally produced canned sardine is still imported.

Owing to these low sardine catches, anchovy catches again dominated the fishery, with average catches of around 225 000 t between 2000 and 2020. Since then, anchovy catches have declined from 156 000 t in 2021 to only 97 000 t in 2024. The 2024 catch was the lowest since 2013.

Catches of West Coast round herring have increased in recent years, from an average of 27 000 t between 2000 and 2012, to an average of 55 000 t between 2016 and 2022. In 2023 the round herring catch increased further to 98 000 t and in 2024 round herring dominated the small pelagic catches for the first time, when a record 120 000 t was landed.

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 typically 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 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, when either of these resources do drop below that threshold, the primary and overriding consideration becomes assisting their speedy recovery, while still having consideration for the associated socio-economic implications.

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. To safeguard the sardine resource until such time as the implications for management of its stock structure was better understood, informal spatial management was introduced in 2015. This took the form of a "voluntary agreement" where limits, with some tolerance about them, were set on the percentage of the sardine TAC that could be caught in the area to the west of Cape Agulhas and the fishing industry was encouraged to develop capacity to catch and process sardine on the South Coast. These limits were adhered to in 2015, 2017 and 2018 but not in 2016.

OMP-18, which was adopted in December 2018, was subsequently 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. A further constraint on the percentage of the sardine catch that can be caught east of Cape Agulhas has also been imposed since 2022, resulting in similar levels of fishing effort on both coasts.

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. Exceptional Circumstances 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, were 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, 2023 and 2024. 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 stock structure. It is envisaged that a new OMP will be adopted during 2025.

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 West Coast round herring, juvenile horse mackerel and lanternfish 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 several 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 biomass survey. The loss of these surveys has had far-reaching consequences both for setting subsequent TACs and for recent understanding of the status of the anchovy and sardine resources. Fortunately, both the 2022 and 2023 recruit and adult biomass surveys were successfully conducted onboard the MFV *Compass Challenger*, albeit that the 2023 biomass survey was only conducted during February/March 2024.This late survey resulted from a delayed return to service of the FRS *Africana* following essential replacement of power-generation units and necessitated a calibration of the survey result to account for the different timing of the survey before the biomass estimates could be used for recommending TACs, TABs and PUCLs for the 2024 fishing season.

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. However, staff shortages at most field stations in recent years has resulted in a reliance on industry-funded observers and factory managers to provide length frequency data, while other biological data are now only obtained from the surveys. A period of complete absence of reliable official scale-monitors at offloading factories potentially also led to a compromise in the quality of reported landing statistics. Initial investigations have suggested that bycatches of sardine in both the anchovy and West Coast 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. Fortunately, catch data monitors employed through the Working for Fisheries programme have since been deployed at all landing sites to monitor and record catches of small pelagic fish.

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 gill raker number and vertebral number; (iii) morphometric characteristics such as gill raker length, and body and otolith shape; (iv) the prevalence and abundance of a digenean parasite biotag; and (v) otolith element 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 populations (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. More recent genomic results have, however, confirmed the existence of only two sardine stocks off South Africa, i.e., a cool-temperate stock off the West Coast and Southwestern Cape, and a warm-temperate stock off the South Coast and whereas fish taking part in the sardine run have ancestry from both these stocks, they mostly originate from the species' cool-temperate stock. Fish from both these stocks 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 could result in population declines if regional stocks adapted to specific temperature ranges are overexploited. Although previous management of the purse-seine fishery for sardine had incorporated a two-stock assessment model and the setting of region-specific catch levels, the latest genetic results suggest a different approach is required where the fitness and growth of sardine is dependent on the environment they find themselves in and that growth of the southern stock is not dependent on recruitment from the cool-temperate stock.

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 organisms (including humans). 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 as well as enabling an assessment of human consumer safety for sardine.

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. Based on previous microplastics research, 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 recent surveys. The fact 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 regarding human consumer safety.

Current status

Annual TACs and landings

The total combined catch of anchovy, sardine and West Coast round herring landed by the pelagic fishery decreased by 44% from 400 000 t in 2016 to just 225 000 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 from 2021 to 2024, and well below the TACs set for these years. The average combined catch of these three species over the last five years of 285 000 t is about 46 000 t lower than the long-term (1949–2024) average annual combined catch of 331 000 t (Figure 59).

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 60a). The 2024 anchovy catch of only 97 000 t is the lowest since 2013 and indicative of the low recruitment in 2023 and 2024.

The directed sardine catch fell rapidly from 63 000 t in 2016 to an all-time low of 2 000 t in 2019 (Figure 60b) because of the unavailability of sardine and drastically reduced TACs given the declaration of Exceptional Circumstances for sardine at the end of 2018 and in subsequent years. In 2019, the directed sardine TAC was only 12 000 t but this was since increased

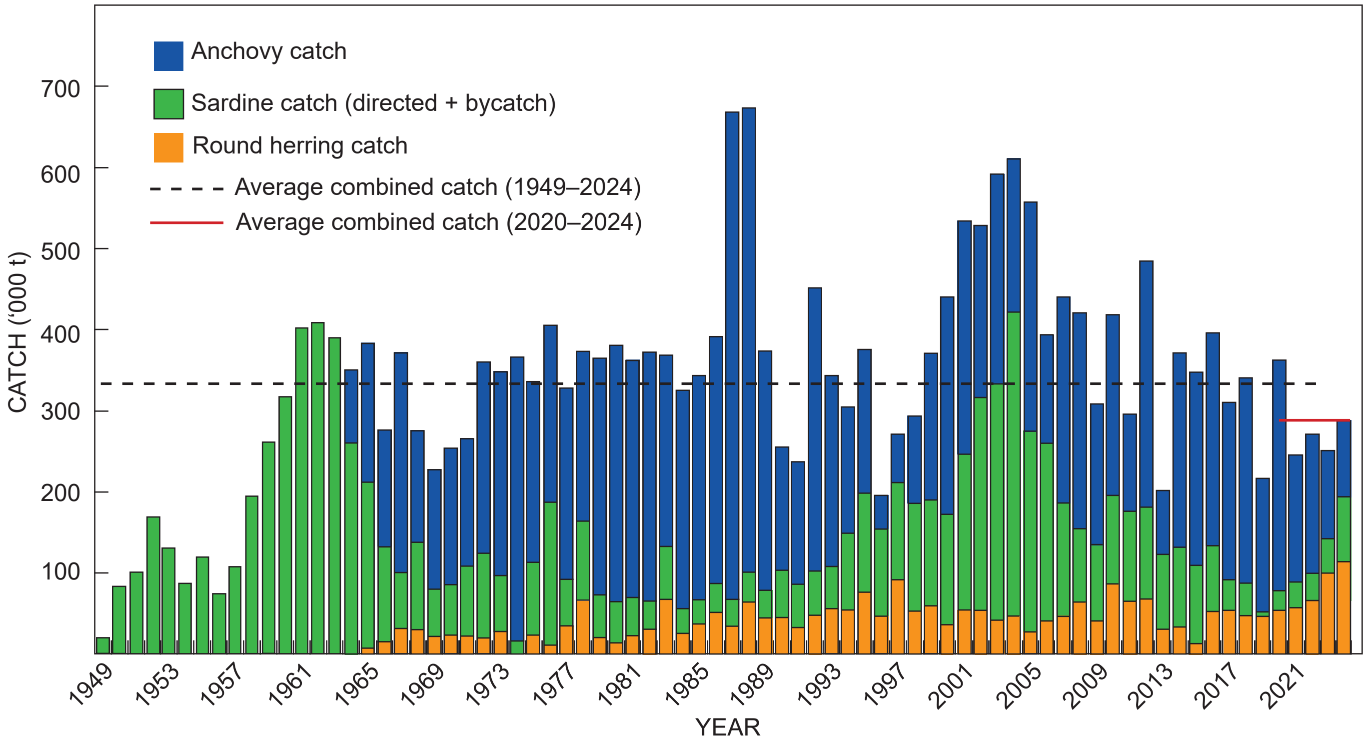


Figure 59: The annual combined catches of anchovy, sardine and round herring by the small pelagic fishery, 1949–2024. Also shown is the long-term average combined annual catch (black dashed line) and for the past five years (2020–2024; red solid line)

to 65 000 t in 2024 because of recovery of the resource since 2022. The landings of sardine in 2022 and 2023 averaged around 37 000 t, with most of these catches having been taken on the South Coast. In 2024, 83% of the sardine TAC was landed, with equal amounts landed on both coasts.

Sardine bycatch, which includes juvenile sardine caught with anchovy, adult sardine, and West Coast round herring as well as adult sardine caught with West Coast round herring, decreased from 17 000 t in 2016 to around 3 000 t in 2018 and 2019 (Figure 60c) but has subsequently ranged from 9 000 to 16 000 t during the past four years, mainly because of increased adult sardine bycatch taken with the increased West Coast round herring catch. The levels of sardine bycatch are well below those allowed in most recent years, principally 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 steadily increased over time from 47 000 t in 2019 to 98 000 t in 2023 and 120 000 t in 2024 (Figure 60d). The average proportion of the precautionary upper catch limit (PUCL) of 100 000 t West Coast round herring landed between 2000 and 2021 was only 0.49 and was thought to reflect the difficulty of catching this species with purse-seine nets. Round herring undergo vast diel vertical migrations, schooling in deeper water, often close to the bottom during the day and out of reach of the purse-seine nets typically used by the South African pelagic fishery. However, just before dusk the fish start migrating into surface waters, where they become accessible to purse-seine nets until just before dawn when they start their descent to the bottom. Between 2022 and 2024, 97% of the West Coast round herring landed were caught between 6 pm and 6 am and the proportion of the PUCL caught increased markedly, despite the PUCL being set at a higher level. This suggests that the local purse seine industry can effectively target West Coast round herring, but that they choose rather to target anchovy or sardine when available and when the TACs for those species are higher. The West Coast round herring PUCL was reduced to 70 000 t in 2022 as a precautionary measure because of the lack of a survey in October/November 2021, but was subsequently increased based on subsequent survey results.

Bycatches of juvenile horse mackerel have also been well below the three-year PUCL of 12 000 t, averaging only 800 t in the 3 most recent years. This three-year PUCL was increased to 15 000 t in 2023 to make provision for those years when a high bycatch of horse mackerel is unavoidable (Figure 60e).

An annual PUCL for mesopelagic fish of 50 000 t was introduced in 2012, following increased catches of lanternfish and lightfish by an experimental pelagic trawl fishery in 2011, when just over 7 000 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, led to this activity not being pursued further. The PUCL 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.

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 61a). 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 after 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 and 990 000 t by the start of 2024. The anchovy recruitment estimate of only 16.5 billion fish in 2023 is the lowest recorded since the beginning of the time-series in 1985. A slight improvement in recruitment was observed in 2024 (55 billion fish) but a follow up biomass survey is needed to determine how many of those recruits have survived and whether there is cause for concern. Nonetheless the most recent anchovy biomass estimate is still within the range projected during simulation testing of OMP-18rev and hence the stock status of this resource is considered optimal.

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 61b). 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 Exceptional Circumstances provisions for this species. By early 2024, the biomass had, however, almost doubled from 560 000 t estimated in 2022 to just over 1 000 000 t. Despite this recent increase, the TAC set for 2024 remained precautionary. The stock status has improved from being considered somewhere between depleted and optimal in the 2023 Status of the South African Marine Fishery Resources report, to being optimal given sustained increases in biomass over the last three years and the most recent 2023 biomass estimate, which is well above the long-term average.

The 2019 West Coast round herring recruit estimate was the third highest on record (Figure 61c) 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, 2022 and 2023 but remained above the long-term average recruitment of 13 billion fish and the adult biomass by the beginning of 2024 remained relatively high at over 1.5 million t.

Shifts in the distribution of both 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,

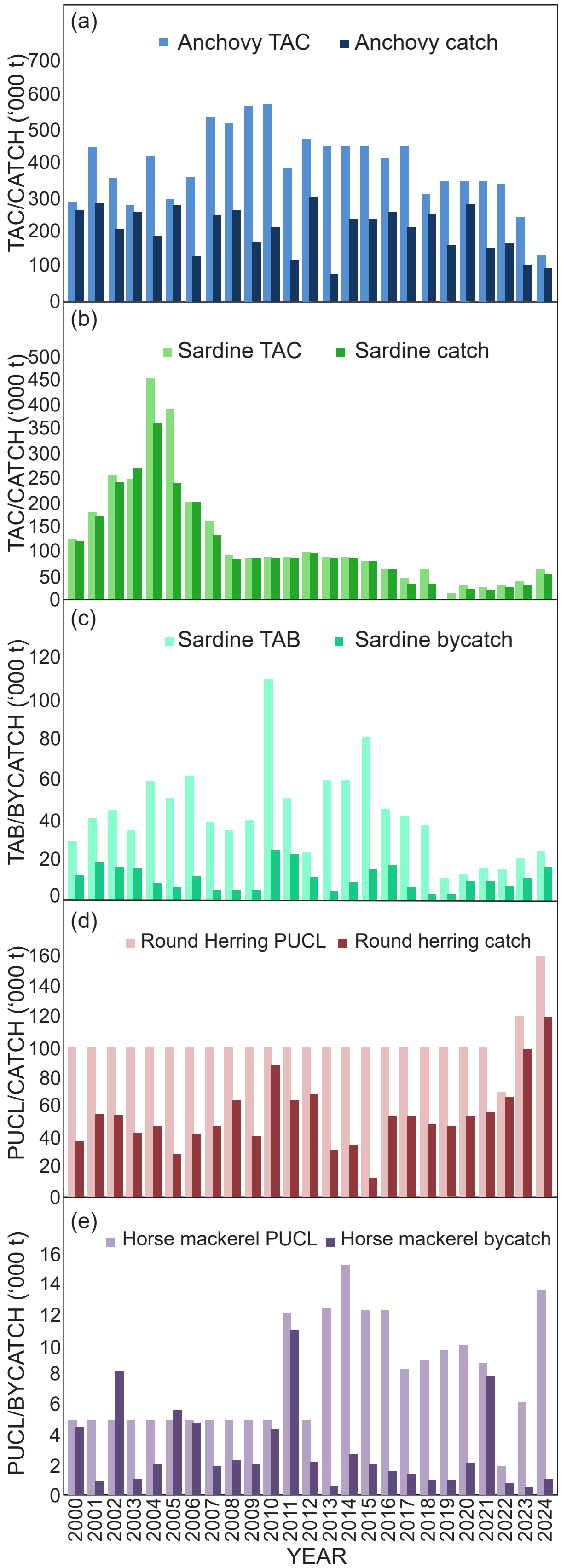


Figure 60: Total allowable catches (TACs), total allowable bycatch (TAB) and precautionary upper catch limits (PUCLs), and subsequent landings of each by the South African pelagic fishery for (a) anchovy, (b) directed sardine, (c) sardine bycatch, (d) West Coast round herring and (e) horse mackerel bycatch, 2000–2024

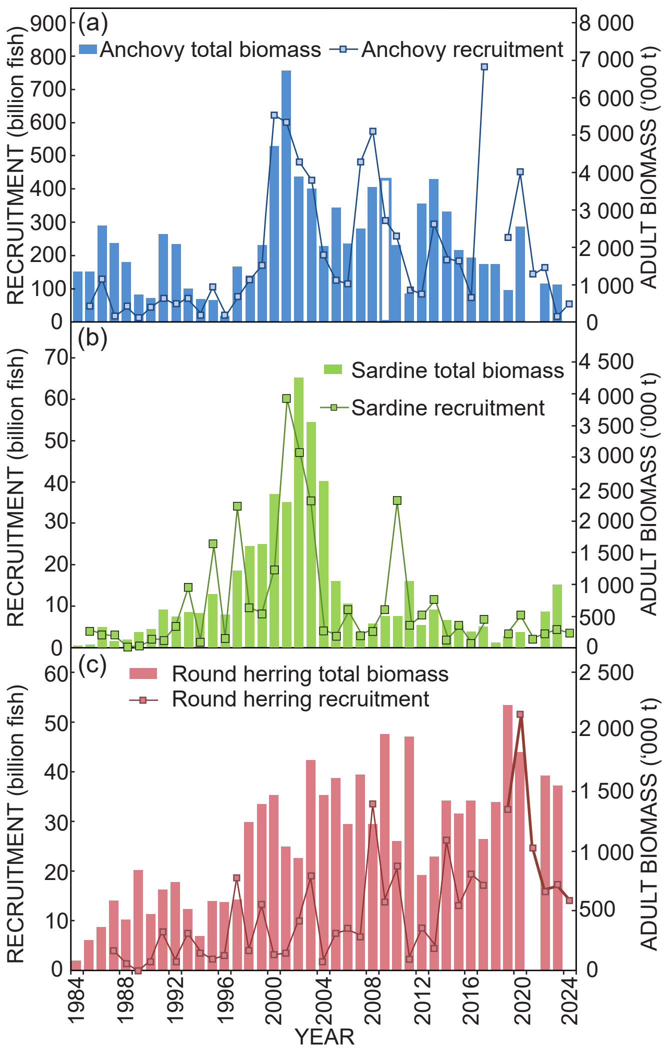


Figure 61: Time-series of acoustically estimated recruitment strength and total biomass of (a) anchovy, (b) sardine and (c) West Coast round herring, 1984–2024. No recruit and biomass surveys were conducted in 2018 and 2021, respectively

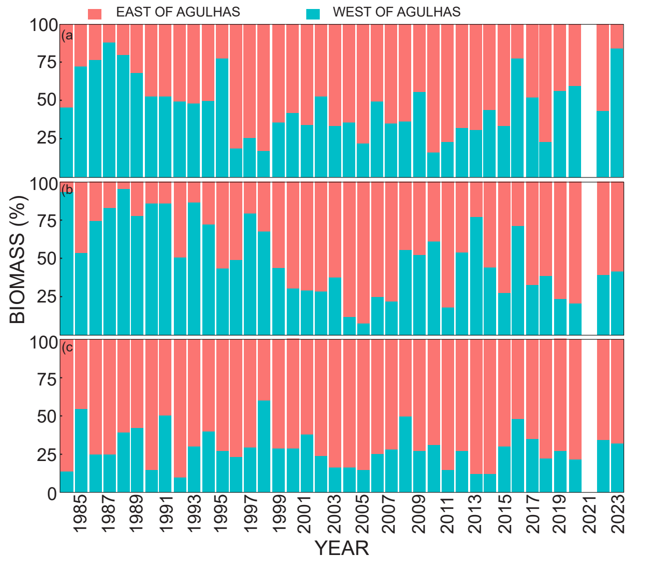


Figure 62: Percentage of the total (a) anchovy, (b) sardine and (c) round herring biomass found to the west and east of Cape Agulhas. No biomass survey was conducted in 2021

with an average of 39% of the adult anchovy biomass observed in the area to the west of Cape Agulhas since 1996 compared to 63% on average in the years preceding the shift (Figure 62a). The distribution of anchovy has, however, been more variable in recent years, with more than 50% of the biomass having been observed in the area to the west of Cape Agulhas in three of the most-recent five years. The percentage of the sardine biomass found in the area to the west of Cape Agulhas remains highly variable but decreased considerably between 2017 and 2020 with a slight recovery in 2022 and 2023. Around 71% (180 000 t) of the sardine biomass was found in the area to the west of Cape Agulhas in 2016 (Figure 62b), 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 and 2023, the percentage located to the west of Cape Agulhas remains relatively low (39% in 2022 and 41% in 2023).

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 Critically Endangered by the IUCN. As part of the implementation of an ecosystem 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 population 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. The distribution of sardine catches over the most recent 10 years (2015-2024) after the introduction of spatial management measures in 2015, compared to that of the two previous 10 year periods (1995-2004 and 2005-2014) when no spatial management was enforced, shows that catches are now spread across the entire coast. Whereas the catches also reflect the distribution and availability of sardine, a smaller percentage of the sardine catch has been taken off the West Coast and a larger percentage has been taken off the South Coast, particularly off Gqeberha, in the most recent period (Figure 63).

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.

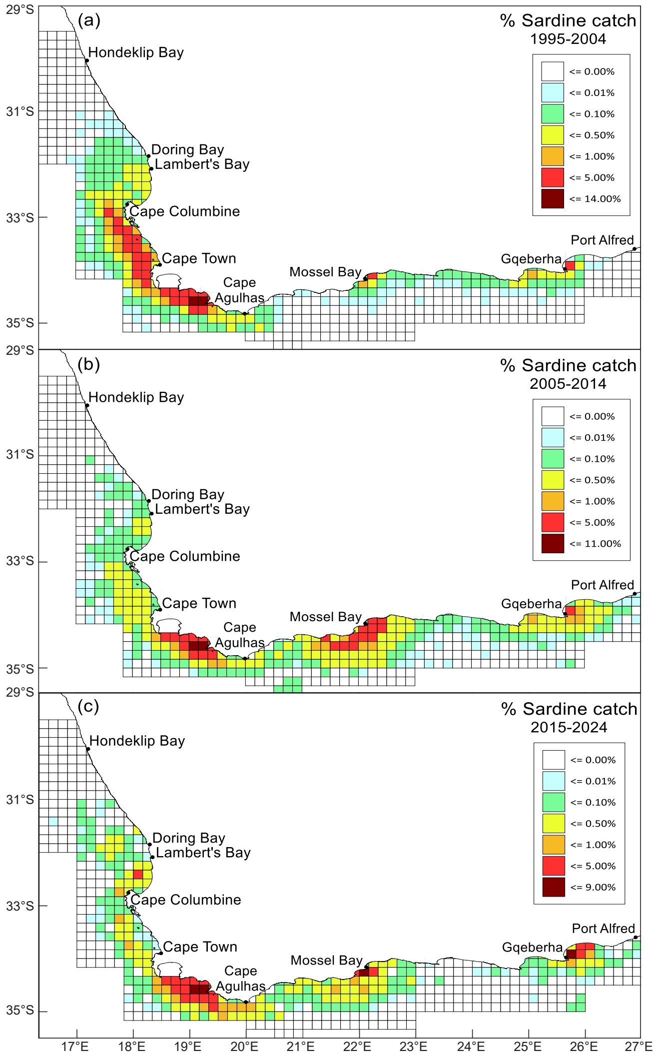


Figure 63: Percentage of the total sardine catch for each 10-year period per 10' × 10' pelagic fishing block

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 subsequently appointed such a panel to review the interpretation of the results from the island closure experiment, explore the value of fishing closure around penguin colonies in providing meaningful benefits to penguins, review the processes and outcomes completed previously, and make recommendations on the future implementation of fishing closures. Following this process, the Minister approved long-term closures 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 64). Further review of these closures is expected during 2025 following refinement of the MIBAs in response to the recommendations by the international panel of experts and the outcome of a court action that seeks to achieve 100% of these areas being closed to fishing.

Climate change implications

Small pelagic fishes have been characterised as excellent bio-indicators of climate-driven changes in marine systems

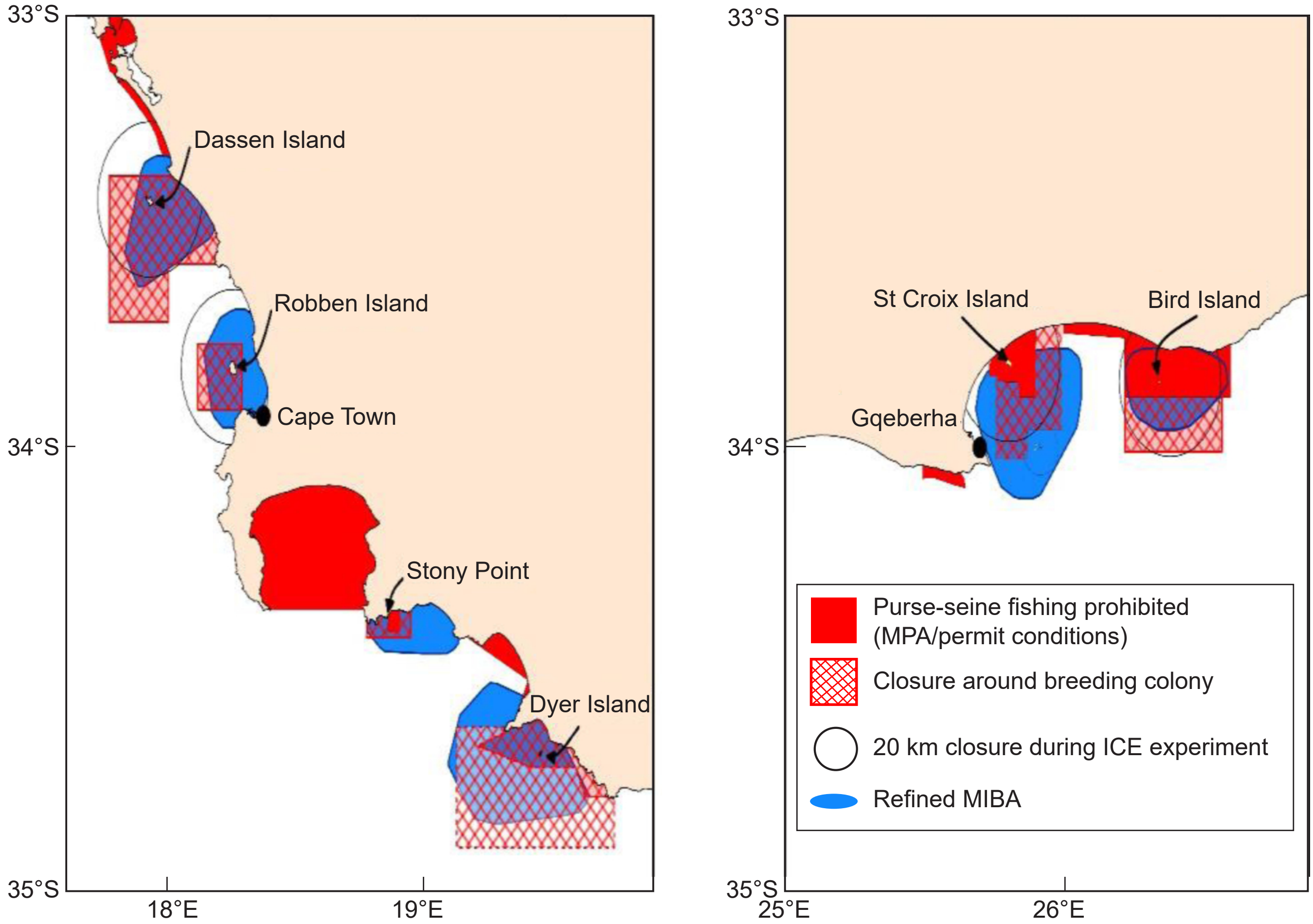


Figure 64: The locations of marine important bird areas (as refined by BirdLife SA), the 20-km-radius closed areas implemented during the island closure experiment (ICE) (note that an area of 5 km-radius around Riy Banks, to the southeast of St Croix Island, was also closed when St Croix Island was closed to fishing), and the 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 interim closure area around Dyer Island includes an inshore area where no pelagic fishing is allowed and an offshore area where only small vessels are allowed to fish

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 sea surface temperature gradient off the South Coast. Spatial catch patterns of both species have also changed, and whereas recent catch patterns of sardine 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 distributions 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, West Coast round herring and sardine in the Southern Benguela ecosystem. Whereas almost all the GAMs had good predictive performance, those for sardine had relatively higher explanatory capabilities compared to those for West Coast 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 West Coast 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. The only exception was for adult sardine where sea surface temperature had the second highest relative importance, substantially lower than that for chlorophyll *a*. This latter predictor was also important for anchovy and West Coast round herring recruits, and West Coast round herring eggs.

These analyses have improved understanding of how present distribution patterns of small pelagic fish are related to environmental variables and is 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 use of these valuable marine resources.

Adaptation measures to climate change 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 harvesting 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.

Further reading

Bakir A, van der Lingen CD, Preston-Whyte F, Bali A, Geja Y, Barry J, Mdazuka Y, Mooi G, Doran D, Tooley F, Harmer R, Maes T. 2020. Microplastics in commercially important small pelagic fish species from South Africa. *Frontiers in Marine Science* 7: article 574663.

DFFE (Department of Forestry, Fisheries and the Environment). 2021. A synthesis of current scientific information relating to the decline in the African penguin population, the small pelagic fishery and island closures. Unpublished report. Cape Town, South Africa: DFFE.

Sakamoto T, van der Lingen CD, Shirai K, Ishimura T, Geja Y, Petersen J, Komatsu K. 2020. Otolith $\delta^{18}O$ and microstructure analyses provide further evidence of population structure in sardine *Sardinops sagax* around South Africa. *ICES Journal of Marine Science* 77: 2669–2680.

Teske PR, Emami-Khoyi A, Golla TR, Sandoval-Castillo J, Lamont T, Chiazzari B, McQuaid CD, Beheregaray LB, van der Lingen CD. 2021. The sardine run in southeastern Africa is a mass migration into an ecological trap. *Science Advances* 7: eabf4514.

Uren RC, van der Lingen CD, Kylin H, Bouwman H. 2020. Concentrations and relative compositions of metallic elements differ between predatory squid and filter-feeding sardine from the South Indian and South Atlantic oceans. *Regional Studies in Marine Science* 35: article 101137.

van der Lingen CD. 2021. Adapting to climate change in South Africa's small pelagic fishery. In: Bahri T, Vasconcellos M, Welsh D, Johnson J, Perry RI, Ma X, Sharma R (eds), *Adaptive management of fisheries in response to climate change. FAO Fisheries and Aquaculture Technical Paper* No. 667. Rome: Food and Agriculture Organization of the United Nations. pp 177–194.

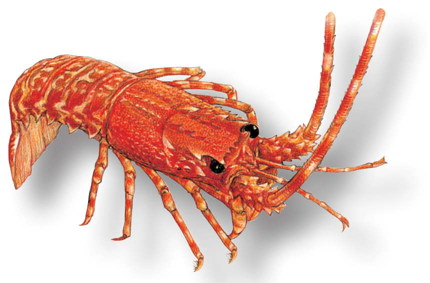
Wu Q, Schlag SS, van der Lingen CD, Bouwman H, Vetter W. 2020. Polyhalogenated compounds (halogenated natural products and PoPs in sardine (*Sardinops sagax*) from the South Atlantic and Indian Oceans. *Journal of Agriculture and Food Chemistry* 68: 6084–6091.

Useful statistics

Pelagic fish catches and TACs/TAB/PUCLs, 1990–2024 (x 1 000 t)

Year	Anchovy	Total sardine	Directed sardine	Bycatch sardine	Horse mackerel	Chub mackerel	WC round herring	Mesopelagic fish	TOTAL	Anchovy TAC	Sardine TAC directed	Sardine TAB	WC round herring PUCL	Horse mackerel PUCL	Mesopelagic PUCL	TOTAL TAC, TAB & PUCL
1990	152	57	42	15	8	0	46	1	263	150	42	0	0	0	0	192
1991	151	53	40	13	1	10	34	1	249	150	37	0	0	0	0	187
1992	349	55	34	21	2	0	48	1	455	350	32	0	0	0	0	382
1993	236	51	30	21	12	0	57	1	357	360	27	0	0	0	0	387
1994	156	95	50	44	8	2	54	1	316	150	50	45	0	0	0	245
1995	178	121	77	44	2	3	77	1	382	210	75	42	0	0	0	327
1996	41	108	79	29	19	1	47	0	216	70	76	29	0	0	0	175
1997	60	119	92	27	13	4	92	0	289	60	88	50	0	0	0	198
1998	108	133	109	24	27	0	53	7	327	175	106	35	0	0	0	316
1999	180	132	118	14	2	0	59	0	373	231	136	26	0	0	0	393
2000	267	135	124	12	5	0	37	0	445	291	126	38	0	5	0	460
2001	288	192	173	19	1	0	55	0	535	451	182	50	0	5	0	688
2002	213	261	245	16	8	0	55	0	537	360	258	54	0	5	0	677
2003	259	290	274	16	1	0	43	0	593	282	250	44	100	5	0	681
2004	190	374	366	8	2	0	47	0	614	423	457	69	100	5	0	1054
2005	283	247	240	6	6	0	28	0	564	297	397	60	100	5	0	859
2006	134	217	206	11	5	0	42	0	398	362	204	71	100	5	0	742
2007	253	140	135	5	2	0	48	0	443	537	162	49	100	5	0	853
2008	266	91	86	5	2	1	64	0	424	518	91	38	100	5	0	752
2009	174	94	89	5	2	1	40	0	312	569	90	43	100	5	0	808
2010	217	112	88	25	4	1	88	0	423	573	90	115	100	5	0	883
2011	120	112	89	23	11	0	65	7	315	390	90	54	100	12	0	646
2012	307	109	98	12	2	0	68	0	487	473	101	27	100	5	50	756
2013	79	92	88	4	1	0	31	0	203	450	90	66	100	12	50	769
2014	240	97	88	9	3	1	34	0	376	450	90	66	100	15	50	771
2015	238	96	81	15	2	1	13	0	351	450	83	73	100	12	50	769
2016	262	80	63	17	2	4	54	0	401	354	65	45	100	12	50	626
2017	217	37	31	6	1	2	54	0	312	450	45	41	100	8	50	694
2018	253	39	37	3	1	2	48	6	350	315	65	37	100	9	50	576
2019	165	5	2	3	1	4	47	3	225	350	12	11	100	9	50	532
2020	285	34	24	10	2	3	54	0	378	350	32	13	100	10	50	555
2021	156	32	23	9	8	2	56	0	254	350	27	18	100	9	50	554
2022	172	33	26	7	1	1	66	0	273	341	30	15	70	2	25	513
2023	109	41	29	11	1	2	98	0	250	248	41	21	120	6	25	460
2024	97	70	54	16	1	5	120	0	294	140	65	25	165	14	25	433

South Coast rock lobster



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

Introduction

The South Coast rock lobster *Palinurus gilchristi* is endemic to the southern coast of South Africa, inhabiting rocky substrates at depths of 50–200 m. The fishery operates between East London and Cape Point and extends up to 250 km offshore along the outer edge of the Agulhas Bank. The fishery is capital-intensive, requiring specialised equipment in the form of longlines with traps, and large ocean-going vessels.
The South Coast rock lobster fishery is currently the largest rock lobster fishery in South Africa by total mass.

Products, including frozen tails, whole or live lobster are exported to the United States of America (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 fishery lucrative. Prices for commodities fluctuate and the sales prices in the USA are currently the equivalent of about R1 000 per kg tail mass. The total export value in 2021 was approximately R353 million.

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 of whom come from previously disadvantaged backgrounds. In addition to sea-going personnel, the sector employs approximately 100 land-based factory (processing) and administrative personnel, also primarily from disadvantaged backgrounds.

History and management

The South Coast rock lobster was first described in 1900 and was recorded occasionally in trawl 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 grounds 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 that occurs entirely within South African waters. From 1977 onwards, the sector operated solely as a local commercial fishery.

The management of this fishery dates back to its inception in 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 65 and 66). The introduction of management measures such as reduction of effort and catches during the early 1980s resulted in some resource recovery (Figures 65 and 66). 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 65), 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 until

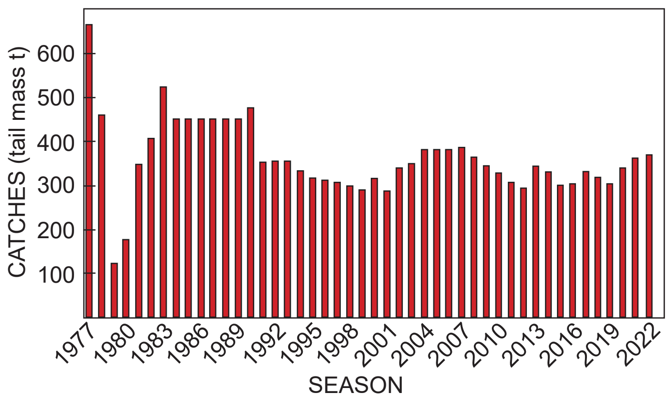


Figure 65: Annual catches of South Coast rock lobster from 1977 to 2022. Note that 1977 refers to the 1977/78 season, etc.

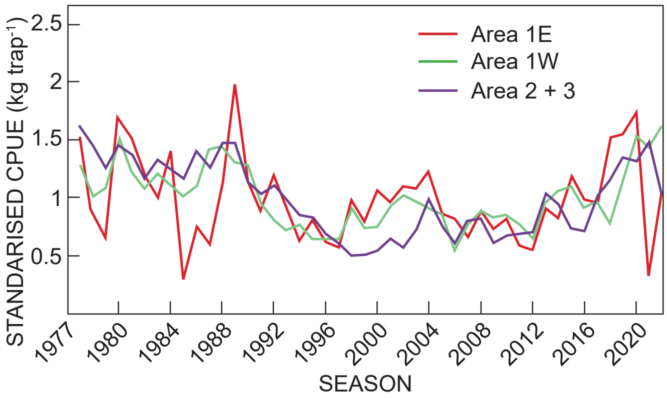


Figure 66: South Coast rock lobster catch per unit effort (CPUE) by area from 1977 to 2022. Note that 1977 refers to the 1977/78 season, etc.

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 the determination of the global TAC 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 conducted again in 2019 (OMP-2019) and this was used to determine the TAC and TAE for the 2019/20–2022/2023 seasons. The objective of this OMP is to increase the spawning biomass of the resource by 30% over a 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 is an age-structured production model (ASPM), which incorporates various biological and fishery-dependent data. Key inputs include size and age composition of the catch, somatic growth rates, and population size estimates. A tagging programme provides critical data on growth and population size estimates, as well as estimates of migration.

Scientific observers are deployed onboard commercial fishing vessels, collecting data on catch composition, biological measurements (length, sex and reproductive state), estimating catch and effort, reporting on gear used, observing fishing practices (including discarding, dumping and bycatch), and also recording the areas where fishing takes place. These data contribute to the annual stock assessment used 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. Additionally, commercial catch-per-unit-effort (CPUE) data are captured from landing slips, which serve as critical input for managing TAC and TAE.

New research planned for this resource includes investigation of innovative methodologies such as non-extractive baited "video fishing" for estimating relative abundance and for studying the behaviour of South Coast rock lobster *in situ*. Paired stereo-cameras will record precise length and biomass estimates. The baited underwater video camera traps will also monitor interactions between bycatch species and catch rates, as well as the fate of bait and other bycatch and discards, and will 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

From 1977 to 1979/80, fishing effort and catches increased above sustainable levels (Figures 65 and 66), and thereafter the catches declined rapidly to 122 t tail mass (Figure 65).

The decline in catches was partly due to the withdrawal of the foreign fishing vessels from South African waters in 1976, and partly to overfishing. By the end of the 1970s, low catch rates forced several local fishing vessels out of the fishery. Between 1980 and 1984, catches gradually recovered, and stable catch rates during this period reignited interest from previously withdrawn fishers. 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.

Images courtesy of Two Oceans Aquarium (https://www.aquarium.co.za/animals/south-coast-rock-lobster)

Table 18: South Coast rock lobster historical records of TAC, TAE, and standardised CPUE by area

Season	TAC	TAE	Standardised CPUE (kg trap^{-1})		
	(tail mass [t])	(allocated seadays)	Area 1E	Area 1W	Area 2+3
1977/78			1.54	1.28	1.61
1978/79			0.86	1.01	1.45
1979/80			0.64	1.08	1.26
1980/81			1.70	1.51	1.45
1981/82			1.50	1.22	1.38
1982/83			1.19	1.08	1.16
1983/84			1.01	1.21	1.34
1984/85	450		1.41	1.10	1.25
1985/86	450		0.28	1.00	1.16
1986/87	450		0.75	1.10	1.40
1987/88	452		0.59	1.42	1.26
1988/89	452		1.09	1.44	1.47
1989/90	452		1.99	1.30	1.47
1990/91	477		1.13	1.28	1.14
1991/92	477		0.88	0.95	1.03
1992/93	477		1.20	0.81	1.11
1993/94	477		0.91	0.72	0.99
1994/95	452		0.62	0.76	0.85
1995/96	427		0.81	0.64	0.83
1996/97	415		0.62	0.65	0.69
1997/98	402		0.57	0.64	0.61
1998/99	402		0.98	0.91	0.50
1999/00	377		0.79	0.73	0.50
2000/01	365	2 339	1.07	0.74	0.54
2001/02	340	1 922	0.96	0.92	0.64
2002/03	340	2 146	1.10	1.02	0.57
2003/04	350	2 038	1.08	0.97	0.72
2004/05	382	2 089	1.23	0.90	1.00
2005/06	382	2 089	0.86	0.85	0.76
2006/07	382	2 089	0.82	0.54	0.60
2007/08	382	2 089	0.66	0.76	0.80
2008/09	363	2 675	0.88	0.89	0.82
2009/10	345	2 882	0.72	0.83	0.61
2010/11	328	2 550	0.82	0.85	0.67
2011/12	323	2 443	0.58	0.77	0.68
2012/13	326	2 250	0.55	0.64	0.70
2013/14	342	2 536	0.91	0.95	1.04
2014/15	359	2 805	0.82	1.05	0.94
2015/16	341	2 858	1.19	1.10	0.73
2016/17	332	2 029	0.98	0.90	0.71
2017/18	338	2 042	0.95	0.97	1.02
2018/19	321	2 148	1.52	0.77	1.16
2019/20	337	2 220	1.55	1.18	1.35
2020/21	358	2 130	1.74	1.54	1.31
2021/22	372	2 094	0.32	1.43	1.48
2023/24	391	1 994	1.06	1.62	1.01

The TAC restricted total catches to 450 t tail mass (970 t whole mass) per year (Table 18); 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 tonnes 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 2023, has recovered and the best-case assessment estimates it at 53%—and spawner biomass was calculated to be about 41%—of pre-fished levels.

Ecosystem interactions

There are some concerns around the levels of whale entanglements in this fishery. Industry Recognized Bodies have taken proactive measures by implementing guidelines on gear management measures to reduce marine-mammal encounters. Additionally, they 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. Apart from whale interactions, no other major ecosystem issues have been identified. However, concerns have been raised about the vulnerability of berried females under current fishing practices. Further research into the spatial and temporal distribution of these females is recommended to address these concerns.

At present, there is no evidence suggesting that climate change is directly affecting the South Coast rock lobster resource. It is likely, however, that this species has the physiological capability to adjust to temperature changes and acidification in a similar way to the closely related and well-researched West Coast rock lobster (see respective chapter).

Further reading

Groeneveld JC. 1997. Growth of spiny lobster *Palinurus gilchristi* (Decapoda: Palinuridae) off South Africa. *South African Journal of Marine Science* 18: 19–29.

Groeneveld JC. 2003. Under-reporting of catches of South Coast rock lobster *Palinurus gilchristi*, with implications for the assessment and management of the fishery. *South African Journal of Marine Science* 25: 407–411.

Groeneveld JC, Branch GM. 2002. Long-distance migration of South African deep-water rock lobster *Palinurus gilchristi*. *Marine Ecology Progress Series* 232: 225–238.

Groeneveld JC, Melville-Smith R. 1994. Size at onset of sexual maturity in the South Coast rock lobster *Palinurus gilchristi* (Decapoda: Palinuridae). *South African Journal of Marine Science* 14: 219–223.

Groeneveld J C, Rossouw G J. 1995. Breeding period and size in the South Coast rock lobster, *Palinurus gilchristi* (Decapoda: Palinuridae). *South African Journal of Marine Science* 15: 17–23.

Images courtesy of Two Oceans Aquarium (https://www.aquarium.co.za/animals/south-coast-rock-lobster)

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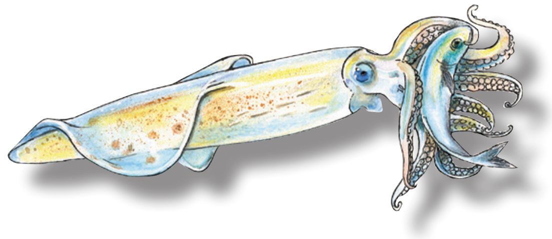
Squid



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

Introduction

The Cape Hope squid *Loligo reynaudii*, locally known as 'chokka', is a ubiquitous loliginid squid that occurs around the southern African coast from Namibia to the Wild Coast off the Eastern Cape (Figure 67). A separate stock targeted by some artisanal fisheries occurs further north off southern Angola, but scant information is available from this 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 estimates in males ranged from 164 to 484 days (with a mean of 323 days) and in females from 125 to 478 days (mean of 316 days). The lifespan is consequently slightly over one year. There is a marked sexual dimorphism in terms of body size, with males reaching up to 46 cm mantle length while the maximum observed size of female chokka is 28 cm.

An assessment of size-composition data collected over a

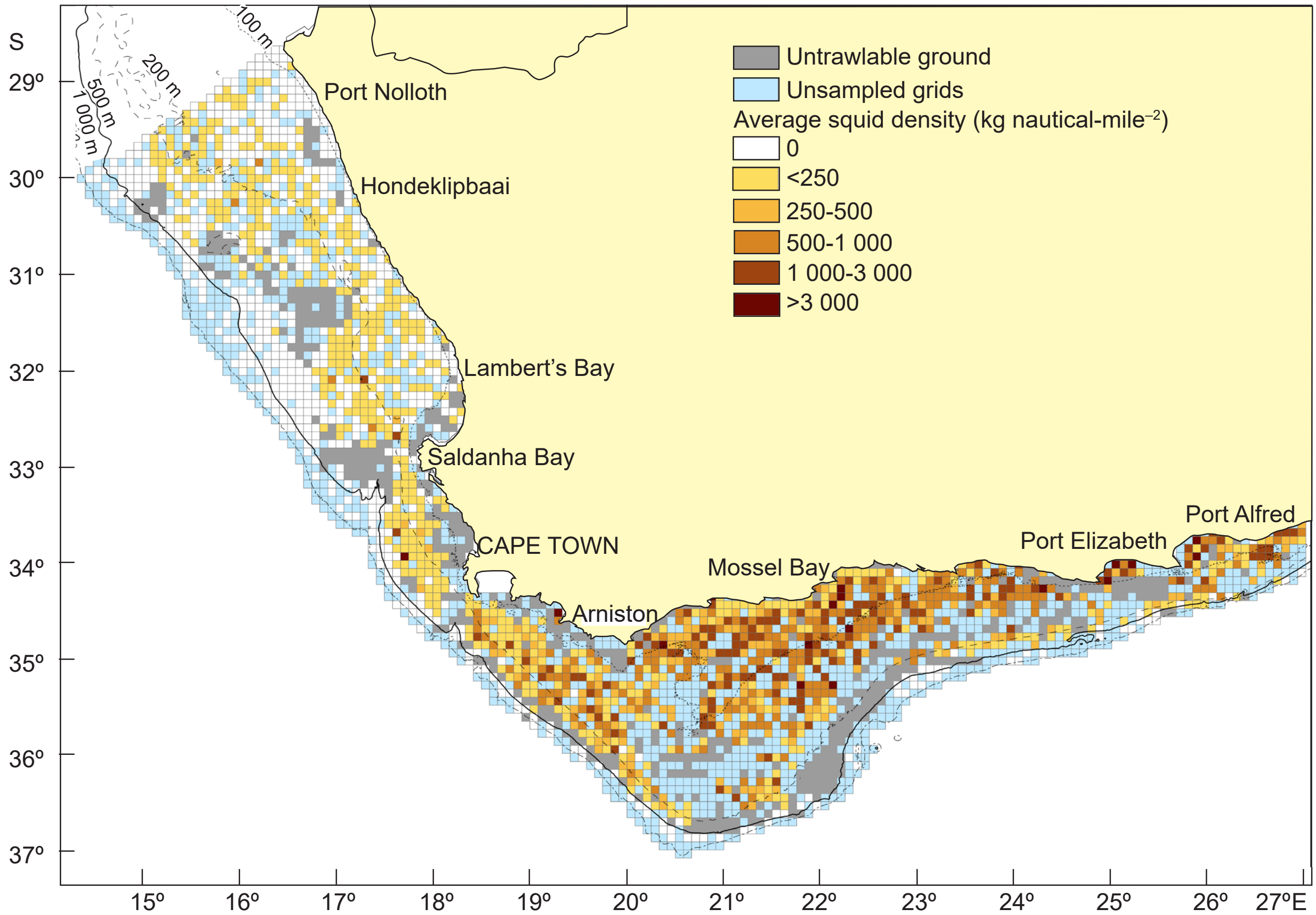


Figure 67: Distribution of chokka squid *Loligo reynaudii* in South African waters, as derived from fishery-independent demersal research surveys. Densities (kg nautical-mile^{-2}) are averages over all survey stations sampled from 1986 to 2023 within each survey grid block

period of 22 years showed no clear long-term trends in the mean length of the stock, although a substantial reduction in the mean lengths, especially in females, was noted over the period 2014–2017. 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 multiple paternity within offspring of individual females is common. Spawning distribution is governed largely by environmental conditions and occurs mostly inshore in relatively sheltered embayments off the southeastern coast in less than 60 m depth, although spawning in deeper water has also been observed.

Their chief prey items are fish and crustaceans, but they also sometimes feed on other cephalopods, and cannibalism is occasional. The abundance of chokka squid over time shows wide fluctuations, which have been attributed largely to varying biological factors such as spawning distribution and survival rates of hatchlings and juveniles, but environmental factors such as temperature, currents, turbidity and macro-scale events such as *El Niños*/*La Niñas* also play a crucial role.

Chokka squid is the target of a dedicated jig fishery that operates between the Cape of Good Hope and Port Alfred. The squid fishery is extremely labour intensive and is relatively stable, providing employment for approximately 3 000 people. The fishery is estimated to generate in excess of R480 million in a good year and is South Africa's third largest fishery in monetary terms. Fishing for chokka is conducted using handlines and squid jigs. Crew often use multiple lines, with up to four or more jigs attached per line. Captured chokka are graded and frozen into size-categorised blocks at sea that are almost exclusively exported to southern European countries, most notably Italy. Apart from the directed commercial jig fishery, squid are also caught as bycatch in the hake-directed demersal trawl fishery and are often targeted by commercial line and recreational fishers for use as bait or for personal consumption.

History and management

In the 1960s and 1970s, the squid resource was exploited as incidental bycatch by demersal trawlers, largely foreign vessels from the Far East. Foreign fishing activity was 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, with catches of chokka typically below 1 000 t per annum since the 1990s (Figure 68).

International demand for squid as a luxury seafood ("calamari") increased from the 1970s. Locally, the presence of large shoals of chokka squid off the South Coast between Plettenberg Bay and Port Elizabeth, coupled with favourable exchange rates in the early 1980s, initiated a rapid increase in the exploitation of the resource with hundreds of vessels converging on South Coast squid shoals. Because there was no specific legislation governing squid exploitation when the fishery commenced, the initial developmental stages were chaotic until the commercial jig fishery was formally established in 1984. Early management measures were largely imposed in the absence of any reliable analyses of resource and fishery dynamics and were essentially pragmatic responses to the rapidly developing fishery based on some biological knowledge but limited data.

A licensing system was introduced between 1986 and 1988 with a view to limiting the number of vessels participating in the fishery. Opportunistic recreational fishers were severely restricted (through bag limits) in favour of *bona fide* commercial/semi-commercial fishers who had developed a catch record

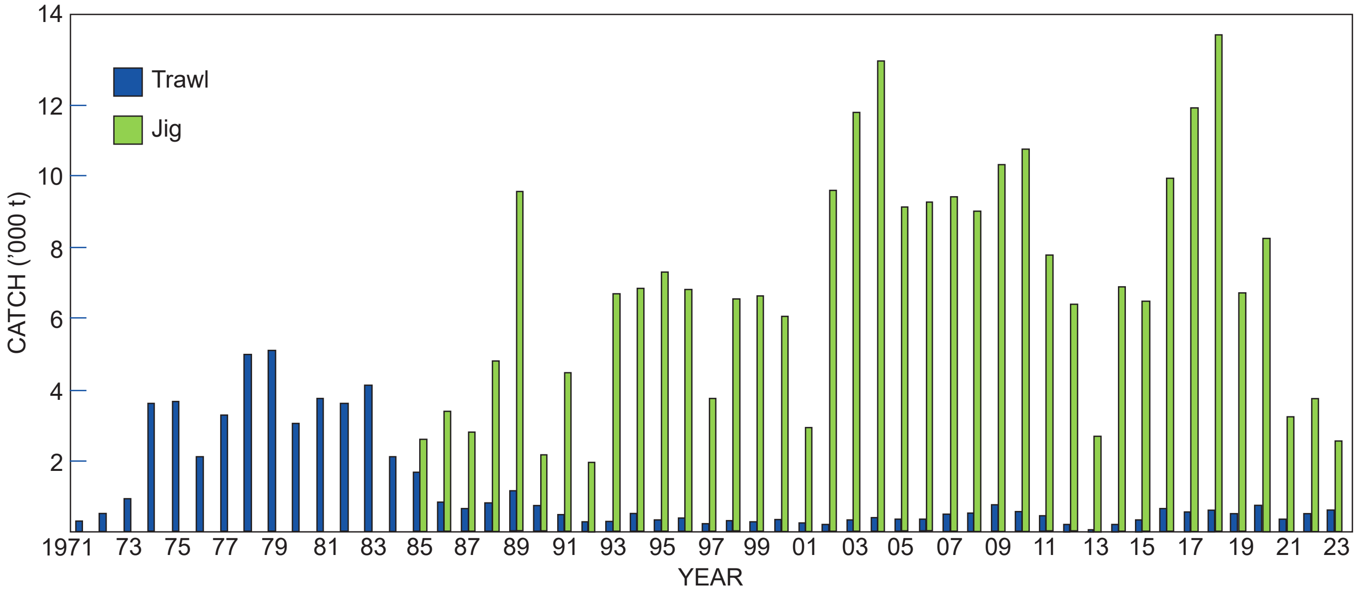


Figure 68: Annual catch (trawl- and jig-caught) squid off South Africa, 1971–2023. Trawl data (catches made by both foreign and domestic fleets) are from external data 1971–1982, and from the DFFE demersal database 1983–2023. Commercial jig catch data are from the South African Bureau of Standards (SABS) as provided by the industry for the period 1985–2006, the National Regulator for Compulsory Standards (NRCS) for the period 2007–2018 and from DFFE commercial logbooks for the period 2019 onwards. Note that although the squid fishing season now extends from 1 May to 30 April the following year, catches are illustrated here by calender year

during the first few years of the fishery. This resulted in a reduction of the number of vessels exploiting the resource from over 500 to about 270. Subsequent management measures included the introduction of a recreational bag limit in 1986 (20 squid per person per day), and the implementation in 1986/87 of a 6-week closed season (main fishing grounds closed to all vessels not registered in the area) to protect spawning females. This latter measure was altered in 1988 to a comprehensive one-month closed season in November each year and subsequently adjusted to a mandatory 5-week closed season covering the late-October to November period each year with the intention of reducing the disturbance to spawning squid and thereby improving recruitment the following year.

In the late 1980s it was agreed that the fishery should be managed in terms of effort rather than catch control, given the absence of a reliable time-series of resource abundance indices at that time, as well as recognising that the lifespan of the species was too short to predict and capitalise on good year-classes. It was subsequently recognised that the earlier restriction on the number of vessels in the fleet was not the most appropriate means of controlling effort, so a restriction was consequently imposed on the number of crew that were permitted to operate in the fishery, initially set at 2 422. This measure has subsequently remained in place with slight adjustments over time arising from various fishing rights allocation processes. The current restriction is a total of 2 443 crew in the fishery, apportioned among the commercial and small-scale components as 2 077 and 366 crew members, respectively.

As data became available (through the ongoing collection of fishery-specific catch and effort data and various research programmes, including hake-directed swept area demersal surveys), efforts were directed at analyses of squid stock dynamics to estimate sustainable effort levels. The results of these analyses were used to recommend a total allowable effort (TAE) restriction on the fishery. Initially expressed as a metric of man-hours, assessments conducted since 2006 have expressed effort in terms of person-days due to the difficulties associated with accurately monitoring fishing effort at an hourly resolution. Estimates of sustainable effort have been implemented in recent years as TAE recommendations ranging from 250 000 to 295 000 person-days per annum. Most vessels in the jig fleet have typically fished for between 60 and 120 days per annum. However, some vessels (and more specifically their crew) have been recorded as fishing for more than 200 days per annum. There is consequently scope for the fishery to exert a level of effort far above what is considered to be sustainable. This “latent effort” concern was the basis for the introduction in 2014 of an additional 3-month closed season (typically covering the period April–June each year), the intention of which was to limit effort in the fishery to sustainable levels. To ameliorate unnecessary negative impacts on the fishery, some flexibility in the duration of this closed season has been permitted depending on the effort that has been exerted during the fishing season relative to the TAE.

The chokka squid fishery is characterised by relatively large variability in catches, which have ranged from 2 000 to over 13 000 t per annum between 1985 and the present (Figure 68). Annual jig catches increased rapidly as the fishery developed during the late-1980s, reaching just under 10 000 t in 1989. Annual catches appeared to stabilise at about 6 000 to 7 000 t during the 1990s but then increased to more then 8 000 t for most of the 2000s. The period post-2010 has displayed considerably more variability in catches, with a rapid decline to an almost “record low” in 2013, recovering to “normal” in 2014 and increasing yet further to a “record high” in 2018. Catches then again declined to in three consecutive years of unusually low catches over the period 2021–2023.

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 threat of reduction to levels at which future recruitment success might be impaired or catch rates 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 and on the South Coast in autumn each year (and also in spring in some years). Interpretation of

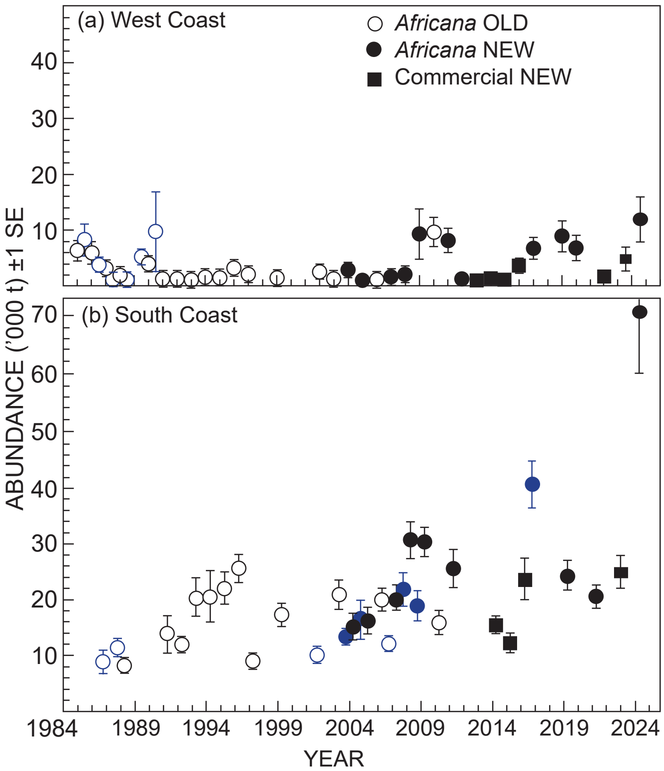


Figure 69: Chokka squid abundance estimates (‘000 t ± 1 SE) derived from fishery-independent swept area demersal surveys. Estimates are illustrated by coast for the various vessel-gear combinations. Summer (West Coast) and autumn (South Coast) surveys are indicated with black symbols, while winter (West 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. Also note the difference in the y-axis scale between the West and South Coast plots

the trends in the time-series of abundance estimates (Figure 69) 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 are considered to provide the most useful indication of spawning stock abundance, given that these surveys are conducted just prior to peak spawning season. Unfortunately, financial and operational constraints have restricted the number of spring surveys that could be conducted in recent years. An alternative fishery-dependent index of chokka abundance is computed from catch and effort data collected from the fishery at the level of individual fishing sessions (Figure 70) and has been used in assessments of the status and productivity of the resource.

Building on previous attempts, the Department is also working towards developing a method of directly estimating the spawning biomass of chokka squid over an extensive portion of the known spawning grounds. Five hydro-acoustic surveys have been carried out to date on the Department's research vessel (FRS *Ellen Khuzwayo*). Efforts are being directed at evaluating the results of these surveys relative to other indices of stock abundance (both fishery-dependent and swept area research survey indices) through developing a time-series of acoustic biomass estimates.

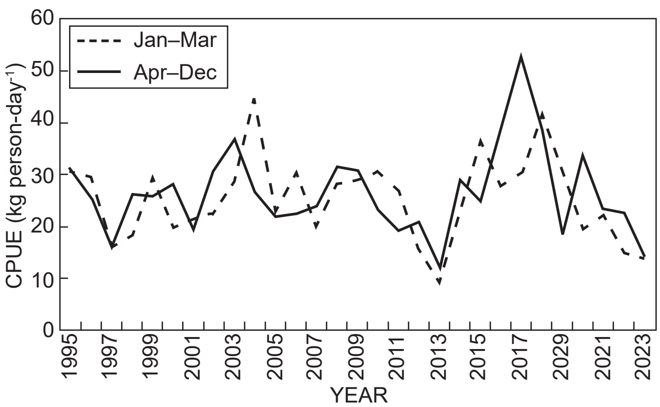


Figure 70: Annual estimates of nominal CPUE (kg person-day^{-1}) for the SA squid jig fishery. The estimates are calculated from catch and effort data reported by a "core" set of 19 vessels that have been active in the fishery for the longest period, and for fishing operations where the number of crew that fished on a given day on each vessel were between 3 and 20 individuals. The calculations also separate the data into January–March and April–December periods, although the former is not used in stock assessments of the resource for a number of reasons. Note that although the squid fishing season now extends from 1 May to 30 April the following year, the data are illustrated here by calender year

Catch and effort data are collected on a regular basis from the commercial jig fishery. Additional landings data available from the National Regulator for Compulsory Specifications were used to "ground-truth" the fishery catch data. Historically, squid catch and effort data were recorded along with linefish data and stored in the National Marine Linefish System. However, a jig-fishery-specific logbook was introduced in 2006 to enable the recording of more-detailed catch and effort information from the fishery. Further amendments have recently been made to the logbook to enable the collection of catch and effort data from small-scale fishers. During the 2020 pandemic, collection and submission of hardcopy logbooks became a challenge, so a trial electronic-data-capturing project was initiated. The pilot project proved to be a success, and the Department subsequently embarked on a rigorous training programme for industry data capturers. Almost all squid fishery-dependent data are now submitted electronically. This is a noteworthy achievement that has resulted from a strong collaboration between a willing industry and the Department, and contributes appreciably to within-season monitoring of effort expended by the fishery, and hence more-precise and effective implementation of the effort restrictions imposed on the fishery (the additional closed season in particular). The squid catch and effort data undergo a process of verification and validation against hard copies and are stored in a dedicated, secure database.

Chokka squid is one of the most comprehensively researched squid species in the world, and aspects of its early adult life history are relatively well known. Current research efforts are being directed at investigating changes in biological characteristics of squid over time, examining genetics of adults in order to elucidate stock identity, understanding environmental influences on the resource and its dynamics, acoustic mapping of inshore spawning grounds, 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-WIO 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. Fourteen scientific manuscripts were published highlighting ecosystem traits that impact the life cycle, recruitment and catches (https://www.sciencedirect.com/special-issue/10W19CTFBGH). Insights continue to emerge from this large study.

An attempt to use hydro-acoustic techniques to measure the extent of squid egg beds (for use as an alternative index of squid abundance) was unsuccessful due to difficulties with separating the acoustic signatures of squid eggs from other benthic organisms and/or features. As noted above, efforts have consequently rather been directed at attempting to estimate the abundance of spawning adults at the start of the peak summer spawning period. Results of this work have been encouraging, but there have been some concerns regarding whether the spatiotemporal coverage of the acoustic surveys can properly encompass the spawning component of the resource, and the acoustically detectable spawning aggregations in particular. Preliminary results of a research project initiated in 2023 that evaluated patterns and trends in commercial CPUE suggest that it is unlikely that large aggregations of acoustically surveyable squid are found consistently in areas—and at times—other than those where acoustic efforts have typically been expended, especially during the summer (November) season.

A key research activity initiated in 2022 has been the development of a new modelling approach to improve the assessment of resource dynamics and status. The model that has been used in recent years as a basis for estimating sustainable effort levels requires improvement, primarily for the following reasons:

- Catch-by-size-category data that have been evaluated recently suggest that the squid stock comprises multiple subcohorts rather than a single primary cohort arising from the summer peak spawning period. In these circumstances, it is more appropriate to model the resource using monthly rather than annual time-steps.
- Given the differences in the growth rates between male and female squid, modelling the resource using a gender-aggregated approach is not appropriate.
- Age estimates of squid indicate that the life cycle should be restricted to a period of 18 months in the model.
- Given these considerations, the approach used in the current model that combines growth and natural mortality into a single estimable parameter should be changed and these parameters should be modelled separately.

Apart from developing the model structure to address these improvements, considerable effort is also being directed at collecting/collating sex-disaggregated monthly catch and effort data to be used in the model-fitting process.

Current status

The most recent assessment of the chokka squid resource was conducted in 2019 and indicated a more positive outlook of resource status and productivity than did the previous (2016) assessment. As a result, the TAE was increased from 270 000 person-days to 295 000 person-days for the 2019 fishing season. Considering the efforts being directed at improving the stock assessment model as described in the previous section, the Department has adopted a *status quo* approach to the TAE pending a revision using the results of the "new" modelling approach. The TAE has consequently been maintained at 295 000 person-days since 2019. The annual effort exerted by the fleet since 2021 has been well below this TAE (Figure 71), providing little basis to move from this *status quo* approach at this time. The effort exerted in 2018, however, and to a much lesser extent in 2016, exceeded the TAE (Figure 71). This was a result of inadequate within-season monitoring of effort, largely a result of the extended time-frame required for the collection and capture of hard copy logbooks at that time. The development of electronic data submission (see above) has largely addressed this short-coming.

Ecosystem interactions

The South African chokka squid fishery employs handheld jigs, mainly targeting aggregations of spawning adult squid. This method selectively targets the desired species. There is little to no bycatch in the 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 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.

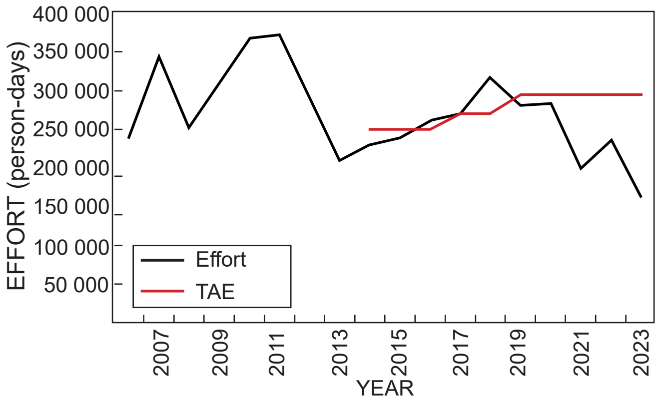


Figure 71: Annual estimates of total effort (person-days) exerted by the chokka squid jig fishery since 2006. The TAE, expressed in the same units from the results of updated stock assessments, is also shown. Note that although the squid fishing season now extends from 1 May to 30 April the following year, catches are illustrated here by calender year

Further reading

Augustyn CJ, Lipinski MR, Sauer WHH, Roberts MJ, Mitchell-Innes BA. 1994. Chokka squid on the Agulhas Bank: life history and ecology. *South African Journal of Science* 90: 143–154.

Glazer JP. 2019. Updated assessment of the squid resource, *Loligo reynaudii*. Report No. FISHERIES/2019/MARCH/SWG-SQ/06. Cape Town: Department of Agriculture, Forestry and Fisheries.

Hampton I, Soule MA, Mwicigi J. 2024. Acoustic assessment of the biomass of aggregated chokka squid *Loligo reynaudii* on its inshore spawning grounds on the southeast coast of South Africa in the season closed for fishing. *African Journal of Marine Science* 46: 17–30.

Lipinski LR, Mmethi MA, Yemane D, Githaiga-Mwicigi J, Sauer WHH. 2021. Are there long-term temporal trends of size composition and the length-weight relationship? Results for chokka squid *Loligo reynaidii* during the peak spawning season off the south coast of South Africa. *African Journal of Marine Science* 43: 227–238.

Lipinski LR, Mwangombe CH, Durholtz D, Yemane D, Githaiga-Mwicigi J, Sauer WHH. 2020. Age estimates of chokka squid *Loligo reynaudii* off South Africa and their use to test the effectiveness of a closed season for conserving this resource. *African Journal of Marine Science* 42: 461–471.

Roel B, Butterworth DS. 2000. Assessment of the South African chokka squid *Loligo vulgaris reynaudii.* Is disturbance of aggregations by the recent jig fishery having a negative impact on recruitment? Fisheries Research 48: 213–228.

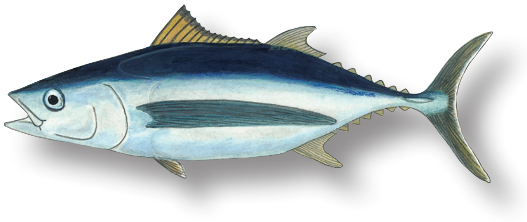
Useful statistics

Squid catches from the commercial jig fishery, bycatches from the hake-directed demersal trawl fishery and information on the squid TAE (2003–2023). Note that trawl bycatch data differ from those previously reported due to ongoing validation and correction of historical data. Although the squid fishing season now extends from 1 May to 30 April the following year, catches are listed here by calender year

Year	Squid commercial jig catches (t)	Squid landings as bycatch from hake trawl (t)	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	334	2 423 unrestricted crew*	22 restricted crew*
2006	9 291	327	2 423 crew or 138 vessels, whichever occurred first	
2007	9 438	466	2 422 crew or 136 vessels, whichever occurred first	
2008	9 021	488	2 422 crew or 136 vessels, whichever occurred first	
2009	10 341	690	2 422 crew or 136 vessels, whichever occurred first	
2010	10 777	510	2 422 crew or 136 vessels, whichever occurred first	
2011	7 796	390	2 422 crew or 136 vessels, whichever occurred first	
2012	6 392	122	2 422 crew or 136 vessels, whichever occurred first	
2013	2 664	47	2 422 crew or 136 vessels, whichever occurred first	
2014	6 907	182	TAE of 250 000 person-days	
2015	6 479	333	TAE of 250 000 person-days	
2016	9 952	546	TAE of 250 000 person-days	
2017	11 919	473	TAE of 270 000 person-days	
2018	13 983	521	TAE of 270 000 person-days	
2019	6 777	481	TAE of 295 000 person-days	
2020	8 410	672	TAE of 295 000 person-days	
2021	3 196	339	TAE of 295 000 person-days	
2022	3 775	442	TAE of 295 000 person-days, 2 443 crew. Apportioned: commercial 250 750 person-days (2 077 crew); small scale 44 250 person-days (366 crew)	
2023	2 544	591		

*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 region of 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 (Ind. and Atl.)	Swordfish (Ind. and Atl.) Bigeye (Ind. and Atl.) Southern bluefin (Ind. and Atl.)	
Fishing pressure	**Unknown**	**Light**	**Optimal** Yellowfin (Ind. and Atl.) Bigeye (Atl.) Swordfish (Ind.) Southern bluefin (Ind. and Atl.) Albacore (Ind. and Atl.)	**Heavy** Swordfish (Atl.) 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 Organisations (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 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 few 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 on the high seas at Vema and Valdivia seamounts, 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 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 limited freezing capacity 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, albacore 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. 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. According to the current (2015) sector specific policy, foreign vessels that operate under

Table 19: 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 2023

Year	Bigeye tuna	Yellowfin tuna	Albacore tuna	Southern bluefin tuna	Swordfish	Shortfin mako shark	Blue shark	Number of active vessels	
								Domestic *	Foreign-flagged
2005	1 076.9	1 597.4	166.8	27.6	475.2	44.7	86.7	9	12
2006	137.6	337.3	108.8	9.7	376.2	16.2	30.5	15	0
2007	676.7	1 086.0	194.9	49.1	518.4	48.5	131.0	17	12
2008	640.1	629.7	300.7	44.2	462.7	49.4	142.5	11	13
2009	765.0	1 096.0	273.5	30.5	439.6	65.1	85.5	15	9
2010	935.4	1 257.1	145.5	34.8	614.4	67.0	99.2	16	7
2011	906.5	1 184.5	339.1	48.1	584.2	481.0	451.3	22	9
2012	822.1	606.9	248.2	78.8	445.7	313.8	332.6	19	8
2013	884.3	1 099.8	293.7	51.0	476.0	481.5	349.0	17	7
2014	620.9	544.4	129.1	37.1	255.2	618.1	647.0	17	3
2015	444.6	629.5	155.7	42.1	418.0	774.6	529.5	18	3
2016	334.7	495.5	84.5	44.0	306.7	869.5	526.6	17	3
2017	508.0	420.1	174.8	114.6	256.2	750.6	549.3	19	3
2018	475.1	485.4	237.8	209.9	316.1	617.2	603.2	23	3
2019	671.5	680.6	357.1	173.7	561.8	201.1	225.3	20	3
2020	409.1	400.3	260.8	102.9	313.9	185.5	64.0	19	0
2021	577.2	569.3	376.4	135.0	462.9	85.5	97.1	19	1
2022	674.0	517.0	223.7	145.6	596.2	98.7	65.2	19	1
2023	740.6	846.7	434.0	108.8	839.4	128.2	25.3	23	0

South African rights will, after an initial one-year trial period, be required to reflag within three (3) years. The return to stringent timeframes for reflagging has resulted in few to no foreign flagged vessels operating in South Africa in recent years. The fishery has slowly changed its profile with less foreign vessel participation, less bycatch and more-effective tuna and billfish targeting (Table 19).

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 20). 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 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 132 fishing Rights being allocated for 140 vessels, valid for a period of 15 years and expiring in 2037. Catches of the fishery have been stable for a number of years, but the fleet has been consolidated to the most effective vessels (Table 20).

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 within the EEZ 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 Organisations (tRFMOs) of which South Africa is a full member: (i) the International Commission for the Conservation of Atlantic

Table 20: Total catch (tonnes) and number of active vessels in the tuna pole-line sector for 2005 to 2023

Year	Albacore	Yellowfin tuna	Snoek	Yellowtail	Skipjack tuna	Bigeye tuna	Southern bluefin tuna	Number of active vessels
2005	3 149.4	975	193.4	13.8	0.9	2	0	132
2006	2 526.6	978.9	118	1.4	0	1.2	0	136
2007	3 682.4	948.5	79.5	19.2	0.2	23.2	0	151
2008	2 190.8	352.1	313.7	13	3.6	25.9	0	142
2009	4 795.3	223.8	186.2	33.4	4	42.8	0.7	152
2010	4 272.8	177.2	476.8	41.2	1.6	14.2	0	145
2011	3 346.8	629.5	163.8	26.9	5.4	40.1	0	145
2012	3 619.6	165.6	180.1	27.5	8	14.9	0	141
2013	3 475.2	373.9	616.8	18.2	2.6	142.2	0	131
2014	3 631.1	1 348.5	288.2	11.5	4.6	49.8	0	111
2015	3 965.1	884.2	332.6	199.3	2.2	57.2	0	117
2016	2 036.9	627.4	219.3	12	1.6	10.5	2.3	126
2017	1 791.7	240.7	443.2	21.3	0.7	24.3	0.1	128
2018	2 513.2	266.1	789.1	10.2	2.1	22.8	2.6	125
2019	4 323.2	458.6	871.8	9.6	3	98.4	1.6	126
2020	4 411	541.8	1 372.9	36.4	1.2	82	2	121
2021	3 381.5	217.8	554.9	7.8	1.6	117.1	1.4	130
2022	5 166.1	854	396.4	8.7	2.3	121.6	0.8	128
2023	2 339.6	1 468.9	300.6	157.8	5.3	159	0.5	117

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 (5 280 t) and swordfish (1 001 t) in the Atlantic. In the Atlantic Ocean there have been periods of low catches of albacore of <2 500 t (2016–2018 and 2023) over the last decade, otherwise averaging approximately 4 000 t per year, and over 5 000 t in 2022. In contrast, South Africa 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 150 t for 2016–2017, 450 t for 2018–2020, 455.3 t for 2021–2023 and currently 527 t for 2024–2026. 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. Over the last decade, a number of the larger TPL vessels with the capability to fish farther offshore and with freezer capacity have converted to longline gear to exploit these valuable resources, with mixed success.

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 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 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.

With the small size of the South African TPL bait-boat vessels (average 16 m LOA) and the nature of the operation which requires the vessel to maximise on crew (who work in pairs to catch and haul albacore), South Africa has not mandated vessels to accommodate human scientific observers and instead catches have been monitored in port during offloading since 2022. Two industry groups within this sector, which collectively cover the entire fleet, are seeking Marine Stewardship Council (MSC) certification, and one group was recently certified in August 2024. The MSC certification process includes assessing and scoring external validation of evidence and information, and the adequacy of information collected through methods such as observer coverage. As such, this sector has voluntarily commenced with onboard human scientific observer coverage on suitable and willing vessels and their observer coverage currently is ~3% of fishing days. 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. The ICCAT and IOTC have adopted minimum standards and programme requirements for the use of electronic monitoring systems (EMS), which when implemented can supplement human observer coverage and fill monitoring gaps. The EMS are camera-based, whereby footage of fishing operations can be stored and reviewed, and data retrieved, when necessary. A few operators across the TPL and LPL sectors are independently trialling EMS, funded privately or through the Fish for Good Pathway Project and Fishery Improvement Project (FIP). The TPL sector has also designed and is trialling an electronic logbook/reporting software for the collection of catch and effort statistics that can be reported in near real-time. Provisions for the incorporation of EMS and electronic logbooks into policy and permit conditions need to be made to support the use of these technological innovations.

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 led 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 21). Furthermore, South Africa has held 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 Working Party on Ecosystems and Bycatch in the IOTC region. 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

The first run of a spatially explicit fisheries risk assessment (SEFRA) under the CCSBT multi-year seabird strategy was conducted in 2019, estimating the seabird bycatch by pelagic longline fisheries operating south of 25° S, for which South Africa shared their observer data on seabird bycatch. When the SEFRA was updated in 2022, the vision was that this work would be the foundation for developing methods suitable for assessing the incidental bycatch of seabirds in all pelagic longline fishing, expanding the scope in future across tRFMOs to a global assessment. Upon conclusion of the third SEFRA update in 2025, the methodology for the global assessment will be finalised. The SEFRA method uses the spatial distribution and abundance of a species, combined with the distribution and intensity of fishing or other threats, to

Table 21: Schedule of the latest stock assessments conducted by tRFMOs. tRFMO = tuna-directed Regional Fisheries Management Organisation, ICCAT = International Commission for the Conservation of Atlantic Tunas, IOTC = Indian Ocean Tuna Commission, CCSBT = Commission for the Conservation of Southern Bluefin Tuna

tRFMO	Year of latest stock assessment	Species
ICCAT	2020	South Atlantic albacore
	2024	Yellowfin tuna
	2021	Bigeye tuna
	2022	South Atlantic swordfish
IOTC	2022	Albacore
	2024	Yellowfin tuna
	2022	Bigeye tuna
	2023	Swordfish
CCSBT	2023	Southern bluefin tuna

estimate their overlap. The vulnerability to capture is assessed by fishing gear and adjusted according to mitigation measures used. The population risk to a seabird group (e.g. petrels, small albatrosses, shearwaters) is assessed using the known population dynamics and biological parameters.

In 2020, a multi-national 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. The study found, amongst others, that there was a highly significant decrease in bycatch rate over time, that night-setting significantly reduced bycatch rates under all conditions and that, at night, moon illumination increased bycatch rate but Tori lines reduced bycatch. In 2024, the Department commenced with a review of the NPOA-Seabirds, the gazetting and implementation of which is planned for 2025. The update of this document represents a significant milestone for DFFE since the last update was provided in 2008.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. The Department's scientists participated 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.

The Common Oceans Tuna Project II (2022–2027), a project that aims to achieve responsible, efficient, and sustainable tuna production and biodiversity conservation in the areas beyond national jurisdiction (ABNJ), includes a component on education, outreach, and capacity-building for the monitoring and implementation of seabird bycatch mitigation. Through this project, training was provided to the skippers and crew of the LPL and TPL on bycatch mitigation measures for seabirds, sharks and turtles.

Finally, in the coming years, the interaction of the TPL fishery with endangered, threatened and protected (ETP) species such as seabirds and sharks will be investigated using the onboard human observer data, supplemented by EMS. As part of their MSC certification, the TPL fishery will draft and implement an ETP management strategy to minimise interaction and mortality of ETP species.

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.

If stock assessments show that a stock has fallen below a critical limit or that fishing mortality is not sustainable, the tRFMOs, driven by the agreements sought by the member countries, will initiate and implement a combination of rebuilding plans, catch limits, quota allocations and monitoring and enforcement measures to bring that stock back to sustainable levels.

Yellowfin tuna

The most recent stock assessment for yellowfin tuna, conducted by ICCAT in 2024, considered the stock was not overfished in 2022, and that no overfishing was occurring in 2022 in the Atlantic Ocean (Figure 72). However, there is a concern that catches above 120 000 t are expected to further degrade the condition of the yellowfin stock if they continue. Also, increased harvests on smaller yellowfin tuna have negative consequences for the long-term sustainability of the stock.

A stock assessment carried out in 2024 for yellowfin tuna in the IOTC area of competence resulted in a stock status estimate that differs substantially from the previous assessment, with a shift in stock status from a high probability of red to a high probability of green in the Kobe plot. Several key differences and improvements in the model and the input data from the 2021 assessment have contributed to this optimistic outlook. Spawning biomass was estimated to be 32% higher than the level that supports the maximum sustainable yield (SB_{2023}/SB_{MSY} = 1.32). Current fishing mortality is estimated to be 25% lower than F_{MSY} (F_{2023}/F_{MSY} = 0.75). The probability of the stock being in the green Kobe quadrant in 2023 is estimated to be 89%, and the yellowfin tuna stock is determined to be not overfished and not subject to overfishing.

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 72). Projections at a level consistent with the estimated MSY level (27 000 t) will maintain biomass levels below B_{MSY} and fishing mortality below F_{MSY} with a high probability of 90% over the projection horizon through 2023. The stock assessment for Indian Ocean albacore tuna in 2022 indicated that current catch appears to be sustainable in the short term although the projections are based on model assumptions that may be associated with high levels of uncertainty.

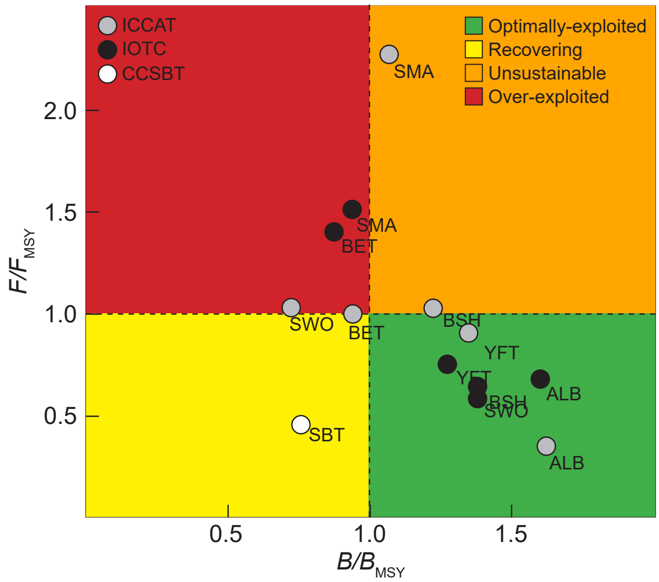


Figure 72: Kobe plot summarising the most-recent stock status estimates of fishing mortality relative to F_{MSY} and biomass relative to B_{MSY} for large pelagic species targeted by the South African longline and tuna pole-line fishery. Only results from formal stock assessments conducted by ICCAT (Atlantic Ocean), IOTC (Indian Ocean) or CCSBT (Southern Ocean) are included. ALB: albacore tuna; BET: bigeye tuna; BSH: blue shark; SBT: southern bluefin tuna; SMA: shortfin mako shark; SWO: swordfish; YFT: yellowfin tuna. 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

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 the 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 2023 (with fisheries data up to 2022) determined that this swordfish stock is optimally exploited (green), not overfished nor subject to overfishing (Figure 72). Spawning biomass in 2021 was estimated to be 35% (80% CI: 32–37%) of the unfished levels. Most recent catches of 23 597 t in 2022 are below the MSY level (30 000 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. The latest Atlantic bigeye stock assessment was done in 2021, based on data up to 2019, and the stock was estimated to be overfished (median SSB_{2019}/SSB_{MSY} = 0.94) but not undergoing overfishing (median F_{2019}/F_{MSY} = 1.00). The stock assessment for Indian Ocean bigeye tuna in 2022 estimated spawning biomass in 2021 to be 25% of the unfished levels and 90% of the level that can support MSY. Fishing mortality was estimated at 1.43 times the F_{MSY} level. On the weight-of-evidence available in 2022, the bigeye tuna stock was determined to be overfished and subject to overfishing. In 2019 the pessimistic outlook for the stock led to 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 2023 at the Extended Scientific Committee (ESC) of CCSBT. The stock, as indicated by relative total reproductive output (TRO), is estimated to be 23% 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 72). 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 stock continues to rebuild, which gave rise to an increase in the TAC by 3 000 t, from 17 647 t to 20 647 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 albatross *Thalassarche cauta*, black-browed *T. melanophrys*, Atlantic yellow-nosed *T. chlororhynchos* 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 tRFMOs. 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. At 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.

Further reading

da Silva C, Winker H, Parker D, Wilke CG, Lamberth SJ, Kerwath SE. 2018. Update and review of the NPOA for Sharks South Africa. *Indian Ocean Tuna Commission, 14th Working Party on Ecosystems and Bycatch, 10–14 September 2018, Cape Town, South Africa*. IOTC-2018WPEB14-11_Rev1.

da Silva C, Parker D, Kerwath S. 2021. Standardization of blue shark *Prionace glauca* catch rates of the Japanese-flagged component of the South African large pelagic longline fleet based on observer records. *Indian Ocean Tuna Commission, 17th Working Party on Ecosystems and Bycatch, 12–14 April 2021, online.* IOTC-2021-WPEB17(DP)-11.

Edwards CTT, Peatman T, Goad D, Webber DN. 2023. Update to the risk assessment for New Zealand seabirds. New Zealand Aquatic Environment and Biodiversity Report No. 314. Wellington, New Zealand: Ministry for Primary Industries.

Farley J, Robertson S, Norman S, Parker D, Eveson P, Luque P, Krusic- Golub K, Fraile I, Zudaire I, Artetxe I, Murua H, Marsac F, Merino G. 2021. Preliminary age and growth of swordfish (*Xiphias gladius*) in the western Indian Ocean. *Indian Ocean Tuna Commission, 19th Working Party on Billfishes, 13–16 September 2021, online*. IOTC-2021-WPB19-21.

Farley J, Krusic-Golub K, Eveson P, Luque PL, Clear N, Fraile I, Artetxe-Arrate I, Zudaire I, Vidot A, Govinden R, Ebrahim A, Ahusan M, Romanov E, Shahid U, Chassot E, Bodin N, Parker D, Murua H, Marsac F, Merino G. 2021. Estimating the age and growth of yellowfin tuna (*Thunnus albacares*) in the Indian Ocean from counts of daily and annual increments in otoliths. *Indian Ocean Tuna Commission, Working Party on Tropical Tunas, 25–30 October 2021, online*. IOTC-2021-WPTT23-05_Rev1.

Jimenez S, Domingo A, Winker H, Parker D, Gianuca D, Neves T, Coelho R, Kerwath S. 2020. Towards mitigation of seabird by-catch in longline pelagic fisheries: Large-scale effectiveness of night setting and Tori lines across multiple pelagic longline fleets. *Biological Conservation* 247: article 108642

Mourato B, Kikuchi E, Gustavo Cardoso L, Sant'Ana R, Parker D. 2022. Preliminary stock assessment of South Atlantic swordfish (*Xiphias gladius*) using Stock Synthesis model. *Collective Volume of Scientific Papers of ICCAT*: SCRS/2022/116.

Parker D, Kikuchi E, Mourato B. 2022. Assessment of the South Atlantic swordfish (*Xiphias gladius*) stock using JABBA. *Collective Volume of Scientific Papers of ICCAT*: SCRS/2022/117.

Parker D. 2022. Standardised catch rates of swordfish (*Xiphias gladius*) for the South African pelagic longline fishery (2004–2020). *Collective Volume of Scientific Papers of ICCAT* 79: 211–224.

Parker D. 2021. Assessment of the Indian Ocean black marlin (*Makaira indica*) stock using JABBA. *Indian Ocean Tuna Commission, 19th Working Party on Billfishes, 13–16 September 2021, online*. IOTC-2021-WPB19-18.

Parker D. 2021. Assessment of the Indian Ocean striped marlin (*Tetrapturus audax*) stock using JABBA. *Indian Ocean Tuna Commission, 19th Working Party on Billfishes, 13–16 September 2021, online*. IOTC-2021-WPB19-15.

Parker D. 2020. Preliminary stock assessment of the Indian Ocean Swordfish (*Xiphias gladius*) using the Bayesian state-space surplus production model JABBA. *Indian Ocean Tuna Commission,18th Working Party on Billfishes, 2–4 September 2020, online*. IOTC-2020-WPB18-18.

Rice J, Parker D. 2021. Stock assessment of blue shark (*Prionace glauca*) in the Indian Ocean using Just Another Bayesian Biomass Assessment (JABBA). *Indian Ocean Tuna Commission,17th Working Party on Ecosystems and Bycatch, 6–10 September 2021*. IOTC–2021–WPEB17(AS)-15.

West W, Kerwath SE, da Silva C, Meyer MR, Mketsu Q. 2024. South Africa's annual report. *Commission for the Conservation of Southern Bluefin Tuna, Ecologically Related Species Working Group (ERSWG), June 2024, Tokyo, Japan*. CCSBT-ERS/2405/Annual report–South Africa. Available at https://www.ccsbt.org/en/content/erswg-15-annual-report-south-africa.

West W, Kerwath SE, da Silva C, Meyer MR, Mketsu Q. 2024. South African national report. *Commission for the Conservation of Southern Bluefin Tuna (CCSBT)*, Extended Scientific Committee, September 2024, Taiwan. CCSBT-ESC/2408/SBT Fisheries–South Africa. Available at https://www.ccsbt.org/system/files/2024-08/ESC29_SBTFisheries_ZA_rev1.pdf.

West W, da Silva C, Mketsu Q, Meyer MR, Kerwath SE. 2024. Annual report of South Africa. *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), Madrid, 23–27 September 2024*. Available at https://www.iccat.int/Documents/BienRep/REP_EN_22-23-II-2.pdf.

West W, da Silva C, Mketsu Q, Meyer MR, Kerwath SE. 2024. South African national report. *Indian Ocean Tuna Commission, 24th Scientific Committee, 2–6 December 2024, Cape Town*. IOTC-2024-SC27-NR24. Available at https://iotc.org/documents/south-africa-national-report-2024.

Winker H, Carvalho F, Kapur M. 2018. JABBA: Just Another Bayesian Biomass Assessment. *Fisheries Research* 204: 277–288.

Table 22: Detailed status of large pelagic resources and allocations by tRFMOs

	Albacore		Yellowfin		Bigeye		Swordfish		Southern bluefin tuna
	Atlantic Ocean	Indian Ocean	Atlantic Ocean	Indian Ocean	Atlantic Ocean	Indian Ocean	Atlantic Ocean	Indian Ocean	Atlantic and Indian Ocean
Stock assessment	2020	2022	2024	2024	2021	2022	2022	2023	2023
MSY	27 264 t (23 734–31 567)	45 000 t (35 000–55 000)	121 661 t (107 485–188 456)	374 000 t (350 000–411 000)	86 833 t (72 210–106 440)	96 000 t (83 000–108 000)	11 481 t (9 793–13 265)	30 000 t (26 000–33 000)	33 207 t (31 471–34 564 t)
Total yield for stock	15 640 t (2019)	34 789 t (2021)	148 211 t (2022)	400 950 t (2023)	57 486 t (2020)	94 803 t (2021)	9 454 t (2021)	23 597 t (2022)	17 139 t (2021)
tRFMO TAC	28 000 t (Recommendation 22-06)	–	110 000 t (Proposal PA1-505F adopted)	–	73 000 t (Proposal PA1-505F adopted)	80 583 t	10 000 t	–	20 647 t (2018–2020)
Quota allocation to South Africa	5 280t	–	–	2 000 t (catch limit)	1 000 t (catch limit)	2 000 t (catch limit)	1 201.2 t (incl. 200.2 t underage)	–	527 t
Relative biomass	$B_{current}/B_{MSY}$ = 1.58 (1.14–2.05)	SB_{2020}/SB_{MSY} = 1.56 (0.89–2.24)	SSB_{2022}/SSB_{MSY} = 1.37 (0.91–2.15)	SB_{2023}/SB_{MSY} = 1.32 (1.00–1.59)	SSB_{2019}/SSB_{MSY} = 0.94 (0.71–1.37)	SB_{2021}/SB_{MSY} = 0.9 (0.75–1.05)	B_{2020}/B_{MSY} = 0.77 (0.53–1.11)	SSB_{2021}/SSB_{MSY} = 1.39 (1.01–1.77)	TRO_{2023}/TRO_{MSY} = 0.85 (0.61–1.29)
Relative fishing mortality	$F_{current}/F_{MSY}$ = 0.40 (0.28–0.59)	F_{2020}/F_{MSY} = 0.68 (0.42–0.94)	F_{2022}/F_{MSY} = 0.89 (0.4–1.46)	F_{2023}/F_{MSY} = 0.75 (0.58–1.01)	F_{2019}/F_{MSY} = 1.00 (0.63–1.35)	F_{2018}/F_{MSY} = 1.43 (1.10–1.77)	F_{2020}/F_{MSY} = 1.03 (0.67–1.51)	F_{2021}/F_{MSY} = 0.60 (0.43–0.77)	F_{2023}/F_{MSY} = 0.46 (0.34–0.65)

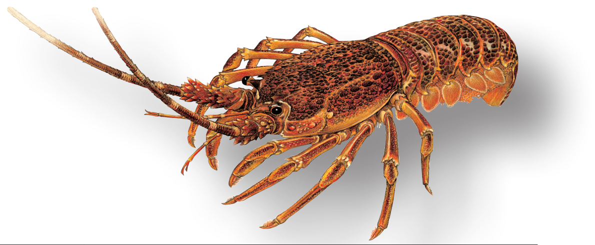
Useful statistics

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 2023

Year	Bigeye tuna	Yellowfin tuna	Albacore tuna	Southern bluefin tuna	Swordfish	Shortfin mako shark	Blue shark	Number of active vessels	
								Domestic *	Foreign-flagged
2005	1 076.9	1 597.4	166.8	27.6	475.2	44.7	86.7	9	12
2006	137.6	337.3	108.8	9.7	376.2	16.2	30.5	15	0
2007	676.7	1 086.0	194.9	49.1	518.4	48.5	131.0	17	12
2008	640.1	629.7	300.7	44.2	462.7	49.4	142.5	11	13
2009	765.0	1 096.0	273.5	30.5	439.6	65.1	85.5	15	9
2010	935.4	1 257.1	145.5	34.8	614.4	67.0	99.2	16	7
2011	906.5	1 184.5	339.1	48.1	584.2	481.0	451.3	22	9
2012	822.1	606.9	248.2	78.8	445.7	313.8	332.6	19	8
2013	884.3	1 099.8	293.7	51.0	476.0	481.5	349.0	17	7
2014	620.9	544.4	129.1	37.1	255.2	618.1	647.0	17	3
2015	444.6	629.5	155.7	42.1	418.0	774.6	529.5	18	3
2016	334.7	495.5	84.5	44.0	306.7	869.5	526.6	17	3
2017	508.0	420.1	174.8	114.6	256.2	750.6	549.3	19	3
2018	475.1	485.4	237.8	209.9	316.1	617.2	603.2	23	3
2019	671.5	680.6	357.1	173.7	561.8	201.1	225.3	20	3
2020	409.1	400.3	260.8	102.9	313.9	185.5	64.0	19	0
2021	577.2	569.3	376.4	135.0	462.9	85.5	97.1	19	1
2022	674.0	517.0	223.7	145.6	596.2	98.7	65.2	19	1
2023	740.6	846.7	434.0	108.8	839.4	128.2	25.3	23	0

Year	Albacore	Yellowfin tuna	Snoek	Yellowtail	Skipjack tuna	Bigeye tuna	Southern bluefin tuna	Number of active vessels
2005	3 149.4	975	193.4	13.8	0.9	2	0	132
2006	2 526.6	978.9	118	1.4	0	1.2	0	136
2007	3 682.4	948.5	79.5	19.2	0.2	23.2	0	151
2008	2 190.8	352.1	313.7	13	3.6	25.9	0	142
2009	4 795.3	223.8	186.2	33.4	4	42.8	0.7	152
2010	4 272.8	177.2	476.8	41.2	1.6	14.2	0	145
2011	3 346.8	629.5	163.8	26.9	5.4	40.1	0	145
2012	3 619.6	165.6	180.1	27.5	8	14.9	0	141
2013	3 475.2	373.9	616.8	18.2	2.6	142.2	0	131
2014	3 631.1	1 348.5	288.2	11.5	4.6	49.8	0	111
2015	3 965.1	884.2	332.6	199.3	2.2	57.2	0	117
2016	2 036.9	627.4	219.3	12	1.6	10.5	2.3	126
2017	1 791.7	240.7	443.2	21.3	0.7	24.3	0.1	128
2018	2 513.2	266.1	789.1	10.2	2.1	22.8	2.6	125
2019	4 323.2	458.6	871.8	9.6	3	98.4	1.6	126
2020	4 411	541.8	1 372.9	36.4	1.2	82	2	121
2021	3 381.5	217.8	554.9	7.8	1.6	117.1	1.4	130
2022	5 166.1	854	396.4	8.7	2.3	121.6	0.8	128
2023	2 339.6	1 468.9	300.6	157.8	5.3	159	0.5	117

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 100 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 and by trap vessels in the offshore region. The resource is also harvested by recreational 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 73). As a result, the fishery on the West Coast, which historically landed the bulk (60%) of the lobster catch, now lands only about 20% 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 the 21st Century.

From about 2014, there was an almost continuous decline in legal catches, reaching 391 t in 2024 (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 73, 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, C and F are exclusively harvested by fishers operating with hoop nets in the nearshore region whereas the resource in Zones B, D (except for Area 7 which is an offshore area only) and E have both a nearshore hoop-net and an offshore trap sector.

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

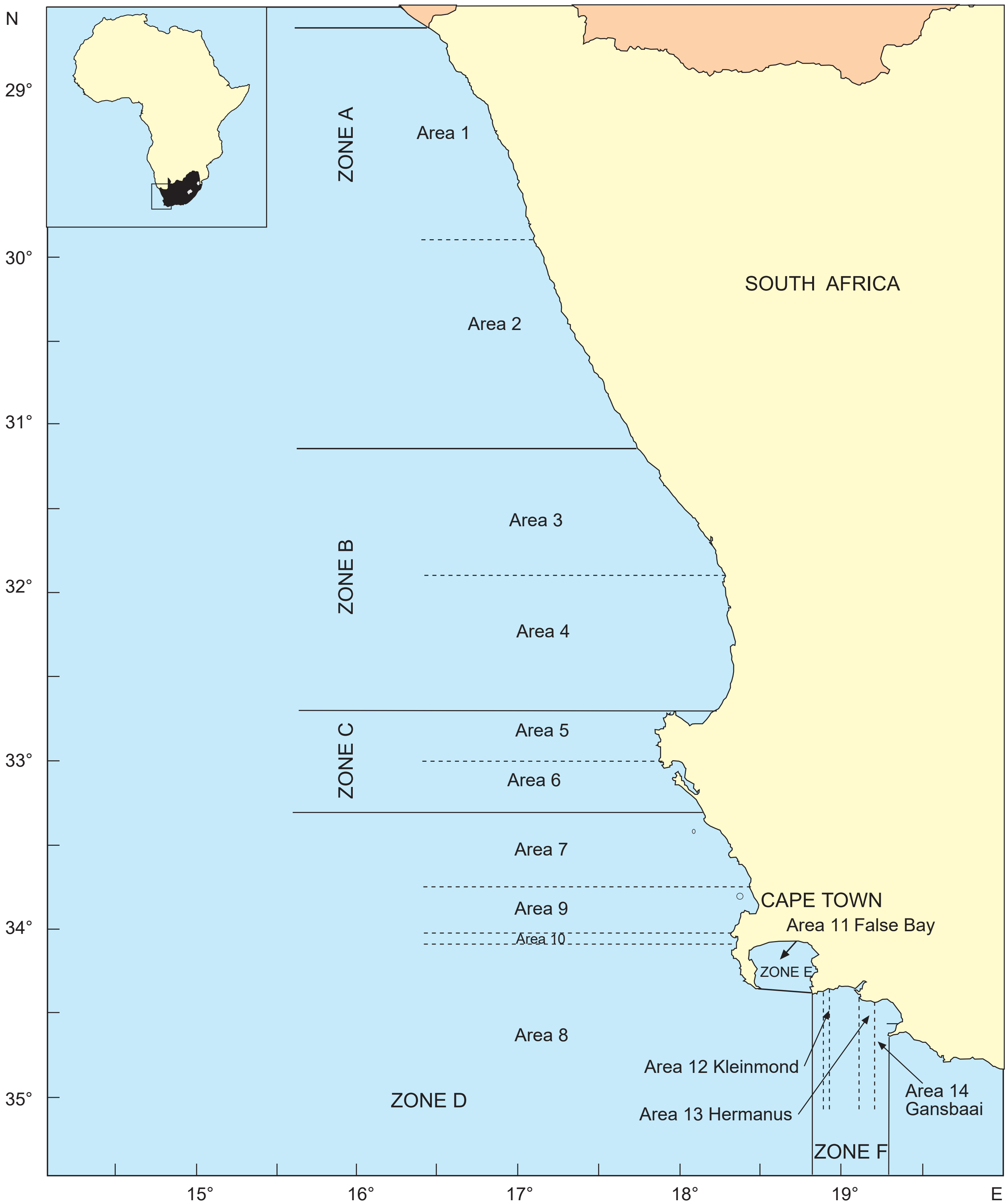


Figure 73: West Coast rock lobster fishing zones and areas. The five super-areas are: areas 1–2, corresponding to zone A; areas 3–4, to zone B; areas 5–6, to zone C; area 7, being the northernmost area within zone D; and area 8+, comprising area 8 of zone D as well as zones E and F

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 more-healthy levels (defined as those 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 73). 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. Such "Exceptional Circumstances" were recognised to have occurred several times in the most recent decade due to worse-than-expected resource performance. This necessitated the OMP being replaced by annual consideration of constant-catch projections based on best assessments, as long as these projections showed some recovery, as the basis to set TACs. However, as time progressed, these assessments indicated continued decline of resource abundance, which in turn necessitated continued reductions in the TAC, though these were recommended to be phased over time to ameliorate the associated negative socio-economic implications. It is noteworthy that in many years 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 ameliorate latent capacity and hence assist in reducing the unacceptably high levels of poaching. This was extended to four months in 2018. In 2023, despite the SWG recommendation of four months, a fishing season of five months was finally granted.

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.

During the 2023/24 season, all relevant data were collected and analysed. The 2023 assessment had lacked a full dataset for the analysis of somatic growth because no tagging took place in 2022 (due to administrative problems). Tagging was resumed in 2023 and therefore a complete dataset from returned lobsters with tags will be available to use for growth determination in 2024. Most recently, a TAC of 460 t was recommended and instituted for the 2023/24 season.

Research and monitoring

Research and monitoring of West Coast rock lobster continues to provide and improve essential data inputs for: (i) assessing the sustainability of the stock; (ii) its management; and (iii) setting annual catch limits for the fishery. Indices of abundance such as catch per unit effort (CPUE) derived from the fishery-independent monitoring survey (FIMS) and commercial catch statistics (Figures 74 and 75), annual assessments of somatic growth rate (Figure 76), 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 by interim relief/small scale 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 are 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 reproduction in females is also under investigation, to formulate energy-

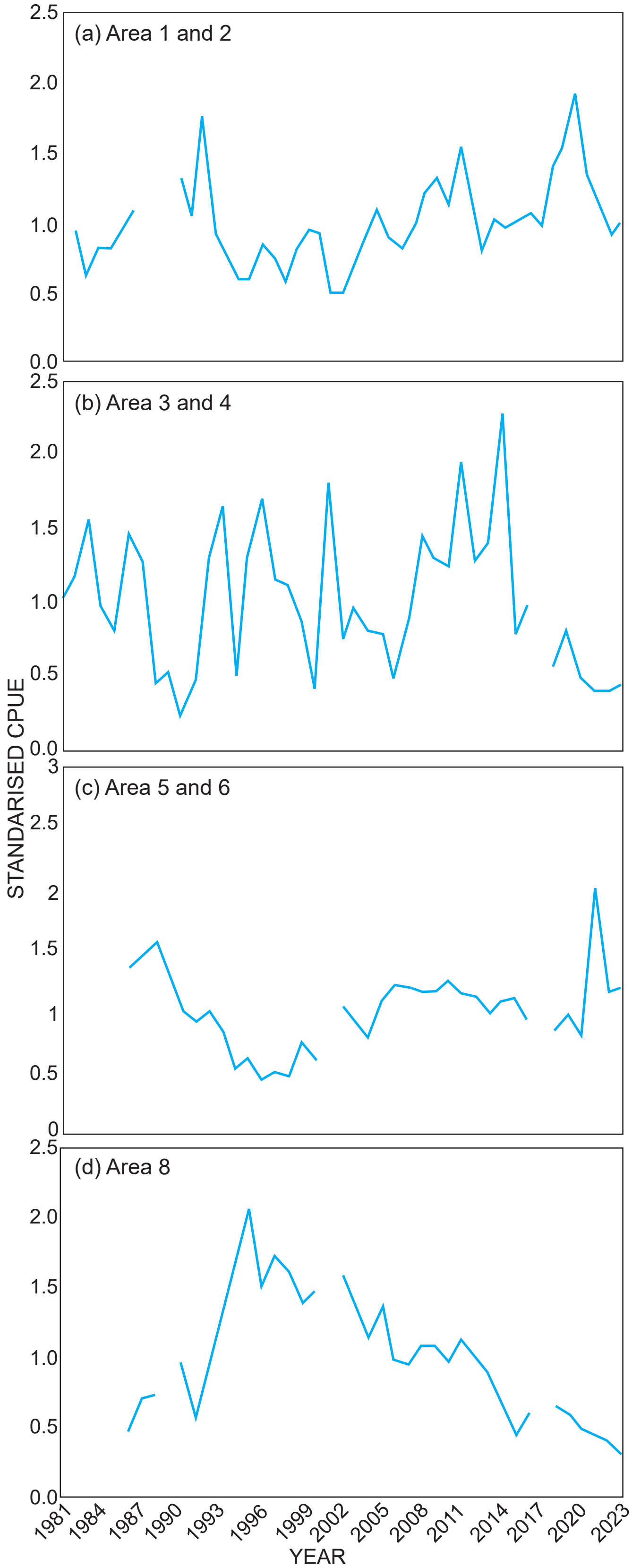


Figure 74: Standardised hoopnet CPUE indices per area (each index has been standardised to its mean)

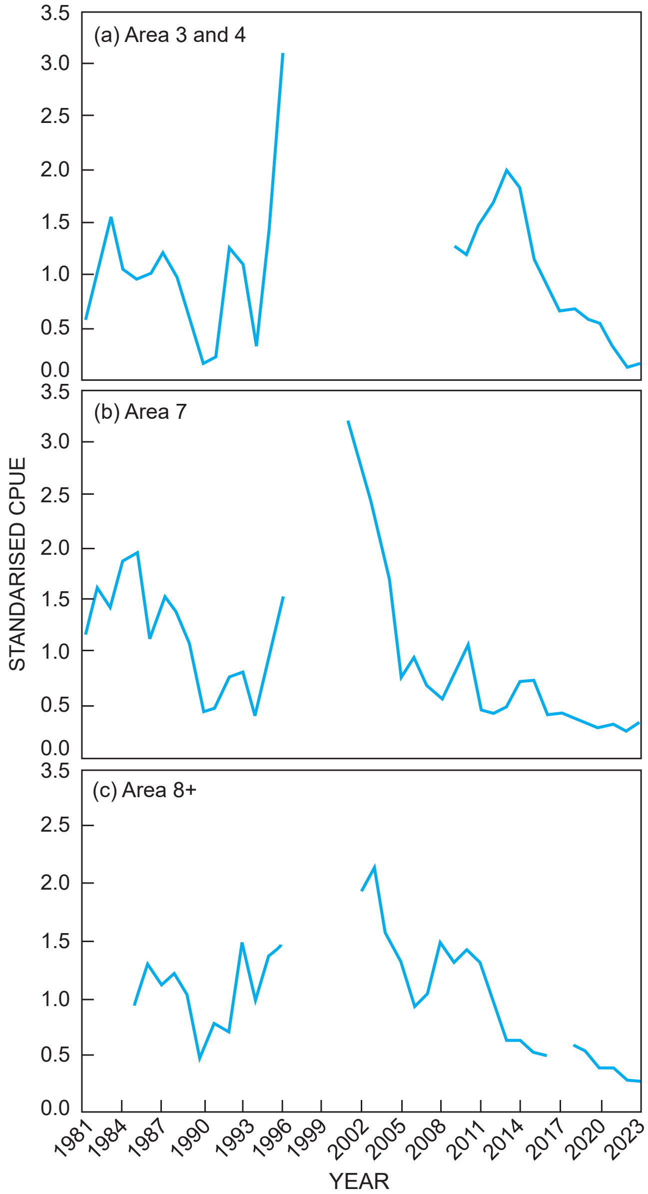


Figure 75: Standardised trap CPUE indices per area (each index has been normalised to its mean)

growth-reproduction conversion factors for predicting future trends in growth and reproductive potential.

Current status

The West Coast rock lobster resource is seriously 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 most recent years, the allocated TAC was higher than that rec-

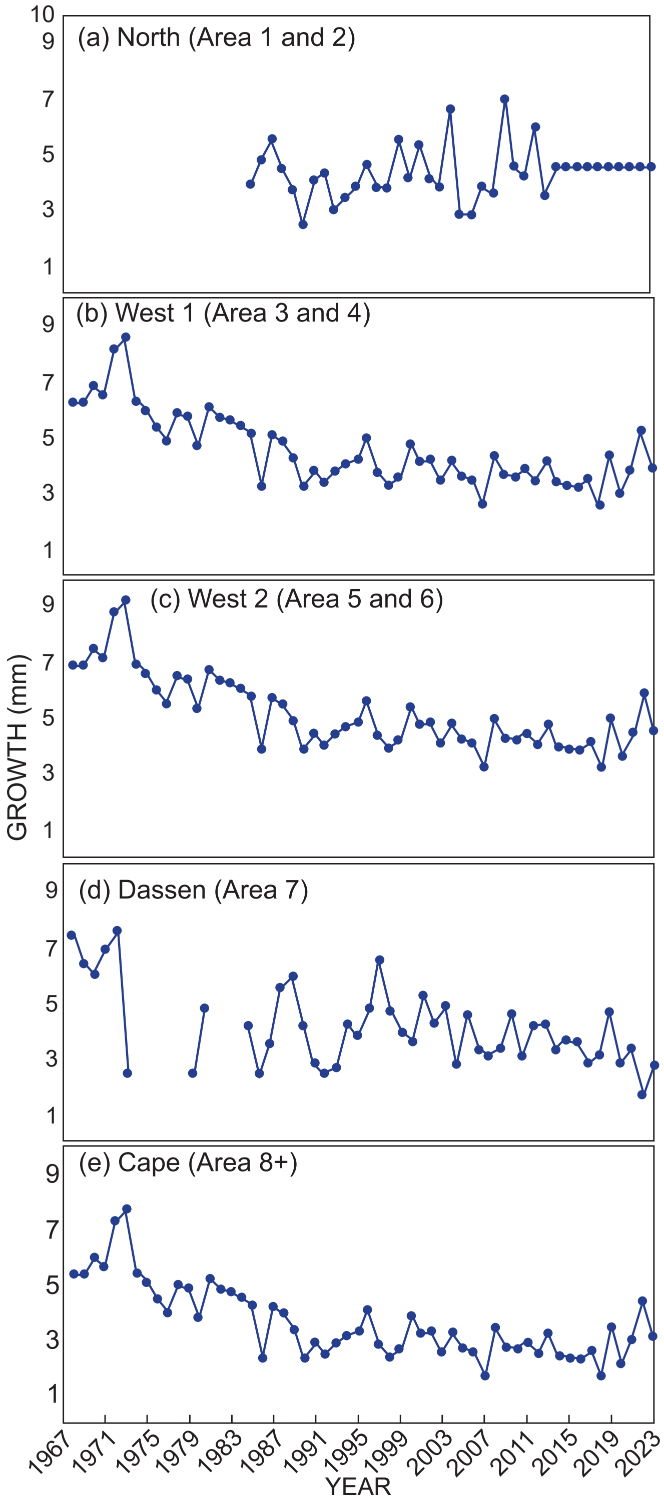


Figure 76: Somatic growth trends per area

ommended 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 concluded at the end of September, with a concomitant higher risk of whale entanglements. Additionally, an awareness programme has been introduced to encourage lobster-trap fishers to avoid leaving excess trap rope untied during fishing and to use weighted dropper lines. Both initiatives have shown success.

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 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 for 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 West Coast rock lobster are physiologically well-adapted to the highly dynamic nature of the Benguela Current large marine ecosystem (BCLME) 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 West Coast rock lobster 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, despite a slight delay in embryonic development. Moreover, electron-microscopic 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 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 West Coast rock lobsterlarval biology, ecology and behaviour complicates speculation on the possible impacts on this phase of the life cycle.

Further reading

Augustyn J, Cockcroft AC, Kerwath S, Lamberth S, Githaiga-Mwicigi J, Pitcher G, Roberts M, van der Lingen C, Auerswald L. 2018. South Africa. In: Phillips B, Perez-Ramirez M (eds), *Climate change impacts on fisheries and aquaculture: a global analysis*. Chichester, UK: Wiley and Sons. pp 479–522.

Eggers JM, Cochrane KL, Sauer WHH. 2022. Estimating the economic income and social contributions derived from the South African west coast rock lobster fishery *African Journal of Marine Science* 44: 255–269.

Eggers JM, Johnston SJ, Cochrane KL. 2024. The ecological and socioeconomic implications of future total allowable catch decisions and illegal fishing scenarios for South Africa's West Coast rock lobster fishery. *Marine Policy* 170: article 106399.

Cockcroft AC, Payne AIL. 1999. A cautious fisheries management policy in South Africa: the fisheries for rock lobster. *Marine Policy* 23: 587–600.

Johnston SJ, Butterworth DS. 2005. Evolution of operational management procedures for the South African West Coast rock lobster (*Jasus lalandii*) fishery. *New Zealand Journal of Marine and Freshwater Research* 39: 687–702.

Melville-Smith R, van Sittert L. 2005. Historical commercial West Coast rock lobster *Jasus lalandii* landings in South African waters. *African Journal of Marine Science* 27: 33–44.

Useful statistics

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

Season	Global TAC	TAC (t)					Total catch[3]
		Offshore		Nearshore			
		Commercial offshore allocation	Interim relief/ small-scale offshore	Commercial nearshore allocation	Interim relief/ small-scale nearshore	Recreational	
1998/99	2 300	1 780				258	2 051
1999/2000	2 156	1 720			145	291	2 152
2000/01	2 018	1 614			230	174	2 154
2001/02	2 353	2 151			[1]	202	2 410
2002/03	2 957	2 713			[1]	244	2 706
2003/04	3 336	2 422		594	[1]	320	3 258
2004/05	3 527	2 614		593	[1]	320	3 222
2005/06	3 174	2 294		560	[1]	320	2 291
2006/07	2 857	1 997		560	[2]	300	3 366
2007/08	2 571	1 754		560	[2]	257	2 298
2008/09	2 340	1 632		451	[2]	257	2 483
2009/10	2 393	1 632		451	180	129	2 519
2010/11	2 286	1 528		451	200	107	2 208
2011/12	2 426	1 541		451	251	183	2 275
2012/13	2 276	1 391		451	251	183	2 308
2013/14	2 167	1 356		451	276	83.5	1 891
2014/15	1 800.85	1 120.25		376.1	235.3	69.2	1 688
2015/16	1 924.08	1 243.48		376.1	235.3	69.2	1 524.4
2016/17	1 924.08	1 204.48		376.1	274.3[4]	69.2	1 564.3
2017/18	1 924.08	994.784	248.7	305.7	305.7[4]	69.2	1 355.7
2018/19	1 084	563.91	140.83	170.25	170.25[4]	38.76	908
2019/20	1 084	563.91	140.83	170.25	170.25[4]	38.76	898
2020/21	837	435.9	108.97	131	131	30.1	719
2021/22	700	351.6	87.9	119.5	119.5	21.6	532
2022/23	550	276.3	61.1	93.9	93.9	16.9	378
2023/24	460	231.1	57.8	78.6	78.6	14.1	391

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

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

2022

This document lists the scientific output of the Branch: Fisheries Management for 2022, arranged by output category. Figures in brackets represent the output for the previous two years, 2021 and 2020, respectively, and are included for comparison. After two years of restrictions on travel and in-person meetings as a result of the COVID-19 pandemic, 2022 saw a return to normal movement, which allowed those categories of output that had been most seriously affected to also return to normal. In the category 'peer-reviewed publications' there were 28 (37, 56) papers. There were 11 (12, 11) documents in the category 'theses/dissertations/tertiary projects', all of which were DFFE-supervised or co-supervised. There were 29 (24, 20) documents in the category 'book chapters, published reports and popular articles', 18 of which were species profiles in a WILDTRUST special publication entitled "*Species profiles of South African sharks, rays and chimaeras,* vol. 1. *Threatened and endemic species*". There were 71 (11, 40) 'contributions to symposia and conferences, and public presentations'. This category of output showed a dramatic post-COVID recovery. The most numerous contributions in 2022 were presentations made at the 17th Southern African Marine Science Symposium (29) and the 14th Conference of the Aquaculture Association of Southern Africa (15). There were 57 (22, 17) 'contributions to workshops, short courses, and management and scientific bodies, and unpublished technical reports', another category that showed a return to normal after being severely affected by the pandemic. Of these, 26 were contributions to activities of the Indian Ocean Tuna Commission (IOTC), 10 to activities of the International Commission for the Conservation of Atlantic Tunas (ICCAT) and 5 to activities of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). Finally, there were 64 (51, 55) 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.

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

Amosu AO, Robertson-Andersson DV, Maneveldt GW, Knapp JL, **Auerswald L**, Bolton JJ. 2022. Environmental response and pH tolerance of induced CO2 in *Ulva rigida* C. Agardh, 1823 (Chlorophyta) under controlled conditions. *Journal of Animal and Plant Sciences* 32: 1605–1615.

Assis J, Neiva J, Bolton JJ, **Rothman MD**, Gouveia L, Paulino C, Mohdnasir H, Anderson RJ, Reddy MM, Kandjengo L, Kreiner A. 2022. Ocean currents shape the genetic structure of a kelp in southwestern Africa. *Journal of Biogeography* 49: 822–835.

Becker FK, **Shabangu FW**, Gridley T, Wittmer HU, Marsland S. 2022. Sounding out a continent: seven decades of bio-acoustics research in Africa. *Bioacoustics* 31: 646–667.

Brink-Hull M, **Cyrus MD**, **Macey BM**, Rhode C, Hull KL, Roodt-Wilding RR. 2022. Dietary effects on the reproductive performance of the sea urchin *Tripneustes gratilla* I: Implications for broodstock conditioning. *Aquaculture* 552: article 738035.

Brink-Hull M, **Cyrus MD**, **Macey BM**, Rhode C, Hull KL, Roodt-Wilding RR. 2022. Dietary effects on the reproductive performance of the sea urchin *Tripneustes gratilla* II: Implications for offspring performance. *Aquaculture* 552: article 738038.

Daly R, Jordaan GL, **Parker** D, Cliff G, Nkabi N, Kyle R, Fennessy ST, Mann BQ. 2022. Movement patterns and catch trends of the diamond ray *Gymnura natalensis* (Dasyatidae) in South African waters. *African Journal of Marine Science* 44: 35–48.

Haupt TM, Ceasar J, Stefanoudis P, von der Meden C, Payne RP, Adams LA, *Anders DR*, Bernard AT, Coetzer W, Florence WK, *Janson LA*, *Johnson AS*, Juby R, Kock AA, Langenkämper D, Nadjim AM, **Parker D**, *Samaai T*, **Snyders LB**, *Upfold L*, **van der Heever GM**, Williams LL. 2022. The WIO Regional Benthic Imagery Workshop: lessons from past IIOE-2 expeditions. *Research Ideas and Outcomes* 8: e81563.

Holness SD, Harris LR, Chalmers R, De Vos D, Goodall V, Truter H, Oosthuizen A, Bernard AT, Cowley PD, **da Silva C**, Dicken M. 2022. Using systematic conservation planning to align priority areas for biodiversity and nature-based activities in marine spatial planning: a real-world application in contested marine space. *Biological Conservation* 271: article 109574.

Kapula VK, Ndjaula HON, Schulze M, **Durholtz D**, Japp D, **Singh L**, Matthee CA, von der Heyden S, Henriques R. 2022. Genetic assessment of seasonal alongshore migration in *Merluccius capensis* in the Benguela region. *Fisheries Research* 250: article 106293.

Kock AA, Lombard AT, Daly R, Goodall V, Meÿer M, Johnson R, Fischer C, Koen P, Irion D, Gennari E, Towner A, Jewell OJD, **da Silva C**, Dicken ML, Smale MJ, Photopoulou T. 2022. Sex and size influence the spatiotemporal distribution of white sharks, with implications for interactions with fisheries and spatial management in the southwest Indian Ocean. *Frontiers in Marine Science* 9: article 811985.

Letsheleha IS, **Shabangu FW**, Farrell D, Andrew RK, la Grange PL, Findlay KP. 2022. Year-round acoustic monitoring of Antarctic blue and fin whales in relation to environmental conditions off the west coast of South Africa. *Marine Biology* 169: article 41.

Madibana MJ, **Fouché CH**, Davids JJ, Mthembu ST, Motubatse

MH, Poni Z, Thomas AE, Nyengule O, Nemakhavhani LR. 2022. Chemical and biophysical indices of soybean meal fermented with *Lactobacillus acidophilus* and *Lactobacillus cereus*-containing products. *Agricultural Science and Technology* 14: 32–39.

Marco HG, **Auerswald L**, Matumba TG, Gäde G. 2022. Distribution of astaxanthin in the spiny lobster *Jasus lalandii*: trends during biological cycles. *Invertebrate Reproduction and Development* 66: 120–134.

Mbokane EM, **Fouche CH**. 2022. The potential use of acid fermented one-day old male chick meat in *Oreochromis mossambicus* diets – its effect on growth performance, digestive enzymes and gut health. *Aquaculture* 554: article 738110.

Mbokane EM, **Mbokane LM**, **Fouche CH**. 2022. The effect of fishmeal replacement with acid-fermented chicken silage on growth, digestive enzyme activity and histology of the intestine and liver of juvenile Mozambique tilapia (*Oreochromis mossambicus*). *Aquaculture International* 30: 1–22.

Mbokane EM, Moyo NAG. 2022. Use of medicinal plants as feed additives in the diets of Mozambique tilapia (*Oreochromis mossambicus*) and the African sharptooth catfish (*Clarias gariepinus*) in Southern Africa. *Frontiers in Veterinary Science* 9: article 1072369.

Nyuliwe CT, Mlambo V, **Madibana MJ**, Wokadala OC, Mwanza M. 2022. Partial substitution of fishmeal with mopane worm meal in dusky kob fingerling (*Argyrosomus japonicus*) diets: feed utilization, digestive enzyme activity, blood parameters, and growth performance. *Aquaculture Journal* 2: 59–71.

Pons M, Watson JT, Ovando D, Andraka S, Brodie S, Domingo A, …, **Kerwath S[E]**… et al. 2022. Trade-offs between bycatch and target catches in static versus dynamic fishery closures. *Proceedings of the National Academy of Sciences of the United States of America* 119: e2114508119.

Ramirez F, Shannon L, **van der Lingen CD**, Julia L, Steenbeek J, Coll M. 2022. Climate and fishing simultaneously impact small pelagic fish in the oceans around the southernmost tip of Africa. *Frontiers in Marine Science* 9: article 1031784.

Samaai T, Turner TL, Kara J, **Yemane D**, Ngwakum BB, Payne RP, **Kerwath S[E]**. 2022. Confirmation of the southern African distribution of the marine sponge *Hymeniacidon perlevis* (Montagu, 1814) in the context of its global dispersal. *PeerJ* 10: e14388.

Seakamela SM, Kotze PGH, Gumede NC, Sibiya N, **Shabangu FW**, *McCue SA*. 2022. Finally seen: a rare sighting of Antarctic blue whale cow–calf pair off the west coast of South Africa. *Polar Biology* 45: 1715–1721.

Shabangu FW, Hofmeyr GJG, Probert R, Connan M, Buhrmann CA, Gridley T. 2022. In-air acoustic repertoire and associated behaviour of wild juvenile crabeater seals during rehabilitation. *Bioacoustics* 32: 261–283.

Shabangu FW, Kowarski KA. 2022. The beat goes on: humpback whale song seasonality in Antarctic and South African waters. *Frontiers in Marine Science* 9: article 827324.

Shabangu FW, **Yemane D**, Best G, Estabrook BJ. 2022. Acoustic detectability of whales amidst underwater noise off the west coast of South Africa. *Marine Pollution Bulletin* 184: article 114122.

Simon CA, du Toit AN, **Lamberth SJ**, Branch GM. 2022. Standardising English and Afrikaans common names for polychaetes harvested as bait in South Africa. *African Zoology* 57: 75–89.

van Niekerk L, **Lamberth SJ,** James NC, Taljaard S, Adams JB, Theron AK, Krug M. 2022. The vulnerability of South African estuaries to climate change: a review and synthesis. *Diversity* 14: article 697.

van Niekerk L, Taljaard S, **Lamberth SJ**, Adams JB, Weerts SP, MacKay CF. 2022. Disaggregation and assessment of estuarine pressures at the country-level to better inform management and resource protection – the South African experience*. African Journal of Aquatic Science* 47: 127–148.

van Staden M, Ebert DA, **da Silva C**, Bester-van der Merwe AE. 2022. Comparative analyses of the complete mitochondrial genomes of two southern African endemic guitarfish, *Acroteriobatus annulatus* and *A. blochii*. *International Journal of Biological Macromolecules* 223: 1094–1106.

Theses/Dissertations/Tertiary Projects

Nobuhle M. 2022. Description of the reproductive cycle of the clam *Venerupis corrugatus* from Langebaan Lagoon. Ad-vanced diploma, Cape Peninsula University of Technology, South Africa. Supervisors: **Arendse DCZ**, Sparks C.

Bennett M. 2022. Determining larval settlement, post-settlement and weaning substrates and regimes for the sea urchin *Tripneustes gratilla* in intensive aquaculture. MSc thesis, University of Cape Town, South Africa. Supervisors: Bolton JJ, **Cyrus MD**, **Macey BM**.

Cloete A. 2022. Growth and survival of juvenile abalone *Haliotis midae* fed diets supplemented with faecal matter from the Cape Sea urchin *Parechinus angulosus*. BSc Hons thesis, University of Cape Town, South Africa. Supervisors: Bolton JJ, **Cyrus MD**, Brink-Hull M, **Macey BM**.

Daniels R. 2022. Acoustic ecology and occurrence of killer whales at sub-Antarctic Marion Island. BSc Hons thesis, University of Cape Town, South Africa. Supervisors: *Lamont T*, **Shabangu FW**.

Galdardt M. 2022. The potential for increasing the recirculation rate in a commercial integrated abalone-*Ulva* aquaculture system. BSc Hons thesis, University of Cape Town, South Africa. Supervisors: Bolton JJ, **Cyrus MD**, Brink-Hull M, **Macey BM**.

Hill F. 2022. Optimal water treatment for kelp spore settlement and juvenile development. BSc Hons thesis, University of Cape Town, South Africa. Supervisors: Bolton JJ, **Cyrus MD**, Brink-Hull M, **Macey BM**.

Mdhluvu R. 2022. Growth performance, blood parameters and meat quality in dusky kob (*Argyrosomus japonicus*, Sciaenidae) offered crocodile meal as a replacement for the fishmeal. MSc thesis, University of Mpumalanga, South Africa. Supervisors: Mlambo V**,**

Madibana MJ.
Munian A. 2022. The search for biomarkers in the growth prediction of the West Coast rock lobster, *Jasus lalandii*. PhD thesis, Stellenbosch University, South Africa. Super-visors: **Auerswald L, Cockcroft AC**, Hoffman LC.
Purdon J. 2022. Cetacean distribution and anthropogenic threats in South African waters to inform conservation in an expanding economy. PhD thesis, University of Pretoria, South Africa. Supervisors: Somers MJ, Findlay K, **Shabangu FW**, Pienaar M.
Torr M. 2022. Investigating relationships between SST patterns and small pelagic fish distributions around the South African coast. BSc Hons thesis, University of Cape Town. Supervisors: *Lamont T*, **van der Lingen CD**.
Werner T. 2022. Growth and survival of the South African Cape sea urchin *Parechinus angulosus* under chronic hypercapnia. BSc thesis, Heinrich-Heine-University Düsseldorf, Germany. Supervisors: Bridges C, **Auerswald L**.

Book Chapters, Published Reports and Popular Articles

Becker FK, **Shabangu FW**, Gridley T, Wittmer HU, Marsland S. 2022. Eavesdropping on nature: why Africa needs more bioacoustics research. *The Conversation*. Available at https://theconversation.com/eavesdropping-on-nature-why-africa-needs-more-bioacoustics-research-175527.
Cliff G, **da Silva C**. 2022. *Centrophorus granulosus*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 33–37.
Cliff G, **da Silva C**. 2022. *Centrophorus moluccensis.* In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 38–41.
Cliff G, **da Silva C**. 2022. *Deania quadrispinosa*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 52–56.
Cliff G, **da Silva C**. 2022. *Echinorhinus brucus*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 22–26.
Cliff G, **da Silva C**. 2022. *Oxynotus centrina*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 61–65.
Cliff G, **da Silva C**. 2022. *Squalus acanthias*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 9–16.
Cliff G, **da Silva C**. 2022. *Alopias pelagicus*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 103–107.
Cliff G, **da Silva C**. 2022. *Alopias superciliosus*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 108–112.
Cliff G, **da Silva C**. 2022. *Alopias vulpinus*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 113–117.
Cliff G, **da Silva C**. 2022. *Mustelus mustelus*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 195–201.
Cliff G, **da Silva C**. 2022. *Rostroraja alba*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 395–399.
Cliff G, **da Silva C**, Ntuli S, Olbers JM, Voorhis R, Leslie R. 2022. *Chondrichthyans of South Africa: a compliance and law enforcement fisheries identification guide*. *Special Publication* No. 1. Durban, South Africa: WILDTRUST.
Cliff G, **Dudley SFJ**. 2022. *Carcharhinus plumbeus*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 287–292.
Cliff G, Fennessy S, **da Silva C**. 2022. *Dalatias licha*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 66–70.
Cliff G, Fennessy S, **da Silva C**. 2022. *Leucoraja wallacei*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 381–385.
da Silva C, Cliff G. 2022. *Centrophorus squamosus*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 42–46.
da Silva C, Cliff G. 2022. *Centroscymnus owstonii.* In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 57–60.
da Silva C, Cliff G. 2022. *Cruriraja durbanensis*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic species*. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 400–403.
da Silva C, Cliff G. 2022. *Raja ocellifera*. In: Cliff G, Olbers JM (eds), *Species profiles of South African sharks, rays and chimaeras*, vol. 1. *Threatened and endemic*

species. *Special Publication* No. 2. Durban, South Africa: WILDTRUST. pp 390–394.

Gabriel NN, Iitembu JA, Hasimuna OJ, Rashidian G, **Mbokane EM**, Moyo NAG, Hlophe-Ginindza SN. 2022. Medicinal plants: a perspective on their application in the African smallholder aquaculture farms. In: Rajeev RK (ed.), *Sustainable agri-culture and food security*. Patancheru, Telangana, India: Semi-Arid Tropics, International Crops Research Institute.

Mann BQ, **Lamberth SJ**. 2022. Human environment: small-scale fisheries. In: Goble BJ, van der Elst RP (eds), *State of the coast KwaZulu-Natal – a review of the state of the coast of KwaZulu-Natal*. Pietermaritzburg: KwaZulu-Natal Department of Economic Development, Tourism and Environmental Affairs. pp 131–134.

Mbokane EM, Mbokane LM, Motimele SS, Hlophe-Ginindza SN. 2022. Successes and challenges of catfish farming in the small-scale industry in Southern Africa. In: Atamanalp M (ed.), *Catfish – advances, technology, experiments*. London, UK: IntechOpen.

van Niekerk L, Adams JB, Taljaard S, Huizinga P, **Lamberth SJ**. 2022. Advancing mouth management practices in Groot Brak Estuary, South Africa. In: Slinger JH, Taljaard S, d'Hont F (eds), *Complex coastal systems – transdisciplinary learning on international case studies*. Delft, The Netherlands: Delft Academic Press. pp 89–104.

van Niekerk L, Sink K, **Lamberth SJ**, *Cilliers G*, Karenyi N, Mackay F, Mtetandaba A, *Nhleko J*, Porter S, Smith M, Taljaard S, Weerts S. 2022. Policy brief: freshwater flowing into the sea is not wasted. CSIR Report No. CSIR/SPLA/ SECO/IR/2022/0011/A prepared for South African National Biodiversity Institute (SANBI) by Council for Scientific and Industrial Research (CSIR) in collaboration with the Department of Forestry, Fisheries and the Environment, Oceanographic Research Institute, University of Cape Town and SANBI. Pretoria, South Africa: CSIR.

van Niekerk L, Taljaard S, Adams JB, **Lamberth SJ**, Lemley D, Weerts S. 2022. Evaluating the vulnerability of South Africa's estuarine lakes to climate change. In: Petja BM (ed.), *Climate change impacts on water resources: implications and practical responses in selected South African systems*. WRC Report No. SP 155/22. Pretoria, South Africa: Water Research Com-mission. pp 143–171.

van Niekerk L, Taljaard S, Adams JB, **Lamberth SJ**, Weerts SP, Lemley D, Riddin T. 2022. *Development of climate change mitigation and adaptation strategies for the estuarine lakes of South Africa*, vol. I. *A review of available information*. WRC Report No. TT 871/1/21. Pretoria, South Africa: Water Research Commission.

van Niekerk L, Taljaard S, Adams JB, **Lamberth SJ**, Weerts SP, Lotter D, Lemley D, Riddin T. 2022. *Development of climate change mitigation and adaptation strategies for the estuarine lakes of South Africa*, vol. II. *Climate change vulnerability assessment and recommended mitigation and adaptation strategies*. WRC Report No. TT 871/2/21. Pretoria, South Africa: Water Research Commission.

van Niekerk L, Taljaard S, Adams JB, **Lamberth SJ**, Weerts SP, Lotter D, Lemley D, Riddin T. 2022. *Development of climate change mitigation and adaptation strategies for the estuarine lakes of South Africa*, vol. III. *Vulnerability assessment appendices*. WRC Report No. TT 871/3/21. Pretoria, South Africa: Water Research Commission.

Contributions to Symposia and Conferences, and Public Presentations

Alessio Gomiero A, Casserly J, O'Donohoe P, Michalek K, Macleod A, **Macey BM**, Lauvset SV, Goris N, Ravagnan E. 2022. Plastic litter fingerprint assessment of different trophic aquaculture systems: method development and application. *Aquaculture Europe 2022, 27–30 September, Rimini, Italy*. (oral presentation)

Arendse DCZ, **Pitcher GC**, **Lewis BR**, **Sassman LC**, **Fortune MN**. 2022. Preliminary results from an investigation of the reproduction cycle of the clam *Venerupis corrugatus*. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (poster presentation)

Auerswald L, Munian A, Hoffman LC, **Cockcroft AC**. 2022. Biological and biochemical parameters as potential growth predictors in male *Jasus lalandii*. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (poster presentation)

Bachoo T, Bolton JJ, Reddy M, **Macey BM**. 2022. Charac-terization of *Ulva* (Ulvaceae, Chlorophyta) species cultured in commercial abalone farms in South Africa, and comparison with closely related wild species. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

Bennett M, **Macey BM**, Bolton JJ, Coyne VE, **Cyrus MD**. 2022. Larval settlement, post-settlement and weaning substrates and regimes for the sea urchin *Tripneustes gratilla* in intensive aquaculture. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

Bolton JJ, **Cyrus MD**, De Prisco JA, Geldart M, Brink-Hull M, **Macey BM**. 2022. Daily rhythms of critical water quality parameters in commercial land-based, partially recirculated abalone-*Ulva* Integrated Multi-Trophic Aquaculture systems, and the potential for increasing recirculation rates. *Aquaculture Europe 2022, 27–30 September, Rimini, Italy.* (oral presen-tation)

Brink-Hull M, **Cyrus MD**, Cloete A, Bolton JJ, **Macey BM**. 2022. Symbiotic integrated aquaculture: sea urchin faecal matter as a dietary supplement for juvenile abalone. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

Brink-Hull M, **Cyrus MD**, Cloete A, Bolton JJ, **Macey BM**. 2022. Using sea urchin faeces as a dietary supplement for juvenile abalone: effects on growth, survival, and the microbiome. *Aquaculture Europe 2022, 27–30 September, Rimini, Italy*. (oral presentation)

Brinkman F, Wilhelm M, **Geja Y**, **van der Lingen CD**. 2022. Using otolith biochronologies from sardine (*Sardinops sagax*) in the southern Benguela to identify ecosystem shifts. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Brown-Webb B, Stander B, Bolton JJ, Lück-Vogel M, **Rothman M**, **Cyrus MD**, **Macey B**, Ohlson H, **Arendse DCZ**, Du Toit D, Meyer I, Mtombeni N, Snyman-van der Walt L, **Bernatzeder A**, Pillay PJ. 2022. Pre-feasibility study of the potential for commercial cultivation of kelp along South Africa's west coast. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

Coetzee V, **Parker D**, **Lamberth SJ**, **Kerwath SE**. 2022. Grunting in murky waters: morphological and ethological discrimination among functional stocks of spotted grunter, an estuarine-dependent fish. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa.* (oral presentation)

Cyrus MD, Bennett M, **Macey BM**, Coyne VE, Bolton JJ. 2022. Identifying suitable settlement substrates and feeds for early-stage growth of the sea urchin *Tripneustes gratilla*: impli-cations for hatchery management protocols and production. *Aquaculture Europe 2022, 27–30 September, Rimini, Italy*. (oral presentation)

da Silva C. 2022. A day in the life of a Government scientist: policy and management. *WildTrust Ocean Stewards Seminars, 27–28 September 2022, Durban, South Africa*.

da Silva C, **Kerwath SE**. 2022. Requiem shark listings in CITES Appendix II. *CoP19 preparatory meeting*, *19 July 2022, online meeting*, *South African National Biodiversity Institute (SANBI), Pretoria.*

de Cubber L, Groenewald G, Horton M, Ouzara T, Le Moan E, Pecquerie L, **van der Lingen C**, Maury O. 2022. A generalized Dynamic Energy Budget model including 3D shape changes for modeling small pelagic fish growth. *PICES/ICES/FAO Symposium on Small Pelagic Fish: New Frontiers in Science and Sustainable Management, 7–11 November 2022, Lisbon, Portugal*. (oral presentation)

De Vos B, Bolton JJ, **Macey BM**, **Cyrus MD**. 2022. Using inter-disciplinary modelling to assess the feasibility of a commercial scale recirculating aquaculture system integrating sea urchins (*Tripneustes gratilla*) and seaweed (*Ulva lacinulata*). *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

De Vos BC, **Cyrus MD**, **Macey BM**, Batik T, Bolton JJ. 2022. The development of machine vision to measure sea urchins. *Aquaculture Europe 2022, 27–30 September, Rimini, Italy*. (oral presentation)

Dudek T, Andersen H, **Yemane D**, Fock H, Duncan S, Ekau W. 2022. Size spectra of zooplankton and mesopelagic fish in the Benguela upwelling system. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Duncan S, Auel H, Bode-Dalby M, Horton M, Koppelmann R, Lahajnar N, **van der Lingen C**, Martin B, Sell A, Hagen W, Fock H. 2022. Pelagic food web structure in the northern and southern Benguela Upwelling Systems. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Fouche CH. 2022. Species selection, biology and reproduction techniques of tilapia. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

Fouche CH. 2022. Thermal induction of tetraploidy in African sharptooth catfish, *Clarias gariepinus*. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

Fouche CH, **Goodman M**. 2022. Development of a novel and efficient method for the oral delivery of bioactive peptides in commercially used finfish that are responsive to GnRHa induced spawning. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

Fouche CH, **Goodman M**, **Hendricks A**, **Sophangisa S**, **Selapa W**. 2022. Development of a relatively cheap fertilizer for the mass culture of *Isochrysis galbana* and *Nannochloropsis oculata*, the preferred algae species for rotifer enrichment and pseudo-green water practices in marine finfish hatcheries. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (poster presentation)

Haupt TM, Novak T, Naylor M, **Auerswald L**. 2022. Physiological responses to changing climates: a case study of a local abalone species. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (poster presentation)

Horton M, Shannon LJ, **van der Lingen CD**. 2022. The eco-morphology of early life history stages of small pelagic fish in the Benguela Upwelling System. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Kerwath S[E], **Lamberth S[L]**. 2022. Island or oasis? The role of shallow oceanic seamounts in structuring populations of yellowtail *Seriola lalandi*. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Kerwath SE, Roodt-Wilding R, *Samaai T*, Winker H, West W, Surajnarayan S, Swart B, Bester-van der Merwe A, Götz A, **Lamberth SJ**, **Wilke C**. 2022. Shallow seamounts represent speciation islands for circumglobal yellowtail *Seriola lalandi*. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa.* (oral presentation)

Lamberth SJ, Baur N, Bornman TG, Brett G, James N, *Krug M*, Russo C, Steyn P-P. 2022. A sequential account of a major ocean weather anomaly; direct and indirect impacts on marine life. *17th Southern African Marine Science Sym-posium (SAMSS), 20–24 June, Durban, South Africa.* (oral presentation)

Lamberth SJ, Bornman TG, **Kerwath SE**, Kock A, **Mansfield L**, **Parker D**, **Rothman M**, Samaai T, Smith M. 2022. Gone west: first observations of surf-zone diatom

Anaulus australis accumulations on the West Coast. 17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa. (poster presentation)

Lamberth SJ, **Kerwath SE**. 2022. What's in the basket? Spatial distribution and availability of harvestable marine species around the South African coast. 17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa. (oral presentation)

Lamberth SJ, **van der Lingen CD**. 2022. Is climate change impacting South Africa's marine fisheries? 22nd Marine and Coastal Educators Network Conference, 28–30 March 2022, online conference. (oral presentation)

Le Moan E, Ouzara T, Flores J, De Cubber L, Menu C, Huret M, Maury O, Groenewald G, Marques S, **van der Lingen C**, Vagner M, Pecquerie L. 2022. Characterising the life trait variability of anchovy species of the genus Engraulis using a DEB (Dynamic Energy Budget) modelling approach. 15th Conference of the French Association of Halieutics, 29 June–1 July 2022, Brest, France. (poster presentation)

Lillis A, Caputo M, Lebrato M, Bowles KR, **Shabangu FW**. 2022. Sounds of a changing sea: using passive acoustic monitoring to explore coastal biodiversity in Mozambique. 17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa. (oral presentation)

Maapea AD, Vine NG, **Macey BM**. 2022. Microbiome of dusky kob (Argyrosomus japonicus) eggs and hatchery water and efficacy of various chemicals for egg disinfection. 14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa. (oral presentation)

Macey BM, Brand MJ, Brink-Hull M, Bolton JJ. 2022. Ulva as a functional ingredient for farmed abalone: Impacts on growth, physiology, and microbiome. 14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa. (oral presentation)

Macey BM, Bolton JJ, **Rothman M**, **Jika Z**, **Ismail I**, **Semoli B**. 2022. South African seaweed aquaculture sector. FAO Seaweed Aquaculture Policy Dialogue, 11–12 May, online meeting. (oral presentation)

Macey BM, Brink-Hull M, Makhahlela BN, Brand MJ, **Cyrus MD**, Bolton JJ. 2022. Impact of Ulva lacinulata on the microbiome of abalone-Ulva IMTA systems. Aquaculture Europe 2022, 27–30 September, Rimini, Italy. (oral presentation)

Miller T, **van der Lingen C**, Brodeur R, Bertrand A, Espinoza P, Alegre A, Navarro J, Gimenez J, Bode A, Schwamborn R, Gimenez T, Kreiner A, Takasuka A. 2022. A global stable isotope-based comparison of small pelagic fish and other nekton across ecosystems with varying levels of productivity. PICES/ICES/FAO Symposium on Small Pelagic Fish: New Frontiers in Science and Sustainable Management, 7–11 November 2022, Lisbon, Portugal. (oral presentation)

Mwangudza P, Jones CLW, **Macey BM**. 2022. Assessment of potential biosecurity measures on the inactivation of macroalgae-transmitted abalone pathogens. 14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa. (oral presentation)

Mwangudza P, Jones CLW, **Macey BM**. 2022. Assessment of potential biosecurity measures on the inactivation of macroalgae-transmitted abalone pathogens. Aquaculture Europe 2022, 27–30 September, Rimini, Italy. (oral pre-sentation)

O'Donohoe P, **Macey B**, Chalde T, Poersch L, Macleod A, Ravagnan E. 2022. Integrated Multi-Trophic Aquaculture All Atlantic Approach – The ASTRAL Project. *The International Institute of Fisheries Economics and Trade Conference, 18–22 July, Galicia, Spain*. (oral presentation)

Opperman M, **Macey BM**, Henning S, Bolton JJ, Wieringa FT, Berger J, Darias MJ. 2022. Mineral content of marine organisms to develop nutrition-sensitive approaches to marine aquaculture in South Africa. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (oral presentation)

Ouzara T, Le Moan E, Flores J, de Cubber L, Menu C, Groenewald G, Marques GM, **van der Lingen C**, Vagner M, Maury O, Pecquerie L. 2022. Comparing life-history traits of small pelagic fish within the framework of Dynamic Energy Budget (DEB) theory: application on several populations of the *Engraulis* genus. *PICES/ICES/FAO Symposium on Small Pelagic Fish: New Frontiers in Science and Sustainable Management, 7–11 November 2022, Lisbon, Portugal*. (oral presentation)

Padare G, Cowley P, Murray T, Du Plessis J, **Lamberth SJ**, Vumazonke L. 2022. Movement patterns of spotted grunter in relation to an existing estuarine protected area. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa.* (oral presentation)

Peña H, **Shabangu FW**, Mamza K, Sarre A, Ahmed M, Uanivi U, Vaz Vehlo F, Stenevik E. 2022. Investigation of bias in echosounder acoustic surveys using omnidirectional sonar from South to Northwest Africa. *Small Pelagic Fish Sym-posium: New Frontiers in Science and Sustainable Manage-ment, 7–11 November 2022, Lisbon, Portugal*. (oral presentation)

Purdon J, **Shabangu FW**, Pienaar M, Somers MJ, Findlay KP. 2022. Cetacean species richness in relation to anthropogenic impacts and areas that provide protection in South African Oceans. *24th Biennial Conference on the Biology of Marine Mammals, 1–5 August 2022, Palm Beach, Florida, USA*. (poster presentation)

Purdon J, Somers M, **Shabangu FW**, Findlay K, Pienaar M. 2022. Cetacean species richness in relation to anthropogenic impacts and areas that provide protection in South African Oceans. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presen-tation)

Raimundo J, **van der Lingen CD**, Bakir A, Garrido S, Lopes C, Caetano M. 2022. Anthropogenic pollutants in small pelagic fishes. *PICES/ICES/FAO Symposium on Small Pelagic Fish: New Frontiers in Science and Sustainable Management, 7–11 November 2022,* *Lisbon, Portugal*. (oral presentation)

Reed J, Lombard A, Sink K, **Kerwath S[E]**. 2022. Empirical move-on rules for bycatch avoidance in the South African midwater trawl fishery. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Reed J, Lombard A, Sink K, **Kerwath S[E]**. 2022. Spatial analyses to assess the effects of new offshore MPAs on a pelagic longline fishery. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Samaai T, **Yemane D**, Turner T, **Kerwath S[E]**, Kara J, Ngwakum B, Payne R. 2022. There and back again: confirmation of the southern African distribution of the cryptic marine sponge *Hymeniacidon perlevis* (Montagu 1814) in the context of global dispersal. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Sassman LC, **Pitcher GC**, **Arendse DCZ**, **Lewis BR**, **Fortune MN**. 2022. Assessment of biofouling associated with shellfish farming in Saldanha Bay. *14th Conference of the Aquaculture Association of Southern Africa, 11–15 July, Stellenbosch, South Africa*. (poster presentation)

Shabangu FW, Caputo M, Lebrato M, Bowles KR, Lillis A. 2022. Heard but not seen: bioacoustics reveals undocumented occurrence of baleen whales in southern Mozambique. *3rd African Bioacoustics Community Conference, 2–7 October 2022, Skukuza, South Africa*. (oral presentation)

Shabangu FW, Caputo M, Lebrato M, Bowles KR, Lillis A. 2022. Heard but not seen: Bryde's and sei whale acoustic occurrence in Bazaruto Archipelago, Mozambique. *12th West-ern Indian Ocean Marine Science Association (WIOMSA) Symposium, 10–15 October 2022, Port Elizabeth, South Africa.* (poster presentation)

Shabangu FW, Caputo M, Lebrato M, Bowles KR, Lillis A. 2022. Heard but not seen: Bryde's and sei whale acoustic occurrence in Bazaruto Archipelago, Mozambique. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Shabangu FW, **Yemane D**, Estabrook BJ, Best G. 2022. Spatio-temporal trends and effects of oceanic noise on whale acoustic occurrence off the west coast of South Africa*. International Statistical Ecology Conference, 27 June–1 July 2022, Cape Town, South Africa*. (oral presentation)

Shabangu FW, **Yemane D**, Estabrook BJ, Best G. 2022. Trends and effects of oceanic noise on whale acoustic detection off South Africa's west coast. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Soares B, *Lamont T*, **Shabangu FW**. 2022. Seasonal charac-terization and environmental influence on humpback whale sounds off the west coast of South Africa. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Sousa-Lima R, Stanley J, Di Iorio D, Havlik MH, Chanda K, Frazao F, Liffers M, van Zeeland L, Thomisch K, **Shabangu FW**, Vela S, Zuffi S, Wall C, Rountree R, Urban E, Sayigh L, Rice A, Radford C, Nedelec S, Looby A, Linke S, Li S, Lammers M, Juanes F, Erbe C, Mooney TA, Lin T-H, Parsons M. 2022. GLUBS – Global Library of Underwater Biological Sounds. *19th Work Meeting of Specialists in Aquatic Mammals of South America*, and *13th SOLAMAC Congress (Latin American Society of Specialists in Aquatic Mammals), 10–11 September 2022, Balia, Brazil*. (oral presentation)

Staby A, Shannon LJ, Sikongo B, Krakstad J-O, **van der Lingen CD**. 2022. Diversity, distribution and role of mesopelagic fishes in the Benguela Current Region. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (poster presentation)

van der Lingen CD. 2022. Just how many sardine stocks are there off South Africa? *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

van der Lingen CD. 2022. Trophodynamic processes and small pelagic fishes. *PICES/ICES/FAO Symposium on Small Pelagic Fish: New Frontiers in Science and Sustainable Management, 7–11 November 2022, Lisbon, Portugal*. (Invited plenary keynote oral presentation)

van der Lingen CD, Shongwe T, Reed CC, **Geja Y, Petersen J**, Staby A, Hulley PA. 2022. Indices and effects of infection by the parasitic copepod *Cardiodectes bellotti* on Hector's lanternfish *Lampanyctodes hectoris* in the Southern Benguela. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (poster presentation)

van Niekerk L, Adams JB, **Lamberth JS**, Lemley DA, *Nhleko J* Riddin T, Rishworth GM, Taljaard, S, Brown S. 2022. How to kill a lake: first recorded acidification of an estuarine-lake in South Africa. *17th Southern African Marine Science Sym-posium (SAMSS), 20–24 June, Durban, South Africa.* (oral presentation)

van Niekerk L, Taljaard S, Adams, JB, **Lamberth SJ**, Lemley D, Weerts S. 2022. Evaluating the vulnerability of estuarine lakes to change: a South African case study. *ECSA 59, 5–9 September, Kursaal, San Sebastian, Spain*. (oral pre-sentation)

van Niekerk L, Taljaard S, Adams JB, **Lamberth SJ**, Lemley D, Weerts S. 2022. Evaluating the vulnerability of estuarine lakes to change: a South African case study. *WIOMSA 12th Scientific Symposium, 10–15 October 2022, Gqeberha, South Africa*. (oral presentation)

Vine NG, Maapea AD, **Macey BM**. 2022. The efficacy of various chemicals in the disinfection of dusky kob *Argyrosomus japonicus* eggs and hatchery water. *Aquaculture Europe 2022, 27–30 September, Rimini, Italy*. (oral presentation)

West W, **Kerwath S[E]**, Attwood C, Roodt-Wilding R. 2022. Swordfish around South Africa: Indian or Atlantic Ocean stock? *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral pre-sentation)

Yemane D*, Kirkman SP, Samaai T*. 2022. Ecoregions of the oceans within the EEZ of southern Africa based on openly available biogeochemical data. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Yemane D, *Kirkman SP*, *Samaai T*. 2022. Use of openly available occurrence data to generate biodiversity maps within the South African EEZ. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Zacharias L, Gibbons MJ, **van der Lingen CD**. 2022. Comparing the trophic structures of mesopelagic fish communities in coastal and oceanic waters of the south Atlantic using morphometric and stable isotope analyses. *17th Southern African Marine Science Symposium (SAMSS), 20–24 June, Durban, South Africa*. (oral presentation)

Contributions to Workshops, Short Courses, and Management and Scientific Bodies; Unpublished Technical Reports

Akuda T, **Somhlaba S**, Ichii T, Namba T, Sarralde R. 2022. Continuation of the research proposal on Antarctic toothfish (*Dissostichus mawsoni*) in Statistical Subarea 48.6 in 2022/23 from a multiyear plan (2021/22–2023/24): Research Plan under CM21-02, paragraph 6(iii). *CCAMLR Working Group Meeting on Statistical Assessment and Modelling*, *June 2022,* online meeting. *CCAMLR WG-SAM-22/02.*

Akuda T, **Somhlaba S**, Ichii T, Namba T, Sarralde R. 2022. Report of research fishing operations at Subarea 48.6 between the 2012/13 and 2021/22 fishing seasons. *CCAMLR Working Group Meeting on Stock Assessment*, *October 2022, Hobart, Australia. CCAMLR WG-FSA-22/24_Rev1.*

Clark A, **Somhlaba S**, **Yemane D**, **Mjelo MJ**, Ngcongo SV, Metse R, Naicker R. 2022. Developing building blocks towards an estimation of unrecorded catches and landings which may include Illegal Unreported and Unregulated (IUU) finishing in the South African Economic Exclusive Zones (EEZs) and territorial waters. Unpublished report. *Benguela Current Convention (BCC), July 2022*.

Coetzee JC, de Moor CL, **van der Lingen CD**, Butterworth DS. 2022. A summary of the South African sardine (and anchovy) fishery. *International Fisheries Stock Assessment Review Workshop, 28 November–2 December 2022, Cape Town, South Africa*. MARAM/IWS/2022/Sardine/BG1.

da Silva C, **Kerwath SE**. 2022. South Africa NPOA Sharks II. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee, 5–9 December 2022, Seychelles. IOTC-2022-WPEB18-10*.

da Silva C, **Kerwath SE**, **Meyer MR**, **Parker D**. 2022. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/Madrid (Spain). ST04_ZAF- BET2021-21P-NP_2022*. [Bigeye tuna]

da Silva C, **Kerwath SE**, **Meyer MR**, **Parker D**. 2022. T ask 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/Madrid (Spain). ST04_ZAF-SBF2021-21P-NP_2022*. [Southern bluefin tuna]

da Silva C, **Kerwath SE**, **Meyer MR**, **Parker D**. 2022. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/Madrid (Spain). ST04_ZAF-BSH2021-21P-NP_2022.* [Blue shark]

da Silva C, **Kerwath SE**, **Meyer MR**, **Parker D**. 2022. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/Madrid (Spain). ST04_ZAF-SMA2021-21P-NP_2022*. [Mako shark]

da Silva C, Kerwath SE, Meyer MR, Parker D. 2022. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/Madrid (Spain). ST04_ZAF-SWO2021-21P-NP_2022*. [Swordfish]

da Silva C, Kerwath SE, Meyer MR, Parker D. 2022. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/Madrid (Spain). ST04_ZAF-YFT2021-21P-NP_2022*. [Yellowfin tuna]

da Silva C, Kerwath SE, Meyer MR, Parker D. 2022. Task 3 – domestic observer program data. *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/Madrid (Spain)*. *ST09_ZAF2021-21P-NP_2022.*

da Silva C, **Kerwath SE**, *Samaai T* (organisers). 2022. Computer vision in Marine Sciences: where are we at in South Africa? *Workshop held during 17th Southern African Marine Science Symposium, 20–24 June, Durban, South Africa*.

Githaiga-Mwicigi J. 2022. An overview of potential threats to the squid resource and fishery. *The Ocean Accounts Framework and Economic Model Development for Small Scale Fisheries, DFFE NOC Workshop*, *18 May 2022, Cape Town, South Africa*. The National Oceanography Centre, United Kingdom, and the Department of Forestry, Fisheries and the Environment, Cape Town, South Africa.

Githaiga-Mwicigi J. 2022. Squid acoustic research at DFFE. *The South African Squid Management and Industrial Association (SASMIA) Annual General Meeting (AGM), 29 March 2022, Gqeberha, South Africa, online meeting*.

Glazer JP, **Durholtz D**. 2022. The South African chokka squid resource *Loligo reynaudii*. Background presentation. *DAFF-MARAM International Stock Assessment Review Workshop, 28 November–2 December 2022, Cape Town, South Africa*.

Glazer JP, **Durholtz D**. 2022. The South African sole resource *Austroglossus pectoralis*. Background presentation. *DAFF-MARAM International Stock Assessment Review Workshop, 28 November–2 December 2022, Cape Town, South Africa*.

Hampton I, Soule M, **Githaiga-Mwicigi J**. 2022. The squid acoustic survey. *The South African Squid Management and Industrial Association (SASMIA) Research Committee, 23 September 2022, Gqeberha, South Africa*, *online meeting.*

Kerwath SE, **Meyer MR**, **Parker D**, **da Silva C**. 2022. TASK 1 – nominal catches. *International Commission for the Conser-vation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/ Madrid (Spain)*. *ST02_ZAF2021-21P-NF#E21-07251_2022.*

Kerwath SE, **Parker D**, **Meyer MR**, **da Silva C**, Mketsu Q, Nonkeneza A, Mamaila B. 2022. Rules of Procedures – Appendix V Compliance Questionnaire for the year 2022 (CoC20). *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee, 5–9 December 2022, Seychelles. IOTC-2022-CoC20-CQ04[E].*

Lamberth SJ. 2022. Monitoring and measuring illegal gillnet catch and effort in SA. *FishFORCE (Fisheries Law Enforcement Academy), Law Enforcement by Peace Officers & Law for FCOs (Gill Netting) Workshop, February 2022, Durban.*

Lamberth SJ. 2022. Monitoring and measuring illegal gillnet catch and effort in SA. *FishFORCE (Fisheries Law Enforcement Academy), Law Enforcement by Peace Officers & Law for FCOs (Gill Netting) Workshop, March 2022, Richard's Bay.*

Macey BM. 2022. IMTA Lab South Africa. *ASTRAL 2nd Annual Meeting*, *26–27 September, Rimini, Italy*.

Macey BM. 2022. Land-based IMTA systems – ASTRAL IMTA Lab South Africa. *Aquaculture Europe 2022, ASTRAL WP2 Workshop 1: New IMTA Cultivation Opportunities, 27–30 September, Rimini, Italy*.

Meyer MR, **da Silva C**, **Kerwath SE**, **Parker D**, Mketsu Q, Nonkeneza A, Mamaila B. 2022. South Africa's annual report to the Compliance Committee. *Commission for the Conservation of Southern Bluefin Tuna (CCSBT), Extended Report of the Seventeenth Meeting of the Compliance Committee, 4–7 October 2022. CCSBT-CC/2210/SBT Fisheries–South Africa*. [Southern bluefin tuna]

Meyer MR, **Kerwath SE**, Mketsu Q. 2022. IOTC record of vessels authorized to operate in the IOTC Area. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. Res_19_04_ Record_ of_IOTC_AFVs_E*.

Meyer MR, **Kerwath SE**, Mketsu Q. 2022. Resolution 21/01 on an interim plan for rebuilding the Indian Ocean yellowfin tuna stock in the IOTC area of competence for 2021. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Com-mittee Meeting, 5–9 December 2022, Seychelles. Res_21_ 01_ Reporting_template_for_active_vessels_YFT_E_F_ ZAF*.

Meyer MR, **Kerwath SE**, Mketsu Q, **Jarvis J**. 2022. Record of active vessels. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. Res_10_08_Reporting_template_for_active_ domestic_vessel_E_F*.

Meyer MR, **Kerwath SE**, **Nesamvuni R**. 2022. ICCAT Recom-mendations 22/12 on the bycatch of sea turtles caught in association with the ICCAT fisheries – implementation into South African large pelagic and tuna pole and line permit conditions for 2023 permit cycle. *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/Madrid (Spain)*.

Meyer MR, **Kerwath SE**, **Parker D**, **da Silva C**. 2022. TASK 1 – fleet characteristics. *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on Research and Statistics (SCRS), 26–30 September 2022, Hybrid/ Madrid (Spain). ST01_ZAF2021-21F-NF_2022*.

Namba T, Sarralde R, Ichii T, Okuda T, **Somhlaba S**, Pompert J. 2022. Updated analysis of the sea ice concentration in research blocks 4 and 5 of Subarea 48.6 with sea surface temperature and winds. *CCAMLR Working Group meeting on Statistical Assessment and Modelling*, *June 2022, online meeting. CCAMLR WG-SAM-22/03.*

Parker D, **da Silva C**, Mketsu Q, **Meyer MR**, **Kerwath SE**. 2022. South Africa – national report 2022. *Indian Ocean Tuna Commission, 23rd Scientific Committee Meeting, 6–10 December 2021, online meeting. IOTC–2022-SC26-NR25*.

Parker D, **Kerwath S[E]**. 2022. Updated stock assessment of blue marlin (*Makira nigricans*) in the Indian Ocean using JABBA. Technical report. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles IOTC WPB-2022.*

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Catch by species and fishing effort by type of fishery, geographic area and month strata (fleets not providing logbook information). *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Indian Ocean Tuna Commission, 25th Scientific Com-mittee Meeting, 5–9 December 2022, Seychelles. FORM 3: _Form_3AR_ rev20_ZAF_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Catch by species in number (or live weight) and effort in number of hooks set by 1° grid area and month strata (extrapolated to annual catch) (fleets providing logbook information). *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. Form_ 3CE_rev20_ZAF_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_Cetaceans_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_Mobulids_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022 Seychelles. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_Seabirds_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_Sharks_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_Thresher Sharks_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_Tuna_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_Turtles_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December 2022, Seychelles. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_Whale Shark_2022*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Length/ weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December, Seychelles. Form_4SF_rev20_ZAF_ALB_2022*. [Albacore tuna]

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Length/ weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December, Seychelles. Form_4SF_rev20_ZAF_BET_2022*. [Bigeye tuna]

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Length/ weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December, Seychelles. Form_4SF_rev20_ZAF_BSH_2022*. [Blue shark]

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Length/ weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December, Seychelles. Form_4SF_rev20_ZAF_SBF_2022*. [Southern bluefin tuna]

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Length/ weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December, Seychelles Form_4SF_rev20_ZAF_SMA_2022*. [Mako shark]

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Length/ weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December, Seychelles. Form_4SF_rev20_ZAF_SWO_2022*. [Swordfish]

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Reported catches summary binary matrix of annual records of retained catches or discards by species and fishery group. *Indian Ocean Tuna Commission, 25th Session of the IOTC Scientific Committee Meeting, 5–9 December, Seychelles. Resolution 18/07_Form1_DR_v1.0_Rev20*.

Parker D, **Kerwath SE**, **Meyer MR**, **da Silva C**. 2022. Total annual retained catches in live weight by IOTC area, species and type of fishery. *Indian Ocean Tuna Commission, 25th Ses-sion of the IOTC Scientific Committee Meeting, 5–9 December, Seychelles. FORM 1: NOMINAL CATCH_Form1_RC_ rev20_ ZAF_2022*.

Shabangu FW, Branch T, Vermeulen E, Samaran F, Stafford K. 2022. Using bioacoustics to separate historic catches of Antarctic and pygmy blue whales from the former Durban whaling ground, western Indian Ocean. Paper SC/68D/ SH/WP03. *International Whaling Commission Virtual Meeting, 25 April–13 May*.

van der Lingen CD. 2022. South African marine fisheries and EAF. *TRAFFIC Summer School, 17–19 June, Durban, South Africa*.

van der Lingen CD. 2022. Status of South Africa's small pelagic fish resources and fisheries. *Benguela Current Convention Small Pelagic Working Group Meeting,12–16 December, Johannesburg, South Africa*.

van der Lingen CD, Horton M, Sardenne F. 2022. WP1 – observation: South Africa. *OMEGA Days Hybrid Workshop, 14–16 June 2022, Brest, France*.

Zhu GP, Wei L, Okuda T, Sarralde R, **Somhlaba S**. 2022. Otolith chemistry reflects local stock connectivity of Antarctic toothfish (*Dissostichus mawsoni*) between research blocks in Subarea 48.6: an updated report. *CCAMLR Working Group Meeting on Fish Stock Assessment, October 2022, Hobart, Australia. CCAMLR WG-FSA-22/36*.

Zhu GP, Wei L, Yang D, Okuda T, Slypko I, **Somhlaba S**, Parker S. 2022. A comparison of methods used for assessing the ontogenetic variation in otolith shape for *Dissostichus mawsoni*. *CCAMLR Working Group Meeting on Fish Stock Assessment*, *October 2022, Hobart, Australia. CCAMLR WG-FSA-22/53.*

Unpublished Working Group Documents

Auerswald L, Butterworth DS, Johnston SJ, **Glazer JP**, Bergh M, **van Zyl DL**, **Schultz LS**. 2022. Recommendations of the Rock Lobster Scientific Working Group for the sustainable management of the West Coast rock lobster resource for the 2022/2023 season. *FISHERIES/2022/AUG/SWG/WCRL26*. Department of Forestry, Fisheries and the Environment, Cape Town.

Auerswald L, Butterworth DS, Johnston SJ, **Glazer JP**, **van den Heever ND**. 2022. Recommendations of the Rock Lobster Scientific Working Group for the sustainable management of the South Coast rock lobster resource for the 2022/23 season. *FISHERIES/2022/AUG/SWG/SCRL/09*. Department of Forestry, Fisheries and the Environment, Cape Town.

Auerswald L, **Conrad SM**. 2022. Recommendation of the Small Invertebrates and Seaweeds Scientific Working Group for the sustainable management of white mussels (*Donax serra*) for the 2023 season. *FISHERIES/2022/AUG/SWG/SIS03*. Department of Forestry, Fisheries and the Environment, Cape Town.

Auerswald L, **John S**. 2022. Recommendation of the Small Invertebrates and Seaweeds Scientific Working Group for the sustainable management of the oyster fishery for 2023. *FISHERIES/2022/AUG/SWG/SIS02*. Department of Forestry, Fisheries and the Environment, Cape Town.

Auerswald L, **Rothman MD**. 2022. Recommendations of the Abalone Scientific Working Group for the sustainable management of abalone for the 2022/23 season. *FISHERIES/2022/OCT/SWG/ABA01*. Department of Fores-try, Fisheries and the Environment, Cape Town.

Auerswald L, **Rothman MD**, **Kemp D**, **Boothroyd C**. 2022. Recommendation of the Small Invertebrates and Seaweeds Scientific Working Group for the sustainable management of seaweed resources for the season March 2023 to February 2024. *FISHERIES/2022/OCT/SWG/SIS01*. Department of Forestry, Fisheries and the Environment, Cape Town.

Auerswald L, **van den Heever ND.** 2022. Recommendations of the Rock Lobster Scientific Working Group for the sustainable management of the KwaZulu-Natal prawn trawl fishery for 2023. *FISHERIES/2022/AUG/SWG/PRN/01*. Department of Forestry, Fisheries and the Environment, Cape Town.

Butterworth DB, **van Zyl DL**. 2022. On the implications of detection of West Coast rock lobsters in areas outside of those conventional fished in Super-Area 8+. *FISHERIES/2022/ JUN/SWG/WCRL03*. Department of Forestry, Fisheries and the Environment, Cape Town.

Coetzee JC, **Shabangu FW**, **Geja Y**, **Maliza L**, **Phillips M**, **Peterson J**, **Jarvis G**, **Jansen M**, **Williams M**, **Biyase S**, **Mahlati O**, **Mxunyelwa N**, **Hendricks A**, **Adonis V**, **Merkle D**. 2022. Results of the 2022 pelagic recruit survey. *FISHERIES/2022/ AUG/SWG-PEL/25rev*. Department of Forestry, Fisheries and the Environment, Cape Town.

Coetzee JC, **Shabangu FW**, **Maliza L**, **Geja Y**, **Merkle D**, **Ntiyantiya D**, **Bali A**, **Peterson J**, **Jarvis G**, **Mxunyelwa N**, **Adonis V**, **April W**, **Johnson M**, **van Neel M**, **Louw A**, **Phillips M**, **Mahlathi O**, **Zweni S**. 2022. Results of the 2022 pelagic biomass survey. *FISHERIES/2022/DEC/SWG-PEL/40*. Depart-ment of Fores-try, Fisheries and the Environment, Cape Town.

de Moor CL, **van der Lingen CD**, Teske PR. 2022. A new hypothesis for South African sardine stock structure. *FISHERIES/2022/MAY/SWG-PEL/11*. Department of Fores-try, Fisheries and the Environment, Cape Town.

Durholtz D. 2022. DFFE demersal research 2022. *FISHERIES/ 2022/APR/SWG-DEM/02.* Department of Forestry, Fisheries and the Environment, Cape Town.

Durholtz D. 2022. Squid jig catch and effort update – revised. *FISHERIES/2022/MARCH/SWG-SQ/08.* Department of Forestry, Fisheries and the Environment, Cape Town.

Durholtz MD. 2022. Standardized hake CPUE indices and catches for the period 1978–2019. *FISHERIES/2022/ OCT/ SWG-DEM/23a*. Department of Forestry, Fisheries and the Environment, Cape Town.

Durholtz D, **Louw GG**. 2022: 2021/2022 Squid jig catch and effort update. *FISHERIES/2022/NOV/SWG-SQ/24.* Depart-ment of Forestry, Fisheries and the Environment, Cape Town.

Fairweather TP. 2022. Agulhas sole: abundance estimates within the sole grounds, survey length frequency by strata, commercial CPUE and CAL, and updated graph for model fit. *MARAM/IWS/2022/Sole/WP2*. University of Cape Town, Cape Town.

Fairweather TP. 2022. Horse mackerel data file. *FISHERIES/ 2022/OCT/SWG-DEM/23*. Department of Forestry, Fisheries and the Environment, Cape Town.

Fairweather TP. 2022. Standardised abundance estimates for key commercial species 2016–2022. *FISHERIES/2022/OCT/ SWG-DEM/19*. Department of Forestry, Fisheries and the Environment, Cape Town.

Fairweather TP, **Glazer TP**, **Durholtz MD**. 2022. Update of annual commercial catch data for hake, Agulhas sole, monkfish and kingklip – October 2022. *FISHERIES/2022/ OCT/SWG-DEM/37*. Department of Forestry, Fisheries and the Environment, Cape Town.

Githaiga-Mwicigi J. 2022. Progress report on the Squid Paralarvae Project. September 2022. *FISHERIES/2022/ SEPTEMBER/SWG-SQ/18*. Department of Forestry, Fishe-ries and the Environment, Cape Town.

Githaiga-Mwicigi J. 2022. Research plan for the squid resource. *FISHERIES/2022/MARCH/SWG-SQ/01*. Department of Forestry, Fisheries and the

Environment, Cape Town.
Githaiga-Mwicigi J. 2022. SA squid monthly catches 2007–2021. *FISHERIES/2021/MARCH/SWG-SQ/02*. Department of Fores-try, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2022. Seismic surveys and squid fishery in Algoa Bay and Gamtoos Basin: project proposal and progress. *FISHERIES/2022/SEPTEMBER/SWG-SQ/20*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2022. Squid acoustic survey-cruise report. RV *Ellen Khuzwayo* November Survey. *FISHERIES/2022/ SEPTEMBER/SWG-SQ/13*. Department of Forestry, Fishe-ries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2022. Squid closed season research 2022. *FISHERIES/2022/SEPTEMBER/SWG-SQ/17*. Department of Forestry, Fisheries and the Environment. Cape Town.
Githaiga-Mwicigi J. 2022. Status of squid jig catch data. *FISHERIES/2022/SEPTEMBER/SWG-SQ/11*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2022. Towards setting the 2022–2023 scientific recommendation for the squid resource. *FISHERIES/2021/ MARCH/SWG-SQ/06a*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. (with the Squid SWG members). 2022. Squid 2022–2023 TAE scientific recommendation, 24 March 2022. *FISHERIES/2021/MARCH/ SWG-SQ/06b.* Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2022. Updated SA squid monthly catches 2007–2021. *FISHERIES/2021/MARCH/SWG-SQ/07.* Depart-ment of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2022. An index of abundance for Zone A West Coast rock lobster. *FISHERIES/2022/JUL/SWG/WCRL21*. Depart-ment of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2022. An updated analysis of the South Coast rock lobster size distributions per season, quarter and area utilizing both observer and industry collected size information over the period 1995–2019. *FISHERIES/2022/JUN/SWG-SCRL/03*. Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2020. Sole TAC and TAE recommendations for 2021. *FISHERIES/2020/OCT/SWG-DEM/31*. Department of Fores-try, Fisheries and the Environment, Cape Town.
Glazer JP. 2022. South Coast rock lobster standardized CPUE indices per area. *FISHERIES/2022/JUL/SWG-SCRL/04rev.* Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2022. Standardized CPUE indices per super-area in the West Coast rock lobster hoopnet fishery. *FISHERIES/ 2022/JUL/SWG/WCRL19*. Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2022. Standardized CPUE indices in the West Coast rock lobster trapboat fishery. *FISHERIES/2022/ JUL/SWG/ WCRL20*. Department of Forestry, Fisheries and the En-vironment, Cape Town.
Glazer JP, Butterworth DS, **Fairweather TP**. 2022. 2022 sole dynamic Schaefer production model results. *FISHERIES/ 2022/NOV/SWG-DEM/40*. Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP, **Fairweather TP**. 2022. The 2022 assessment of the South African monkfish resource. *FISHERIES/2022/NOV/ SWG-DEM/41*. Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2022. The separation of catch by area in the South Coast rock lobster fishery. *FISHERIES/2022/ JUN/SWG-SCRL/02*. Department of Forestry, Fisheries and the Environment, Cape Town.
Johnston S, **van Zyl DL**, **Schultz L**. 2022. New catch-at-length data obtained since 2018 from trap samples *FISHERIES/2022/ JUN/SWG/WCRL05*. Department of Forestry, Fisheries and the Environment, Cape Town.
Kerwath SE, Parker D, Meyer MR, **da Silva C**. 2022. Recommendations of the Large Pelagics and Sharks Scientific Working Group for the sustainable management of tuna and swordfish resources. *FISHERIES/2022/ LPSSWG/01*. Department of Forestry, Fisheries and the Environment, Cape Town.
Lamberth SJ, **da Silva C**, **Kerwath SE**, **Parker D**. 2022. Recommendations of the Linefish Scientific Working Group for management of sustainable beach-seine and gillnet (smallnet/driftnet) fisheries for the period 2022–2023. *FISHERIES/2022/LSWG-LF/3*. Department of Forestry, Fisheries and the Environment, Cape Town.
Parker D, **de la Cruz Y**, **da Silva C**, **Kerwath SE**. 2022. Recommendations of the Linefish Scientific Working Group for the sustainable management of linefish resources. *FISHERIES/2022/LSWG/01*. Department of Forestry, Fisheries and the Environment, Cape Town.
Parker D, **Meyer MR**, **de la Cruz Y**, **da Silva C**, **Kerwath SE**. 2022. Recommendations of the Linefish Scientific Working Group for the sustainable management of demersal shark longline resources. *FISHERIES/2022/LSWG/02*. Department of Forestry, Fisheries and the Environment, Cape Town.
Ross-Gillespie A, Butterworth DS, **Glazer JP**, **Fairweather TP**. 2022. The 2022 operational management procedure for the South African *Merluccius paradoxus* and *M. capensis* resources. *FISHERIES/2022/OCT/ SWG-DEM/34rev*. Depart-ment of Forestry, Fisheries and the Environment, Cape Town.
Shabangu FW. 2022. *Ad hoc* recommendation of the Small Pelagic Scientific Working Group to increase the round herring precautionary upper catch limit for the 2022 fishing season. *FISHERIES/2022/APR/ SWG-PEL/10*. Department of Forestry, Fisheries and the Environment, Cape Town.
Shabangu FW. 2022. Interim recommendation of the Small Pelagic Scientific Working Group to increase the round herring precautionary upper catch limit for the

2022 fishing season. *FISHERIES/2022/AUG/SWG-PEL/26*. Department of Forestry, Fisheries and the Environment, Cape Town.

Shabangu FW. 2022. Outstanding and completed tasks from previous SWG-PEL meetings. *FISHERIES/2022/AUG/SWG- PEL/30*. Department of Forestry, Fisheries and the Environment, Cape Town.

Shabangu FW. 2022. Recommendation of the Small Pelagic Scientific Working Group for the final anchovy and sardine total allowable catch for the 2022 fishing season. *FISHERIES/ 2022/AUG/SWG-PEL/27*. Department of Forestry, Fisheries and the Environment, Cape Town.

Shabangu FW. 2022. Recommendation of the Small Pelagic Scientific Working Group for the initial anchovy total allowable catch and sardine total allowable by-catches for the 2022 fishing season. *FISHERIES/2022/JAN/SWG-PEL/02*. Department of Forestry, Fisheries and the En-vironment, Cape Town.

Shabangu FW. Recommendation of the Small Pelagic Scientific Working Group to increase the sardine total allowable catch for the 2022 fishing season. *FISHERIES/2022/FEB/SWG-PEL/07*. Department of Forestry, Fisheries and the Environment, Cape Town.

Shabangu FW. 2022. Revised recommendation of the Small Pelagic Scientific Working Group for the interim sardine total allowable catch for the 2022 fishing season. *FISHERIES/ 2022/FEB/SWG-PEL/06*. Department of Forestry, Fisheries and the Environment, Cape Town.

van der Lingen CD. 2022. A synthesis of studies of South African sardine population structure. *FISHERIES/2022/JUN/SWG-PEL/16*. Department of Forestry, Fisheries and the Environment, Cape Town.

van der Lingen CD. 2022. The South African sardine boom in the early-2000s coincided with anomalously warm SSTs off the west coast. *MARAM/IWS/2022/Sardine/WP1*. University of Cape Town, Cape Town.

van der Lingen CD, *Lamont T*. 2022. Can the relative distribution of small pelagic fishes be related to SST anomalies off the South African West Coast? *FISHERIES/2022/MAY/SWG-PEL/13*. Department of Forestry, Fisheries and the Envi-ronment, Cape Town.

van der Lingen CD, **Merkle D**. 2022. Spatial patterns of directed sardine catches off the South Coast from January to July 2022. *FISHERIES/2022/AUG/SWG-PEL/24*. Department of Forestry, Fisheries and the Environment, Cape Town.

van der Lingen CD, **Coetzee JC**, **Merkle D**. 2022. Is there evidence to suggest multiple stocks of West Coast round herring (*Etrumeus whiteheadi*) off South Africa? *FISHERIES/2022/ SEP/SWG-PEL/36*. Department of Forestry, Fisheries and the Environment, Cape Town.

van Zyl DL. 2022. Current separation of the inshore and offshore sectors. *FISHERIES/2022/APR/SWG/WCRL02*. Department of Forestry, Fisheries and the Environment, Cape Town.

van Zyl DL. 2022. Data and data updates available for West Coast rock lobster assessment for the 2022/2023 season. *FISHERIES/2022/JUN/SWG/WCRL04*. Department of Fores-try, Fisheries and the Environment, Cape Town.

van Zyl DL. 2022. TAC split per sector per area and catches. *FISHERIES/2022/JUN/SWG/WCRL06*. Department of Fores-try, Fisheries and the Environment, Cape Town.

van Zyl DL. 2022. West Coast rock lobster annual TAC, catch, effort and CPUE per area. *FISHERIES/2022/JUN/SWG/ WCRL07*. Department of Forestry, Fisheries and the Environment, Cape Town.

van Zyl DL, **Savel F**. 2022. Updated poaching data available for West Coast rock lobster assessment for the 2022/2023 season *FISHERIES/2022/JUN/SWG/WCRL11*. Department of Forestry, Fisheries and the Environment, Cape Town.

van Zyl DL, **Schultz L**. 2022. Tagging data to be used for the 2022 assessment *FISHERIES/2022/JUL/SWG/WCRL14*. Department of Forestry, Fisheries and the Environment, Cape Town.

van Zyl DL, **Schultz L**. 2022. CPUE data to be used for the 2022 assessment *FISHERIES/2022/JUL/SWG/WCRL15*. Depart-ment of Forestry, Fisheries and the Environment, Cape Town.

van Zyl DL, **Williamson R**, **Sosibo L**. 2022. FIMS data to be used for the 2022 assessment. *FISHERIES/2022/JUN/ SWG/WCRL08*. Department of Forestry, Fisheries and the Environment, Cape Town.

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

2023

This document lists the scientific output of the Branch: Fisheries Management for 2023, arranged by output category. Figures in brackets represent the output for the previous two years, 2022 and 2021, respectively, and are included for comparison. (Figures for 2021 had been affected by restrictions on travel and in-person meetings as a result of the COVID-19 pandemic.) In the category 'peer-reviewed publications' there were 26 (28, 37) papers. There were 18 (11, 12) documents in the category 'theses/dissertations/tertiary projects', all of which were DFFE-supervised or co-supervised. There were 8 (29, 24) documents in the category 'book chapters, published reports and popular articles', 7 of which were estuary reports prepared for the Department of Water and Sanitation. There were 31 (71, 11) 'contributions to symposia and conferences, and public presentations'. Four of these were presentations at the *7th Southern African Shark and Ray Symposium*, 4 at the *33rd Congress of the Phycological Society of Southern Africa* and 4 at the *6th South African National Antarctic Programme Research Symposium*. The decline from 2022 is largely explained by the absence in 2023 of large, national meetings, such as the *17th Southern African Marine Science Symposium* and the *14th Conference of the Aquaculture Association of Southern Africa*. There were 60 (57, 22) 'contributions to workshops, short courses, and management and scientific bodies, and unpublished technical reports'. Of these, 23, 8 and 4, respectively, were contributions to activities of the Indian Ocean Tuna Commission (IOTC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), and 4 to those of the Atlantic Ocean Sustainable, Profitable, and Resilient Aquaculture (ASTRAL) project. Finally, there were 54 (64, 51) 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.

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

Bachoo T, Bolton JJ, **Macey BM**, Kandjengo L, Reddy MM. 2023. Resolving the identity of commercially cultivated *Ulva* (Ulvaceae, Chlorophyta) in integrated seaweed-abalone aquaculture farms in South Africa. *Journal of Phycology* 59: 1272–1283.

Bass D, Hartikainen H, **Christison K**, Stentiford G, Batista F, Ellis R. 2023. Environmental DNA/RNA for pathogen detection and surveillance: guidelines and opportunities. *Trends in Parasitology* 39: 285–304.

Boonzaaier-Davids MK, Ma KCK, McQuaid CD. 2023. Epibiotic association of encrusting cheilostome bryozoans on shells of an invasive mussel from rocky shores of South Africa, with the description of a new aviculiferous species of *Chaperia*. *Zootaxa* 5258: 197–210.

Currie JC, Harris LR, Atkinson LJ, **Fairweather TP**, Sink KJ. 2023. Mapping fine-scale demersal trawl effort for application in ecosystem assessment and spatial planning. *African Journal of Marine Science* 45: 165–179.

da Silva C, Samaai T**, Kerwath S**, Adams L, Watson K, Bernard A, **van der Heever G**, Angel A, Schoombie S, Frainer G, Franken ML. 2023. Leaping into the future: current application and future direction of computer vision and artificial intelligence in marine sciences in South Africa. *Research Ideas and Outcomes* 9: e112231.

Deville D, Mori S, Kawai K, Escánez A, Macali A, Lishchenko F, Braid H, **Githaiga-Mwicigi J**, Mohamed KS, Bolstad KSR, Miyahara K, Sugimoto C, Fernández-Álvarez FA, Sanchez G. 2023. Cryptic biodiversity in the commercial diamondback squid *Thysanoteuthis rhombus* Troschel 1857. *Reviews in Fish Biology and Fisheries* 34: 293–313.

De Vos B, Cyrus MD, **Macey BM**, Batik T, Bolton JJ. 2023. Combining computer vision and standardised protocols for improved measurement of live sea urchins for research and industry. *Aquaculture, Fish and Fisheries* 3: 507–517.

Faure-Beaulieu N, Lombard AT, Olbers J, Goodall V, **da Silva C**, Daly R, Jordaan G, **Kerwath SE**, Kock A, Mann BQ, Murray TS. 2023. A systematic conservation plan identifying critical areas for improved chondrichthyan protection in South Africa.*Biological Conservation* 284: article 110163.

Forde S, von der Heyden S, Le Moan A, Nielsen ES, **Durholtz D**, Kainge P, Kathena JN, Lipinski MR, Ndjaula HON, Matthee CA, Henriques R. 2023. Management and conservation implications of cryptic population substructure for two commercially exploited fishes (*Merluccius* spp.) in southern Africa. *Molecular Ecology Resources*. DOI: 10.1111/1755-0998.13820.

Firth DC, **Auerswald L**, Strydom P, Hoffman LC. 2023 The status of marine mussel pollution research in South Africa (2012–2022). *Foods* 12: 3983.

Grefsrud ES, **Arendse DCZ**, Meier S, Olsen SA, Andersen S. 2023. Adding fish waste to the diet of Iceland scallop (*Chlamys islandica*) – effects on feeding and reproductive ability. *Journal of Aquaculture Environment Interactions* 15: 195–213.

Madibana MJ, Mlambo V, **Lewis BR,** Toefy R. 2023. Effect of varied daily feeding intensities on growth performance and feed utilisation of South African dusky kob (*Argyrosomus japonicus*) juveniles reared in a recirculating aquaculture system. *African Journal of*

Agriculture, Nutrition and Development 23: 22984–22999.

Nashima FP, Strydom NA, **Lamberth SJ**. 2023. Assessing the application of the revised Remane Model to fish species in a fluvially dominated cool-temperate southern African coastal system. *Scientific Reports* 13: article 7465.

Pitcher GC, **du Randt A**, **Seanego KG**, Tsanwani M. 2023. Variability and controls of the ocean acidification metrics pH and pCO_2 in a large embayment of an Eastern Boundary Upwelling System (EBUS). *Estuarine, Coastal and Shelf Science* 292: article 108473.

Piwoni-Piórewicz A, Hsiang Liow L, Krzemińska M, Chełchowski M, Iglikowska A, Ronco F, Mazurkiewicz M, Smith AM, Gordon DP, Waeschenbach A, Najorka J, Figuerola B, **Boonzaaier-Davids MK**, Achilleos K, Mello H, Florence WK, Vieira LM, Ostrovsky AN, Shunatova N, Porter JS, Sokolover N, Cumming RL, Novosel M, O'Dea A, Lombardi C, Jain SS, Huang D, Kukliński P. 2024. Skeletal mineralogy of marine calcifying organisms shaped by seawater temperature and evolutionary history—a case study of cheilostome bryozoans. *Global Ecology and Biogeography*: e13874.

Probyn TA, **Pretorius M**, **Daya F**, **du Randt A**, **Busby A**. 2023. The effects of suspended bivalve culture on benthic community structure and sediment fluxes in Saldanha Bay, South Africa. *African Journal of Marine Science* 45: 137–148.

Qwabe W, Samaai T, Harris JM, Palmer RM, **Kerwath SE**. 2023. First mesophotic *Ecklonia radiata* (Laminariales) records within the iSimangaliso Wetland Park marine-protected area, east coast, South Africa. *Journal of the Marine Biological Association of the United Kingdom* 103: e91.

Sardenne F, Raynon T, Munaron J-M, **van der Lingen CD**, Sadio O, Diop K, Brosset P, Lebigre C, Soudant P, Vagner, M, Pecquerie L. 2023. Lipid-correction models for δ_{13}C values across small pelagic fishes (Clupeiformes) from the Atlantic Ocean. *Marine Environmental Research* 192: article 1062123.

Seanego KG, **Pitcher GC**, Probyn TA, **du Randt A**, **Mansfield LM**. 2023. Water quality characteristics of Vanderkloof Dam and its potential for rainbow trout farming. *Water SA* 49: 136–154.

Sink KJ, Adams LA, Franken M-L, Harris LR, Currie J, Karenyi N, Dayaram A, Porter S, *Kirkman S*, Pfaff M, van Niekerk L, Atkinson LJ, Bernard A, Bessinger M, Cawthra H, de Wet W, Dunga L, Filander Z, Green A, Herbert D, Holness S, **Lamberth SJ**, Livingstone T, Lück-Vogel M, Mackay F, Makwela M, Palmer R, van Zyl W, Skowno A. 2023. Iterative mapping of marine ecosystems for spatial status assessment, prioritization, and decision support. *Frontiers in Ecology and Evolution* 11: article 1108118.

Stentiford GD, Tyler CR, Ellis RP, Bean TP, Mackenzie S, Brugere C, Holt CC, Peeler EJ, **Christison KW**, Rushton J, Bass D. 2023. Defining and averting syndemic pathways in aquaculture: a major global food sector. *Frontiers in Sustainable Food Systems* 7: article 1281447.

Vaihola S, **Yemane D**, Kininmonth S. 2023. Spatiotemporal patterns in the distribution of albacore, bigeye, skipjack, and yellowfin tuna species within the exclusive economic zones of Tonga for the years 2002 to 2018. *Diversity* 15: article 1091.

van den Heever GM, **Yemane D**, Leslie RW, **van der Lingen CD**, Gibbons MJ. 2023. Modelling and comparing the distributions and associations of two co-occurring catshark species off South Africa. *Journal of Fish Biology* 103: 1095–1105.

van Staden M, Ebert DA, Gennari E, Leslie RW, McCord ME, Parkinson M, Watson RG, Wintner S, **da Silva C**, Bester-van der Merwe AE. 2023. Molecular taxonomy of South Africa's catsharks: how far have we come? *Diversity* 15: article 828.

Vaughan DB, **Christison KW**, Hansen H. 2023. *Rajonchocotyle* Cerfontaine, 1899 (Monogenea: Hexabothriidae) species from South Africa, with discussion of the literary accounts of *R. emarginata* (Olsson, 1876). *Journal of Parasitology* 109: 148–168.

Vaughan DB, **Christison KW**, Hansen H, Bullard SA. 2023. Hexabothriidae species may have extensive distribution ranges reflecting multiple host species: evidence from three new South African records. *ZooTaxa* 5254: 151–180.

Theses/Dissertations/Tertiary Projects

Agabi Y. 2023. Investigating population structure in South African monkfish *Lophius vomerinus* using multiple methods. PhD thesis, University of Cape Town, South Africa. Supervisors: Attwood C, **van der Lingen CD**.

Brand M. 2023. *Ulva* as a functional feed: a practical investigation into the effects of *Ulva lacinulata* on the growth, consumption, health, and gut microbiota of the farmed abalone *Haliotis midae*. PhD Thesis, University of Cape Town, South Africa. Supervisors: Bolton JJ, **Macey BM**.

Duma N. 2023. Cretaceous bryozoan fossils from Needs Camp, South Africa. MSc minor dissertation in Applied Ocean Sciences, University of Cape Town. Supervisors: **Boonzaaier-Davids MK**, Taylor PD.

Elliot D. 2023. Microplastic ingestion by two estuarine-associated mullet species, *Chelon richardsonii* and *Chelon dumerili* in the Breede Estuary, South Africa. MSc minor dissertation in Applied Ocean Sciences. University of Cape Town. Supervisors: **Kerwath SE**, **Lamberth SJ.**

Gbenle J. 2023. Enhancing the nutritive value of marama beans for simple non-ruminants through fungal-mediated solid-state fermentation. MSc thesis, University of Mpumalanga, South Africa. Supervisors: Mlambo V**, Madibana MJ,** Mert M.

Horton MC. 2023. Investigating the trophic ecologies of early life stages of small pelagic fishes in the Benguela upwelling ecosystem. PhD thesis, University of Cape Town, South Africa. Supervisors: Shannon LJ, **van der Lingen CD**.

Khauleza N. 2023. Feeding the broodstock spotted grunter (*Pomadasys commersonni*) for conditioning purposes

housed within a recirculating aquaculture system (RAS). Marine Science Diploma project, Cape Peninsula University of Technology, South Africa. Supervisor: **Goodman M**.

Khauleza N. 2023. Water quality management of a recirculating aquaculture system: assessment of biofilter efficiency for nitrogenous waste treatment at the Marine Research Aquarium. Marine Science Diploma project, Cape Peninsula University of Technology, South Africa. Supervisors: **Seanego K**, **Goodman M**.

Lehubye P. 2023. Shell boring polychaetes (Annelida: Polychaeta) associated with farmed abalone (*Haliotis midae*) in South Africa. BSc Hons (Environmental Management), University of South Africa. Supervisors: **Christison KW**, Louw H.

Mashiloane T. 2023. Black mulberry fruit as a nutraceutical source for juvenile dusky kob: physiological and tissue nutrient responses. MSc thesis, University of Mpumalanga, South Africa. Supervisors: Mlambo V, **Madibana MJ**.

Mateyisi NZ. 2023. Stable isotope analysis of two co-existing brown algae and associated sea urchins. MSc thesis, Walter Sisulu University, South Africa. Supervisors: Dlaza TS, **Rothman MD,** Dyer DC.

Mbanjwa H. 2023. An assessment of clinically relevant health markers or farmed mussels in South Africa. Postgraduate Diploma, Cape Peninsula University of Technology, South Africa. Supervisors: **Christison KW**, Puckree-Padua C.

Mbona N. 2023. A study of the impact of Polychaete parasites (Spionidae) on the condition index of farmed Pacific Oyster *Magallana gigas* from Saldanha Bay, West Coast of South Africa. Postgraduate Diploma, Cape Peninsula University of Technology, South Africa. Supervisors: **Christison KW,** Puckree-Padua C.

Mobara A. 2023. Application of a multi-method approach to the stock identification and discrimination of kingklip, *Genypterus capensis* (Smith, 1847), off the South African coast. PhD thesis, University of Cape Town, South Africa. Supervisors: Attwood C, **van der Lingen CD**.

Mthombeni AS. 2023. The effect of different microalgae *Isochrysis galbana* and *Rhodomonas salina* on the population development and fecundity of the calanoid copepod *Centropages brachiatus*. Marine Science Diploma project, Cape Peninsula University of Technology. Supervisor: **Guwa O**.

Nyuliwe TC. 2023. Growth, blood parameters, digestive enzymes, and fillet composition of juvenile dusky kob fed on mopane worm meal-based diets. MSc thesis, University of Mpumalanga, South Africa. Supervisors: Mlambo V, **Madibana MJ**, Wokadala CO.

Rhamashia T. 2023. *Ulva* in aquaculture: fertility and the search for a warm tolerant culture species. Hons thesis, University of Cape Town, South Africa. Supervisors: Bolton JJ, Brink-Hull M, **Macey BM**.

Schäfer I. 2023. Acoustic occurrence and behaviour of baleen whales during winter around the subantarctic Prince Edward Islands. BSc Hons thesis, University of Cape Town, South Africa. Supervisors: *Lamont T*, **Shabangu FW**.

Book Chapters, Published Reports and Popular Articles

James N, van Niekerk L, **Lamberth SJ**. 2023. Climate change and the Knysna Estuary. In: Breen C, Whitfield AK (eds), *Knysna Estuary – jewel of the Garden Route*. Knysna, South Africa: Knysna Basin Project. pp 251–270.

van Niekerk L, Taljaard S, Adams JB, Lemley D, MacKay CF, Riddin T, Weerts SP, **Lamberth SJ**. 2023. *Classification of significant water resources and determination of resource quality objectives for water resources in the Usutu to Mhlathuze catchments: aMatigulu/iNyoni Estuary Ecological Consequences Report*. DWS Report: WEM/WMA3/4/00/CON/CLA/0123 Vol. 2 Supporting Information. Prepared by CSIR. Pretoria: Department of Water and Sanitation.

van Niekerk L, Taljaard S, Adams JB, Lemley D, MacKay CF, Riddin T, Weerts SP, **Lamberth SJ**. 2023. *Classification of significant water resources and determination of resource quality objectives for water resources in the Usutu to Mhlathuze catchments: iSiyaya Estuary Ecological Consequences Report*. DWS Report: WEM/WMA3/4/00/CON/CLA/0123 Vol. 2 Supporting Information. Prepared by CSIR. Pretoria: Department of Water and Sanitation.

van Niekerk L, Taljaard S, Adams JB, Lemley D, MacKay CF, Riddin T, Weerts SP, **Lamberth SJ**. 2023. *Classification of significant water resources and determination of resource quality objectives for water resources in the Usutu to Mhlathuze catchments: resource quality objectives, Vol. 2: Estuaries Report*. Prepared by CSIR. DWS Report: WEM/WMA3/4/00/CON/CLA/0623 Vol. 2. Pretoria: Department of Water and Sanitation.

van Niekerk L, Taljaard S, Adams JB, Lemley D, MacKay CF, Riddin T, Weerts SP, **Lamberth SJ**. 2023. *Classification of significant water resources and determination of resource quality objectives for water resources in the Usutu to Mhlathuze catchments: uMhlathuze Estuary Ecological Consequences Report*. DWS Report: WEM/WMA3/4/00/CON/CLA/0123 Vol. 2 Supporting Information. Prepared by CSIR. Pretoria: Department of Water and Sanitation.

van Niekerk L, Taljaard S, Adams JB, Lemley D, MacKay CF, Riddin T, Weerts SP, **Lamberth SJ**. 2023. *Classification of significant water resources and determination of resource quality objectives for water resources in the Usutu to Mhlathuze catchments: uMlalazi Estuary Ecological Consequences Report*. DWS Report: WEM/WMA3/4/00/CON/CLA/0123 Vol. 2 Supporting Information. Prepared by CSIR. Pretoria: Department of Water and Sanitation.

van Niekerk L, Taljaard S, Adams JB, Lemley D, MacKay CF, Riddin T, Weerts SP, **Lamberth SJ**. 2023. *Classification of significant water resources and determination of resource quality objectives for water resources in the Usutu to Mhlathuze catchments: iNhlabane Estuary Ecological Consequences Report*. DWS Report: WEM/WMA3/4/00/CON/CLA/0123 Vol. 2 Supporting Information. Prepared by CSIR. Pretoria: Department of Water and Sanitation.

van Niekerk L, Taljaard S, Adams JB, Lemley D, MacKay CF, Riddin T, Weerts SP, **Lamberth SJ**. 2023. *Classification of significant water resources and resource quality objectives for water resources in the Usutu to Mhlathuze catchments: Ecological Consequences Report, Vol. 2: Estuaries*. DWS Report: WEM/ WMA3/4/00/ CON/CLA/0123 Vol. 2. Prepared by WRP Consulting Engineers (Pty) Ltd. Pretoria: Department of Water and Sanitation.

Contributions to Symposia and Conferences, and Public Presentations

Adebowale C, Naude V, Rogers, T, da Silva C, Dicken ML, Waries S, Naidoo K, O'Riain J. 2023. Heavy metal and organic compound bioaccumulation in bronze whaler sharks (Carcharhinus brachyurus) along the coastline of South Africa. 7th Southern African Shark and Ray Symposium, 24–27 October, Umhlanga, South Africa. (oral presentation)

Bolton JJ, **Macey BM**, Cyrus MD, Brink-Hull M. 2023. Commercial integrated aquaculture of abalone and the green seaweed *Ulva* in land-based systems in South Africa: an update. *AfriMAQUA 2023 Conference, 23–28 October, Mombasa, Kenya*. (oral presentation).

Bolton JJ, **Macey BM**, Cyrus MD, Brink-Hull M. 2023. IMTA in action: two decades of growing the green seaweed *Ulva* in integrated land-based systems on South African abalone farms. *Aquaculture Europe 2023, 18–21 September, Vienna, Austria*. (oral presentation)

Brink-Hull M, Bolton JJ, Cyrus MD, Makhahlela NB Brand MJ, Coyne VE, **Macey BM**. 2023. Bacterial dynamics in a commercial integrated abalone-*Ulva* farm: from hatchery to grow-out. *Aquaculture Europe 2023, 18–21 September, Vienna, Austria*. (oral presentation)

Brink-Hull M, Bolton JJ, Cyrus MD, Makhahlela BN, Brand MJ, Coyne VE, **Macey BM**. 2023. The bacterial benefits associated with integrated abalone-*Ulva* farming at different stages of production. *AfriMAQUA 2023 Conference, 23–28 October, Mombasa, Kenya*. (oral presentation)

Brink-Hull M, Cyrus MD, Cloete A, Bolton JJ, **Macey BM**. 2023. Symbiotic aquaculture: faecal material from sea urchins fed *Ulva*, as a probiotic for hatchery-produced abalone. *33rd Congress of the Phycological Society of Southern Africa (PSSA2023), 23–27 January, The Dunes, Arniston, South Africa*. (oral presentation)

Brown-Webb B, Bolton JJ, Lück-Vogel M, **Macey B**, **Bernatzeder A**, **Cyrus MD**, Du Toit D, Meyer I, Mtombeni N, Ohlson H, Pillay PJ, **Rothman MD**, Snyman-Van der Walt L, **Arendse DCZ**, Stander B. 2023. Pre-feasibility study on the potential for commercial cultivation of kelp along South Africa's West Coast. *Congress of the Phycological Society of Southern Africa (PSSA2023), 23–27 January, Arniston, South Africa*. (oral presentation)

Bwoga JA, Kaiser H, **Christison KW**. 2023. Population genetics of Genus *Gyrodactylus*, their prevalence and epidemiological impact. *153rd Annual Meeting of the American Fisheries Society, 20–24 August, Michigan, USA*. (oral presentation)

Christison KW, Tabei S, Grewar J. 2023. Surveillance for the demonstration of freedom from infection with abalone herpes virus in South Africa. *6th FRDC Scientific Conference on Aquatic Animal Health and Biosecurity, 3–7 July, Cairns, Australia*. (oral presentation)

Christopherson G, Sunde J, **Arendse DCZ**, Moodley G. 2023. Emerging species for sea cucumber aquaculture. *SANOCEAN Conference, 24–29 September, Oslo, Norway*. (oral presentation)

Cyrus MD, Bolton JJ, De Prisco JA, Geldart M, Brink-Hull M, **Macey BM**. 2023. The ups and downs of water quality within a commercial recirculating IMTA Abalone/*Ulva* system: effects of increased recirculation on critical parameters. *24th International Seaweed Symposium, 19-24 February 2023, Hobart, Tasmania, Australia*. (oral presentation).

da Silva C, **Kerwath SE.** 2023. Fisheries related shark research in South Africa. Do we have our priorities straight? *7th Southern African Shark and Ray Symposium, 24–27 October, Umhlanga, South Africa*. (oral presentation)

da Silva C, Kerwath SE. 2023. Sustainability and fisheries in the WIO: a case study of the South African tuna longline. *Marine Resource Sustainability Challenges in Southern Africa and the West Indian Ocean, 29–30 June, Nelson Mandela University, Gqeberha*. (oral presentation)

Jones CLW, Britz PJ, Courtois de Viçose G, Falade A, **Macey BM**, Madlala N, Mwangudza P, Onomu AJ, Slater M, Vine NG, Weich D, Wu Y. 2023. Recent advances in abalone IMTA in South Africa – the AquaVitae story. *The 11th International Abalone Symposium, 22 February–2 March, Auckland, New Zealand*. (oral presentation)

Kerwath SE, da Silva C. 2023. Sustainable fisheries and socio-economic impacts. *Marine Resource Sustainability Challenges in Southern Africa and the West Indian Ocean, 29–30 June, Nelson Mandela University, Gqeberha*. (oral presentation)

Klein JD, Maduna SN, Dicken ML, **da Silva C**, Soekoe M, McCord ME, Potts WM, Hagen SB, Bester-van der Merwe AE. 2023. Local adaptation with gene flow in the highly dispersive bronze whaler *Carcharhinus brachyurus*. *7th Southern African Shark and Ray Symposium, 24–27 October, Umhlanga, South Africa*. (oral presentation)

Lamberth SJ, **da Silva C**, **Kerwath SE**. 2023. Monitoring and measuring illegal gillnet and other cryptic catches in SA? *7th Southern African Shark and Ray Symposium, 24–27 October 2023, Umhlanga, South Africa*. (oral presentation)

Macey BM, De Vos B, Cyrus MD, Brink-Hull M, Bolton JJ. 2023. Sea urchin aquaculture in South Africa: from research to commercial scale. *AfriMAQUA 2023 Conference, 23–28 October, Mombasa, Kenya*. (oral presentation)

Macey BM, De Vos BC, Cyrus MD, Brink-Hull M, Bolton JJ.

2023. Urchin-*Ulva* IMTA in South Africa: from research to pilot commercial scale. *Aquaculture Europe 2023, 18–21 September, Vienna, Austria*. (oral presentation)

Mansfield LM, **Pitcher GC**, **du Randt A**, Smith M. 2023. The hydrography of Walker Bay and the development of Harmful Algal Blooms. *33rd Congress of the Phycological Society of Southern Africa (PSSA), 23–27 January, Arniston, South Africa.* (oral presentation)

Okkers N, Beukes D, Maneveldt G, **Macey BM**. 2023. Antimicrobial activity of *Ulva* sp. extracts against marine invertebrate and fish pathogens. *33rd Congress of the Phycological Society of Southern Africa (PSSA2023), 23–27 January, The Dunes, Arniston, South Africa*. (oral presentation)

Pitcher GC, **du Randt A**, **Seanego KG**. 2023. St Helena Bay an embayment exhibiting enhanced carbon sequestration. *33rd Congress of the Phycological Society of Southern Africa (PSSA), 23–27 January, Arniston, South Africa.* (oral presentation)

Schäfer I, **Shabangu FW**, *Lamont T*. 2023. Acoustic occurrence and behaviour of baleen whales during winter around Prince Edward Islands. *6th South African National Antarctic Programme Research Symposium, 27 November–1 December, Cape Town, South Africa*. (oral presentation)

Shabangu FW. 2023. How marine mammals respond to underwater ambient noise. *Discovery of Sound in the Sea (DOSITS) Webinar, 25 October, University of Rhode Island and Inner Space Center, Rhode Island, USA*. (invited oral presentation)

Shabangu FW, Daniels R, Jordaan RK, de Bruyn PJN, *van den Berg MA*, *Lamont T*. 2023. Killer whale acoustic patterns respond to prey abundance and environmental variability around the Prince Edward Islands, Southern Ocean. *6th South African National Antarctic Programme Research Symposium, 27 November–1 December, Cape Town, South Africa*. (oral presentation)

Shabangu FW, Jacobs L, *van den Berg M*, **Louw G**, *Lamont T*, Tessaglia-Hymes CT, Klinck H. 2023. Life near the sea ice edge: listening for whales off the Maud Rise, Antarctica. *6th South African National Antarctic Programme Research Symposium, 27 November–1 December, Cape Town, South Africa*. (poster presentation)

Shabangu FW, **Lamberth S**, Madhusudhana S, von den Meden C, **van der Heever G**, Gon O, Truter H. 2023. Rhyming in the cold: fish calls between two sub-Antarctic Islands, Southern Ocean. *6th South African National Antarctic Programme Research Symposium, 27 November–1 December, Cape Town, South Africa*. (poster presentation)

van der Lingen CD. 2023. Biology and ecology of southern African sardine *Sardinops sagax*. *Lecture to University of Bergen MSc students, FRV* GO Sars *Training Cruise, September, Bergen, Norway*.

van der Lingen CD. 2023. Using stable isotopes in studies of marine trophic ecology. *PRIMA Learning Stable Isotope Workshop, 20–23 February, Cape Town, South Africa*. (oral presentation).

van Niekerk L, James N, **Lamberth SJ**, Taljaard S, Adams J, Lemley D, Weerts S, Theron A, *Krug M*. 2023. Evaluating the vulnerability of estuaries to climate change. *DFFE 2023 Integrated Coastal Management Lekgotla: Coastal Planning and Climate Change for South Africa's future, 27 February–1 March*, virtual meeting. (oral presentation)

Yemane D, *Samaai T*, *Kirkman S*. 2023. Changes in species distribution and biodiversity patterns in response to projected climate change off South Africa. *5th International Symposium on Effects of Climate Change on World oceans, 17–21 April, Bergen, Norway*. (oral presentation [recorded video])

Contributions to Workshops, Short Courses, and Management and Scientific Bodies; Unpublished Technical Reports

Akuda T, **Somhlaba S**, Namba T, Sarralde R. 2023. Cap-DLISA: A pilot approach to capacity building to support the development of integrated stock assessments for CCAMLR data limited toothfish research fisheries. *CCAMLR Scientific Committee, October 2023, Hobart, Australia. SC-CAMLR-42/BG04.*

Akuda T, **Somhlaba S**, Namba T, Sarralde R. 2023. Continuation of the research on Antarctic toothfish (*Dissostichus mawsoni*) in Statistical Subarea 48.6 in 2023/24 from a multiyear plan (2021/22–2023/24): Research Plan under CM 21-02, paragraph 6(iii). *CCAMLR Working Group meeting on Statistical Assessment and Modeling, June 2023, Kochi, India. CCAMLR WG-SAM-23/01_Rev1.*

Akuda T, **Somhlaba S**, Ichii T, Namba T, Sarralde R. 2023. Report of research fishing operations at Subarea 48.6 between the 2012/13 and 2022/23 fishing seasons. *CCAMLR Working Group meeting on Fish Stock Assessment, October 2023, Hobart, Australia. CCAMLR WG-FSA-23/42.*

Branch TA, Monnahan CC, Leroy EC, **Shabangu FW**, Širović A, Al Harthi S, Allison C, Balcázar Cabrera N, Barlow DR, Calderan SV, Cerchio S, Double MC, Dréo R, Gavrilov AN, Gedamke J, Hodge KB, Jenner CS, Jenner MN-M, Letsheleha IS, McCauley RD, Miksis-Olds JL, Miller BS, Panicker D, Pierpoint C, Rand ZR, Rogers T, Royer J-Y, Samaran F, Stafford KM, Thomisch K, Torres LG, Torterotot M, Tripovich JS, Warren VE, Willson A, Willson MS. 2023. Further revisions to the historical catch separation of pygmy blue whale populations using contemporary song detections. *International Whaling Commission Meeting,* 24 April–6 May, *Bled, Slovenia*. *SC/69A/SH/09*.

Christison KW. 2023. Self declaration of freedom from diseases. *WOAH Training of National Focal Points for Aquatic Animal* Health (Cycle IV) Workshop, 2–4 October, Kigali, Rwanda.

Christison KW. 2023. South Africa surveillance, monitoring

and reporting. *Launch of the Regional Aquatic Animal Health* Network (Southern Africa) (FISHGOV2) Workshop, 25–27 July, Lusaka, Zambia.

Christison KW. 2023. The Aquatic Animal Health Standards Commission. *Launch of the Regional Aquatic Animal* Health Network (North Africa) (FISHGOV2) Workshop, *25–27 April, Tunis, Tunisia*.

Christison KW. 2023. The Aquatic Animal Health Standards Commission. *Launch of the Regional Aquatic Animal Health Network (Southern Africa) (FISHGOV2) Workshop,* 25–27 July, Lusaka, Zambia.

Cueto PS, Bosch M, **Macey BM**, Brink-Hull M, Waters C, O'Donohoe P, Poérche L, Chalde T, Bagi A, Michalek K, Sandoval MM, Vermeulen F. 2023. Deliverable 5.3. Monitoring of microbial diversity and early warning of pathogens. All Atlantic Ocean Sustainable, Profitable, and Resilient Aquaculture (ASTRAL) project. Grant Agreement no. 863034. https://zenodo.org/records/10849143.

da Silva C, Lamberth SJ, Kerwath SE. 2023. National Plan of Action Workshop: National Shark Research Forum. *7th Southern African Shark and Ray Symposium, 24–27 October, Umhlanga, South Africa*.

da Silva C, Lamberth SJ, Kerwath SE. 2023. Research prioritisation to manage sharks and rays in South African fisheries. *IOTC-2023-WPEB19-10*.

da Silva C, Meyer MR, Kerwath SE. 2023. Catch by species and fishing effort by type of fishery, geographic area and month strata (fleets not providing logbook information). *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/ Hybrid. FORM 3: _ Form_3AR_rev20_ZAF_2023.*

da Silva C, Meyer MR, Kerwath SE. 2023. Catch by species in number (or live weight) and effort in number of hooks set by 1° grid area and month strata (extrapolated to annual catch) (fleets providing logbook information). *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. Form_ 3CE_rev20_ZAF_2023.*

da Silva C, Meyer MR, Kerwath SE. 2023. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/ Hybrid. FORM 1B: DISCARD_Form_1DI_rev20_ ZAF_Cetaceans_2023.* [Cetaceans]

da Silva C, Meyer MR, **Kerwath SE**. 2023. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. FORM 1B: DISCARD_Form_1DI_rev20_ZAF_ Mobulids_2023.* [Mobulids]

da Silva C, Meyer MR, Kerwath SE. 2023. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. FORM 1B: DISCARD_Form_1DI_rev20_ZAF_ Seabirds_2023*. [Seabirds]

da Silva C, Meyer MR, Kerwath SE. 2023. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. FORM 1B: DISCARD_Form_1DI_ rev20_ZAF_ Sharks_2023. [Sharks]*

da Silva C, Meyer MR, Kerwath SE. 2023. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. FORM 1B: DISCARD_Form_1DI_rev20_ZAF_ Thresher Sharks _2023*. [Thresher sharks]

da Silva C, Meyer MR, Kerwath SE. 2023. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. FORM 1B: DISCARD_Form_1DI_rev20_ZAF_ Tuna_2023*. [Tuna]

da Silva C, Meyer MR, Kerwath SE. 2023. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. FORM 1B: DISCARD_ Form_1DI_rev20_ZAF_ Turtles_2023*. [Turtles]

da Silva C, Meyer MR, Kerwath SE. 2023. Estimates of total annual discard levels in live weight (or number) by IOTC area, species and type of fisher. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/ Hybrid. FORM 1B: DISCARD_Form_1DI_rev20_ ZAF_Whale Shark_2023* [Whale sharks]

da Silva C, Meyer MR, Kerwath SE. 2023. Length/weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid.Form_4SF_rev20_ZAF_ ALB_2023.* [Albacore tuna]

da Silva C, Meyer MR, Kerwath SE. 2023. Length/weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. Form_4SF_rev20_ZAF_ BET_2023*. [Bigeye tuna]

da Silva C, Meyer MR, Kerwath SE. 2023. Length/weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. Form_4SF_rev20_ZAF_ BSH_2023*. [Blue shark]

da Silva C, Meyer MR, Kerwath SE. 2023. Length/weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid.Form_4SF_rev20_ZAF_ SBF_2023*. [Southern bluefin tuna]

da Silva C, Meyer MR, Kerwath SE. 2023. Length/weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. Form_4SF_rev20_ZAF_*

SMA_2023. [Mako shark]

da Silva C, Meyer MR, Kerwath SE. 2023. Length/weight data by species, type of fishery and 5° grid area and month strata. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid.Form_4SF_rev20_ ZAF_SWO_2023*. [Swordfish]

da Silva C, Meyer MR, Kerwath SE. 2023. Reported catches summary binary matrix of annual records of retained catches or discards by species and fishery group. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. Resolution 18/07_Form1_DR_v1.0_ Rev20*.

da Silva C, Meyer MR, Kerwath SE. 2023. TASK 1 – nominal catches. *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing Committee on* Research and Statistics (SCRS), 25–29 September, *Hybrid/Madrid (Spain). ST02_ZAF2022-21P-NF#E21-07251 _2022.*

da Silva C, Meyer MR, Kerwath SE. 2023. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing* Committee on Research and Statistics (SCRS), 25–29 *September, Hybrid/Madrid (Spain). ST04_ZAF-BET2022-21P-NP_2022.* [Bigeye tuna]

da Silva C, Meyer MR, Kerwath SE. 2023. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing* Committee on Research and Statistics (SCRS), 25–29 *September, Hybrid/Madrid (Spain). ST04_ZAF-BSH2022-21P-NP_2022.* [Blue shark]

da Silva C, Meyer MR, Kerwath SE. 2023. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing* Committee on Research and Statistics (SCRS), 25–*29 September, Hybrid/Madrid (Spain). ST04_ZAF-SBF2022-21P-NP_2022.* [Southern bluefin tuna]

da Silva C, Meyer MR, Kerwath SE. 2023. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing* Committee on Research and Statistics (SCRS), 25–29 *September, Hybrid/Madrid (Spain). ST04_ZAF-SMA2022-21P-NP_2022.* [Mako shark]

da Silva C, Meyer MR, Kerwath SE. 2023. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing* Committee on Research and Statistics (SCRS), 25–29 *September, Hybrid/Madrid (Spain). ST04_ZAF-SWO2022-21P-NP_ 2022.* [Swordfish]

da Silva C, Meyer MR, Kerwath SE. 2023. Task 2 – size sampling (tunas and sharks). *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing* Committee on Research and Statistics (SCRS), 25–29 *September, Hybrid/Madrid (Spain). ST04_ZAF-YFT2022-21P-NP_2022.* [Yellowfin tuna]

da Silva C, Meyer MR, Kerwath SE. 2023. Task 3 – domestic observer program data. *International Commission for the Conservation of Atlantic Tunas, Meeting of the Standing* Committee on Research and Statistics (SCRS), 25–29 *September, Hybrid/Madrid (Spain). ST09_ZAF2021-21P-NP_2022.*

da Silva C, Meyer MR, Kerwath SE. 2023. Total annual retained catches in live weight by IOTC area, species and type of fishery. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. FORM 1: NOMINAL CATCH_Form1_RC_ rev20_ZAF_2023.*

Dupont C, O'Donohoe P, Smith M, Poersch L, **Macey BM**, Michalak K. 2023. Deliverable 2.10. Technology validation and recommendations for improvement. All Atlantic Ocean Sustainable, Profitable, and Resilient Aquaculture (ASTRAL) project. Grant Agreement no. 863034. https://zenodo.org/records/10848542.

Durholtz D. 2023. SA hake genetics and stock structure. *Background presentation to the DFFE-MARAM International Stock Assessment Review Workshop, 28 November–1 December, Cape Town, South Africa*. MARAM/IWS/2023/HAKE/P1.

Durholtz D. 2023. Excerpt from the 2019 IWS panel report pertaining to SA hake stock structure. *Background paper tabled at the DFFE-MARAM International Stock Assessment Review Workshop, 28 November–1 December, Cape Town, South Africa. MARAM/IWS /2023/Hake/BG2.*

Githaiga-Mwicigi J. 2023. Anchors and the South African squid jig fishery a DEEPLY rooted issue? *The South African Squid Management and Industrial Association (SASMIA) Annual General Meeting (AGM), 9 June, Gqeberha, South Africa.*

Githaiga-Mwicigi J. 2023. Squid research at DFFE. *The South African Squid Management and Industrial Association (SASMIA) Annual General Meeting (AGM), 9 June, Gqeberha, South Africa.*

Githaiga-Mwicigi J, **Glazer J**, **Louw GG**, **Durholtz D**. 2023. The South African commercial squid jig fishery. *International Stock Assessment Workshop (IWS), 27* November–1 December, *Cape Town, South Africa*. *MARAM/Squid/Pres1.*

Lamberth SJ. 2023. Estuarine fish and fisheries: research, monitoring and management. Management of estuaries in South Africa: short learning course programme, August, Nelson Mandela University, Gqeberha.

Lamberth SJ. 2023. Monitoring and measuring illegal gillnet bycatch of birds, sharks, mammals and reptiles in SA? Top Predator SWG, Department of Forestry, Fisheries and the Environment, September, Cape Town, South Africa.

Lamberth SJ, van Niekerk L 2023. Verlorenvlei estuarine lake environmental water requirements: pyrite dissociation in Verlorenvlei. Verlorenvlei Intergovernmental Task Team, April, Elands Bay.

Lamberth SJ, *Krug M*, Olbers J. 2023. Monitoring and measuring illegal gillnet catch and effort in SA. Developing a tool to identify hotspots and evaluate catch and effort trends in the illegal gillnet fishery. *Operation Phakisa Workshop, October, Strand,*

South Africa.
Macey BM. 2023. IMTA Lab South Africa. *All Atlantic Ocean Sustainable, Profitable, and Resilient Aquaculture (ASTRAL) 3rd Annual Meeting, 17–18 September, Vienna, Austria.* (oral presentation)
Macey BM. 2023. Sustainable strategies for improving health in intensive aquaculture systems. AfriMAQUA 2023 Conference and Marine Aquaculture Training Programme, 27–28 October, Mombasa, Kenya. (lecture)
Macey BM. 2023. Sustainable strategies for improving health of intensive aquaculture systems. Joint AfriMAQUA/ LIMAQUA Integrated Aquaculture Training Module, 19–22 June, Marine Research Aquarium, Sea Point, Cape Town. (lecture)
Makhado A, Huggett J, Dakwa F, Mdluli N, **Shabangu FW**, Koubbi P, Cotté C, Djian V, Goberville E, Izard L, Leroy B, Merland C, Rintz CL, Thellier M, Swadling K, Melvin J, Kitchener J, Brokensha L, Reisinger R. 2023. Baseline spatial data prior to the ecoregionalisation of the Eastern Sub-Antarctic Region. *Commission for the Conservation of Antarctic Marine Living Resources, Tasmania, Australia.*
Meyer MR, Kerwath SE, Mketsu Q. 2023. IOTC record of *vessels authorized to operate in the IOTC Area. IndianOcean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India) /Hybrid. Res_19_04_ Record_of_IOTC_ AFVs_E.*
Meyer MR, Kerwath SE, Mketsu Q. 2023. Resolution 21/01 on an interim plan for rebuilding the Indian Ocean yellowfin tuna stock in the IOTC area of competence for 2021. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8*

December, Mumbai (India) /Hybrid.Res_21_01_ Reporting_template_for_active_vessels_YFT_E_F_ ZAF.
Mketsu Q, Kerwath SE, Parker D, **Meyer MR, da Silva C, Nonkeneza A**, Mamaila B. 2023. Rules of Procedures – Appendix V Compliance Questionnaire for the year 2022 (CoC20). *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. IOTC-2023-CoC20-CQ04[E].*
Namba T, Sarralde R, Ichii T, Okuda T, **Somhlaba S**, Pompert J. 2023. Updated analysis of the sea-ice concentration in research blocks 4(RB4) and 5(RB5) of Subarea 48.6 with sea-surface temperature and winds and statistical analysis of repeated accessibility. *CCAMLR Working Group meeting on Statistical Assessment and Modeling, June 2023, Kochi, India. CCAMLR WG-SAM-23/24.*
O'Donohoe P, Casserly J, Waters C, Sanchez I, Checa D, **Macey BM**, Poersch L, Macleod A, Michalek K, Chalde T. 2023. Deliverable 4.4. ASTRAL IMTA systems' compliancy to eco-value chain standards and recommendations. All Atlantic Ocean Sustainable, Profitable, and Resilient Aquaculture (ASTRAL) project. Grant Agreement no. 863034. https://zenodo.org/records/10777250.
Shabangu FW, Buchan S, Barlow D, Branch T, Cerchio S, McCauley R, Miller B, Samaran F, Sirovic A, Sousa-Lima R, Stafford K, Torres L. 2023. Low- and mid-latitude analysis of Antarctic blue whale song to establish any differences between wintering grounds: progress and future work. *International Whaling Commission Meeting,* Bled, Slovenia, 24 April–6 May. *SC/69A/SH/WP05*.
Shabangu FW, Stafford KM, Branch T, Vermeulen E, van den Berg M, *Lamont T*, Munoz T, van Uffelen L. 2023. Passive acoustic monitoring of marine mammals around Prince Edward Islands, southern Indian Ocean. *International* Whaling Commission Meeting, Bled, Slovenia, 24 April–6 *May*. *SC/69A/SH/WP02*.
van der Heever G, van den Heever N, Nkwenkwe M. 2023. South Coast rock lobster (SCRL) fishing activity in two proposed shark and ray sanctuaries. DFFE Sharks and Rays Inception Meeting, October, virtual meeting.
West W, da Silva C, Mketsu Q, Meyer MR, Kerwath SE. 2023. South Africa National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2023. *Indian Ocean Tuna Commission, 26th Session of the IOTC Scientific Committee, 4–8 December, Mumbai (India)/Hybrid. IOTC–2023-SC26-NR24*.

Unpublished Working Group Documents

Auerswald L, Glazer JP. 2023. Season amendments as requested by stakeholders in comparison with existing season limits. *FISHERIES/2023/AUG/ SWG/WCRL24*. Department of Forestry, Fisheries and the Environment, Cape Town.
Auerswald L, Butterworth DS, Johnston SJ, **Glazer JP**, Bergh M, **van Zyl DL, van der Heever G, Schultz LS**. 2023. Recommendations of the Rock Lobster Scientific Working Group for the sustainable management of the West Coast rock lobster resource for the 2023/2024 season. *FISHERIES/2023/AUG/SWG/WCRL26*. Department of Forestry, Fisheries and the Environment, Cape Town.
Auerswald L, Butterworth DS, Johnston SJ**, Glazer JP, van den Heever ND, van der Heever G**. 2023. Recommendations of the Rock Lobster Scientific Working Group for the sustainable management of the South Coast rock lobster resource for the 2023/24 season. *FISHERIES/2023/ AUG/SWG/ SCRL/09*.Department of Forestry, Fisheries and the Environment, Cape Town.
Auerswald L, Everett B, Fenessy S, **van den Heever ND, van der Heever G, Nkwenkwe M**. 2023. Recommendations of the Crustacean Trawl Scientific Working Group for the sustainable management of the Crustacean Trawl fishery for 2024. *FISHERIES/2023/AUG/SWG/CT/03*. Department of Forestry, Fisheries and the Environment, Cape Town.
da Silva C, Lamberth SJ Kerwath SE. 2023. A national strategy for the conservation of South African fisheries: prioritizing Chondrichthyes for research, conservation and management. A research plan for Chondrichthyes

in South Africa. Unpublished DFFE report. Department of Forestry, Fisheries and the Environment, Cape Town.
da Silva C, Lamberth SJ, Kerwath SE. 2023. Research prioritisation to manage sharks and rays in South African Fisheries. Unpublished DFFE report. Department of Forestry, Fisheries and the Environment, Cape Town.
da Silva C, Olbers J, Cliff G, **Lamberth SJ, Kerwath SE.** 2023. Literature review on all shark and rays impacted by South African Fisheries. Large Pelagic and Sharks Scientific Working Group document. *PSSWG 2023 November#5*. Department of Forestry, Fisheries and the Environment, Cape Town.
Durholtz D. 2023. DFFE demersal research 2023. Demersal Scientific Working Group document. *FISHERIES/2023/ JUN/SWG-DEM/02.* Department of Forestry, Fisheries and the Environment, Cape Town.
Durholtz D. 2023. Squid jig catch and effort update. Squid Scientific Working Group document. *FISHERIES/2023/ APRIL/SWG-SQ/06.* Department of Forestry, Fisheries and the Environment, Cape Town.
Fairweather TP. 2023. Examination of catch and effort distribution for the Dual Right midwater fleet and the *Desert Diamond*. *FISHERIES/2023/OCT/ SWG-DEM/20*. Department of Forestry, Fisheries and the Environment, Cape Town.
Fairweather TP. 2023. HMKC input data. *FISHERIES/2023/ OCT/SWG-DEM/07*. Department of Forestry, Fisheries and the Environment, Cape Town.
Fairweather TP. 2023. Standardised survey abundance estimates for key commercial species 2017–2023. *FISHERIES/2023/SEP/SWG-DEM/06*. Department of Fore -stry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. Feedback from the International Stock Assessment Workshop. 2023. *FISHERIES/2023/DE -CEMBER/SWG-SQ/21*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. June Squid Survey-Scientific Cruise Report. *FISHERIES/2023/DECEMBER/ SWG-SQ/23*. Depa -rtment of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. November 2022 Squid acoustic survey: overall cruise report. *FISHERIES/2023/ DECE -MBER/SWG-SQ/08*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. November squid survey-summary report presentation. *FISHERIES/2023/DECEMBER/ SWG-SQ/26*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. Possible adjustments to the 2022/23 additional squid closed season. *FISHERIES/2023/MARCH /SWG-SQ/05*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. Research plan for the squid resource. *FISHERIES/2023/MARCH/SWG-SQ/01*. Department of Forest -ry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. Squid jig monthly catch data. *FISHERIES/2023/MARCH/SWG-SQ/02*. Department of Forestry, Fisheries and the Environment. Cape Town.
Githaiga-Mwicigi J. 2023. The gazetted October/November squid closed season. *FISHERIES/2023/ DECEMBER/SWG-SQ/27*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. Towards developing a new stock assessment model: application of Industry's chokka squid catch size grading. *FISHERIES/2023/ DECEMBER/SWG-SQ/19*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J. 2023. Towards developing a new stock assessment model: collation of monthly sex-aggregated length-frequency squid data. *FISHERIES/2023/DECEMBER/SWG-SQ/20*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J (with the Squid SWG members). 2023. Further TAE scientific recommendation for the squid resource 2022–23. FISHERIES/2023/ MARCH/SWG-SQ/07. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J (with the Squid SWG members). 2023. Squid 2023–24 TAE scientific recommendation. FISHERIES/2023/APRIL/SWG-SQ/17Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J et al. 2023. June squid closed season research plan. *FISHERIES/2023/DECEMBER/ SWG-SQ/11a*. Department of Forestry, Fisheries and the Environment, Cape Town.
Githaiga-Mwicigi J, Yemane D, Hampton I. 2023. The diurnal changes project. *FISHERIES/2023/APRIL/ SWG-SQ/12.* Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2023. An index of abundance for Zone A West Coast rock lobster. *FISHERIES/2023/JUL/SWG-WCRL/09*. Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2023. South Coast rock lobster standardized CPUE indices per area. *FISHERIES/2023/JULY/ SWG/SCRL/04*. Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2023. Standardized CPUE indices per super-area in the West Coast rock lobster hoopnet fishery. *FISHERIES/2023/ JUL/SWG-WCRL07*. Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2023. Standardized CPUE indices per super-area in the West Coast rock lobster trapboat fishery. *FISHERIES/2023/ JUL/SWG-WCRL08*. Department of Forestry, Fisheries and the Environment, CapeTown.
Glazer JP. 2023. Standardized offshore hake CPUE indices and catches for the period 1978–2022. *FISHERIES/2023/OCT/SWG-DEM/16*. Department of Forestry, Fisheries and the Environment, Cape Town.
Glazer JP. 2023. South Coast rock lobster standardized CPUE indices per area. *FISHERIES/2023/JULY/ SWG/SCRL/04*. Department of Forestry, Fisheries and the Environment, Cape Town.

Glazer JP. 2023. The separation of catch by area in the South Coast rock lobster fishery. *FISHERIES/2023/JULY/ SWG/SCRL/05 REVISED*. Department of Forestry, Fisheries and the Enviro -nment, Cape Town.

Glazer JP, **Fairweather TP**. 2023. Standardized offshore hake CPUE indices and catches for the period 1978–2022. *FISHERIES/2023/OCT/SWG-DEM/16*. Department of Fore -stry, Fisheries and the Environment, Cape Town.

Glazer JP, **Fairweather TP**, **Durholtz MD**. 2023. Sole dynamic Schaefer production model results. *FISHERIES/2023/ NOV /SWG-DEM/22*. Department of Forestry, Fisheries and the Environment, Cape Town.

Hampton I, Soule M, **Githaiga-Mwicigi J**. 2023. Squid monitoring program: concept squid survey programme. *FISHERIES/2023/ APRIL/SWG-SQ/12*. Department of Forestry, Fisheries and the Environment, Cape Town.

Kerwath SE. 2023. Seventy-four Research Plan. *FISHERIES/ LSWG /#4/Aug 2023*. Department of Forestry, Fisheries and the Environment, Cape Town.

Lamberth SJ, de la Cruz Y, da Silva C, Kerwath SE. 2023. Recommendations of the Linefish Scientific Working Group for the sustainable management of linefish resources. *FISHERIES/2022/LSWG/01*. Department of Forestry, Fisheries and the Environment, Cape Town.

Lamberth SJ, Meyer MR, de la Cruz Y, da Silva C, Kerwath SE. 2023. Recommendations of the Linefish Scientific Working Group for the sustainable management of demersal shark longline resources. *FISHERIES/2022/ LSWG/02*. Department of Forestry, Fisheries and the Environment, Cape Town.

Rothman MD, **Auerswald L**, **Boonzaaier-Davids M**, **Conrad S**. 2023. Recommendations of the Abalone Scientific Working Group for the sustainable management of abalone for the 2023/24 season. *FISHERIES/2023/ OCT/SWG/ABA01*. Department of Forestry, Fisheries and the Environment, Cape Town.

Rothman MD, **Auerswald L**, **Kemp D**, **Boothroyd CJT**. 2023. Recommendation of the Small Invertebrates and Seaweeds Scientific Working Group for the sustainable management of seaweed resources for the season March 2024 to February 2025. *FISHERIES/2023/OCT/SWG/SIS01*. Department of Forestry, Fisheries and the Environment, Cape Town.

Shabangu FW. 2023. Interim recommendations of the Small Pelagic Scientific Working Group for the sustainable management of small pelagic resources for the season 2024. *FISHERIES/2023/DEC/ SWG-PEL/28*. Department of Forestry, Fisheries and the Environment, Cape Town.

Shabangu FW. 2023. Recommendations of the Small Pelagic Scientific Working Group for the final sardine total allowable catch. *FISHERIES/2023/OCT/SWG-PEL/19*. Department of Forestry, Fisheries and the Environment, Cape Town.

Shabangu FW. 2023. Recommendation of the Small Pelagic Scientific Working Group for the final small pelagic total allowable catch, total allowable by-catch and precautionary upper catch limit for the 2023 fishing season. *FISHERIES/2023/JUL/SWG-PEL/16.* Department of Forestry, Fisheries and the Environment, Cape Town.

Shabangu FW, **Coetzee JC**, **Phillips M**, Maliza L, **Geja Y**, **April W**, Ntiyantiya D, **Peterson J**, Jarvis G, van Neel M, Zweni S, Mahlati O, Mxunyelwa N, Louw A, Adonis V, Jansen M, Nzimande P, **Merkle D**. 2023. Results of the 2023 pelagic recruit survey. *FISHERIES/2023/JUL/SWG-PEL/11*. Depart ment of Forestry, Fisheries and the Environment, Cape Town.

Soule M, **Githaiga-Mwicigi J**. 2023. June squid survey-acoustic presentation. *FISHERIES/2023/ DECEMBER/SWG-SQ/25*. Department of Forestry, Fisheries and the Environment, Cape Town.

van den Heever N, Nkwenkwe M, Senyolo T. 2023. Extraction and repairs affected to the Crustacean Trawl Fishery data for 2022. *FISHERIES/2023/AUG/SWG/ CT/01*. Department of Forestry, Fisheries and the Environment, Cape Town.

van der Lingen CD. 2023. Comparing finer-resolution spatial patterns in prevalence-at-length of sardine during October to December 2010–2022. *FISHERIES/2023/ SEP/SWG-PEL/18*. Department of Forestry, Fisheries and the Environment, Cape Town.

van der Lingen CD. 2023. Concerns regarding the use of *Cardiocephaloides* spp as a parasite biotag for South African sardine stock identification and estimations of inter-stock movement. *FISHERIES/2023/NOV/SWG-PEL/26*. Department of Forestry, Fisheries and the Environment, Cape Town.

van der Lingen CD. 2023. Latest understanding of climate change impacts on the spatial distribution of anchovy and sardine off South Africa. Document 5.1 submitted to the African Penguin International Review Panel, Cape Town, July 2023.

van der Lingen CD. 2023. The temporal pattern of South African anchovy catches over the past decade (2013–2022). *FISHERIES/2023/SWG-PEL/JUL/14*. Department of Forestry, Fisheries and the Environment, Cape Town.

van der Lingen CD, de Moor CL, **Coetzee JC**. 2023. Available data for determining the occurrence and distribution of cool temperate and warm temperate sardine components by life history stage. *FISHERIES/2023/ MAY/SWG-PEL/9rev* and *MARAM/IWS/2023/Sardine/ P2*. Department of Forestry, Fisheries and the Environment, Cape Town and University of Cape Town, Cape Town.

van Zyl D, van der Heever GM, Auerswald L. 2023. Preliminary results on research investigating the eastward expansion of the WCRL resource. *FISHERIES/2023/ SEPT/SWG/WCRL25*. Department of Forestry, Fisheries and the Environment, Cape Town and University of Cape Town, Cape Town.

West W, da Silva C, Kerwath SE. 2023. Population structure of swordfish across the ICCAT/IOTC management boundary. *IOTC-2023-WPB21-09*. Department of Forestry, Fisheries and the Environment, Cape Town and University of Cape Town, Cape Town.

Notes