STATUS OF THE SOUTH AFRICAN MARINE FISHERY RESOURCES 2016






agriculture, forestry & fisheries

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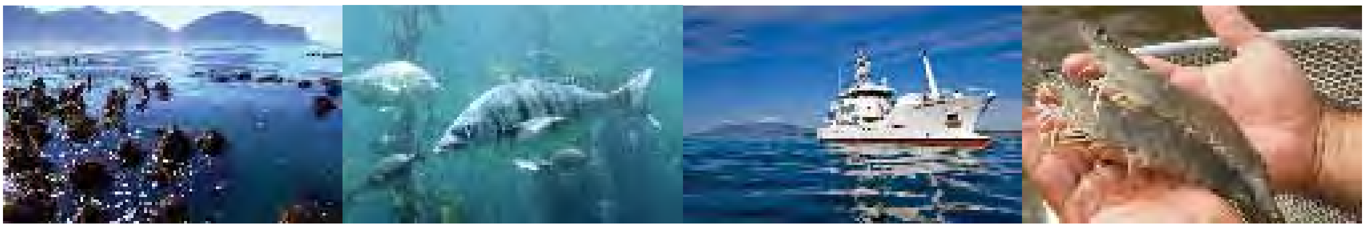
Acronyms and abbreviations

ASPM	Age-Structured Production Model
BCC	Benguela Current Commission
BRUV	Baited Remote Underwater Video
CAL	Catch-at-length
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CITIES	Convention for International Trade in Endangered Species
CL	Carapace Length
CoG	Centre of Gravity
CPUE	Catch Per Unit Effort
DAFF	Department of Agriculture, Forestry and Fisheries
EAF	Ecosystem Approach to Fisheries
EC	Exceptional Circumstances
EEZ	Exclusive Economic Zone
EFZ	Exclusive Fishing Zone
ERA	Ecological Risk Assessment
FIAS	Fishery-Independent Abalone Survey
FIMS	Fishery-Independent Monitoring Survey
FMA	Fishery Management Area
FMSY	Fishing mortality that would produce MSY level
FRAP	Fishing Rights Allocation Process
GERMON	Genetic Structure and Migration of Albacore Tuna Project
GIS	Geographic Information System
GLM	General Linear Model
GLMM	General Linear Mixed Model
ICCAT	International Convention for the Conservation of Atlantic Tunas
ICSEAF	International Commission for the South East Atlantic Fisheries
IFREMER DIO	French Research Institute for Exploration of the Sea, Indian Ocean Delegation
IOTC	Indian Ocean Tuna Commission
IUCN	International Union for Conservation of Nature
IUU	Illegal, Unreported and Unregulated fishing
KZN	KwaZulu-Natal
LMP	Linefish Management Protocol
MLRA	Marine Living Resources Act
MLS	Minimum Legal Size
MPA	Marine Protected Area
MSC	Marine Stewardship Council
MSY	Maximum Sustainable Yield
NMLS	National Marine Linefish System
NPOA	National Plan of Action
NRCS	National Regulator for Compulsory Standards
OMP	Operational Management Procedure
ORI	Oceanographic Research Institute
PBS	Pelagic Biomass Survey
PEI-EEZ	Prince Edward Island Exclusive Economic Zone
PMCL	Precautionary Maximum Catch Limit
PSAT	Pop-up Satellite Archival Tag
PUCL	Precautionary Upper Catch Limit
RFA	Responsible Fisheries Alliance
RFMO	Regional Fisheries Management Organization
RY	Replacement Yield
SADSTIA	South African Deep-Sea Trawling Industry Association
SAEON	South African Environmental Observation Network
SANBI	South African National Biodiversity Institute
SASSI	South African Sustainable Seafood Intiative
SECIFA	South-East Coast Inshore Fishing Association
SB	Shell Breadth
SPOT	Smart Position-only Tag
SSB	Spawning Stock Biomass
SSBMSY	Spawning Stock Biomass at MSY Level
SWIO	Southwest Indian Ocean
SWIOFP	Southwest Indian Ocean Fisheries Programme
TAB	Total Allowable By-catch
TAC	Total Allowable Catch
TAE	Total Allowable Effort
TRAFFIC	The Wildlife Trade Monitoring Network
TURF	Territorial User Rights in Fisheries
UCT	University of Cape Town
USA	United States of America
WWF	World Wide Fund for Nature



Overview

This report presents the most up-to-date information and analyses of the status of marine fishery resources in South Africa at the time of compilation. The number of fish stocks covered in this report has increased from 43 in 2012 to 45 in 2014, and to 52 in the current report.

The latest assessments indicate that a total of 52% of stocks are considered not to be of concern (blue and green categories)[1] , while 48% of stocks are of concern (orange and red categories). These figures indicate an improvement over the past six years, with 46% of stocks being considered not to be of concern in 2012 and 49% in 2014.

There are some changes to the perception[2] of certain fish stocks since the previous reports in 2012 and 2014. The number of stocks for which the status and fishing pressure are unknown has increased slightly since the two previous reports. This is due to the inclusion of geelbek and santer for the first time in the report in 2016. The number of stocks considered under-utilised has remained the same since the last report.

The number of stocks which are considered to be in an optimal state has increased from 15 in 2012 to 16 in 2014, and 20 in 2016. This can largely be attributed to the inclusion for the first time in this report of monkfish and kingklip, and the improved perception of the status of albacore (both Indian and Atlantic Ocean stocks), swordfish (Indian Ocean stock) and blue sharks which have resulted from improvements in assessments by the relevant Regional Fisheries Management Organizations (IOTC and ICCAT).

Table 1. Number and percentage of stocks considered of concern or not.

	2012	2014	2016
Stocks not of concern	20 (46%)	22 (49%)	27 (52%)
Stocks of concern	23 (54%)	23 (51%)	25 (48%)
Number of stocks assessed per year	**43**	**45**	**52**

The number of stocks which are considered to be of concern has remained the same from 2014 to this report. However, the number of stocks considered to be over-exploited has continued to increase from 12 in 2012 to 13 in 2014 and to 15 in 2016. Two of the deteriorations since 2014 represent deteriorations in the perception of stock status (Atlantic Ocean bigeye tuna and Indian Ocean yellowfin tuna), while the third arises from the inclusion for the first time of dusky kob in this report.

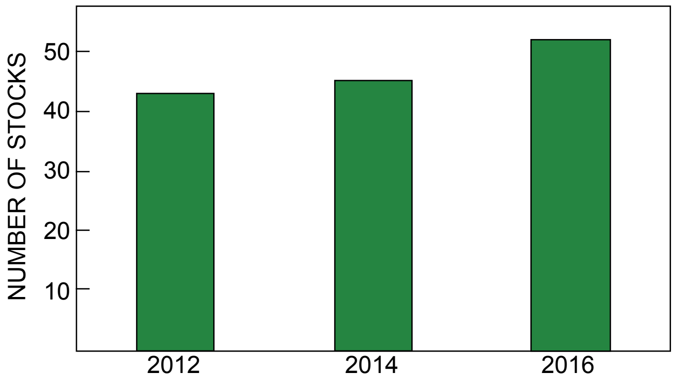


Figure 1. The number of fish stocks assessed between 2012 and 2016.

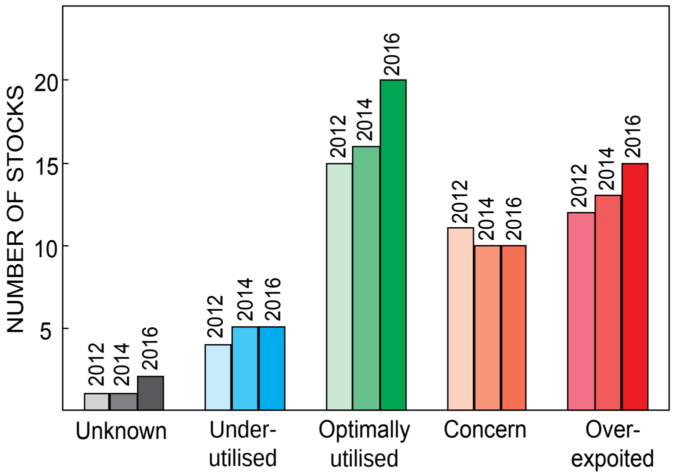


Figure 2. Number of fish stocks according to status 2012, 2014 and 2016.

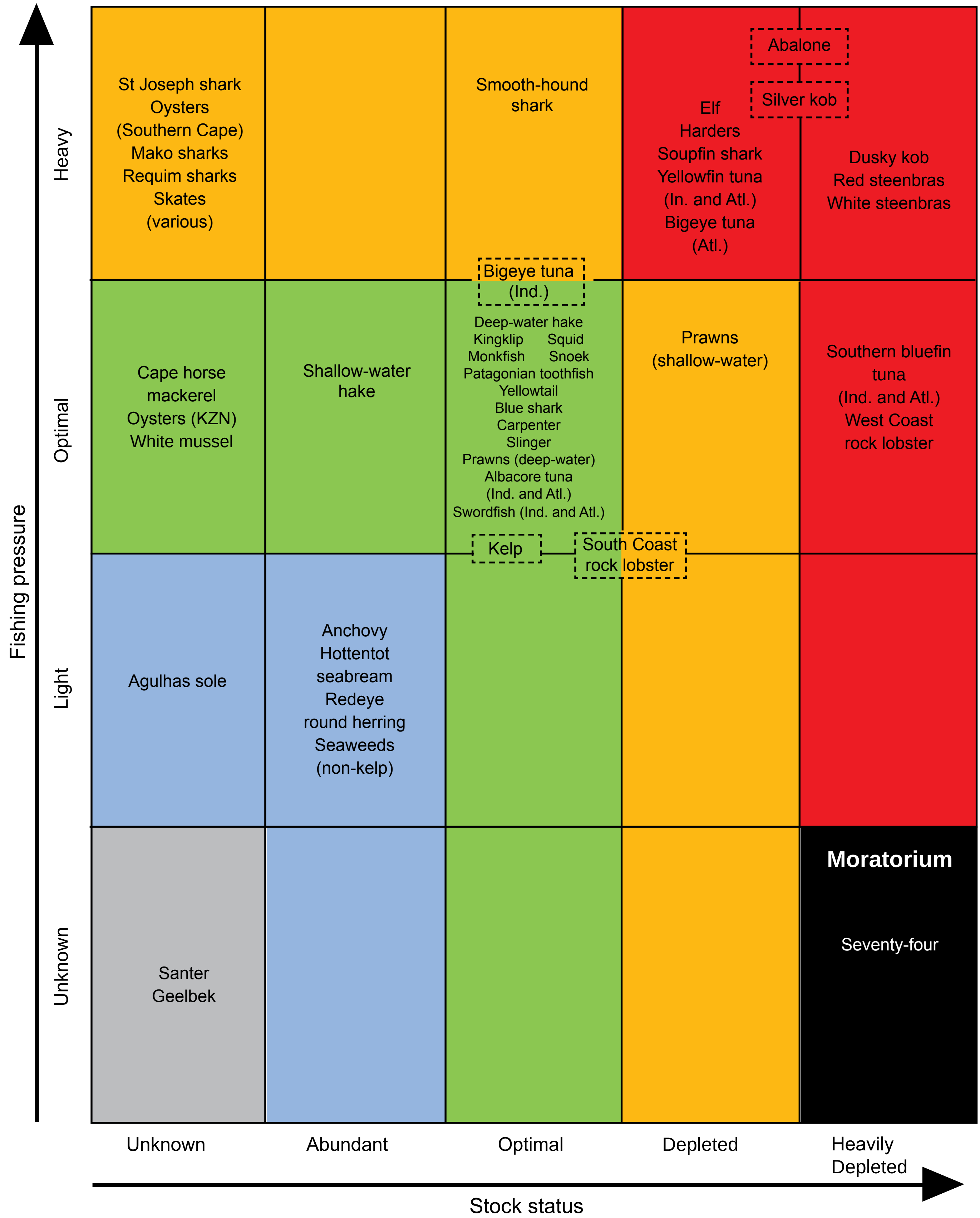
The following is a brief summary for each resource:

- **Abalone:** The status of the abalone resource continues to decline in response to extremely high levels of illegal harvesting and over-allocation of Total Allowable Catches.
- **Agulhas sole:** Uncertainty still remains regarding the true status of the Agulhas sole stocks. Total Allowable Catches have been reduced, and a fishing effort restriction implemented in recent years in the event that the low catch rates are indicative of declining abundance of the sole resource.
- **Cape hakes:** The deep-water hake resource is currently below the target Maximum Sustainable Yield Level. The resource is currently being managed to bring it back up to this level through reductions in annual catches. Shallow-water hake remains well above the estimated Maximum Sustainable Yield Level.
- **Cape horse mackerel:** The most recent assessment for Cape horse mackerel indicated a decline in catch rates that may indicate declines in the abundance of this resource. Total Allowable Catches have been reduced, and effort limitation implemented in response.

[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 'worse case scenario'.

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

- **Kingklip:** The kingklip resource is estimated to be at about 40% of the pre-fished biomass, and thus close to the target Maximum Sustainable Yield Level, and the Precautionary Upper Catch Limit for this resource has remained stable in recent years as a result.
- **Linefish:** Stocks of hottentot seabream, carpenter, slinger, snoek and yellowtail are considered to be in good condition and are not over-fished. However, many other stocks are still in a depleted or heavily depleted state, and continue to be over-fished. Collapsed resources, such as seventy-four, red steenbras, dageraad, spotted grunter and dusky kob, require stronger intervention in order to rebuild stocks.
- **Netfish:** Previous improvements in the abundance of harders, the main target of the beach-seine and gill-net fisheries, have been eroded by an increase in illegal harvesting of these resources and by adverse environmental conditions which disrupt breeding cycles.
- **Oysters:** The oyster resource along the KwaZulu-Natal coast is considered to be optimally exploited, although uncertainty remains around the actual stock status. Similar uncertainty also remains regarding the status of oysters in the Southern Cape. Their level of exploitation, considered to be heavy, together with illegal harvesting from sub-tidal "mother beds", remain causes for concern.
- **Patagonian toothfish:** Recent assessment of the Patagonian toothfish resources indicated that uncertainties still remain around the true status of the resource, largely due to the difficulties of accounting for the removal of fish from longlines by predatory marine mammals in the Catch Per Unit Effort index.
- **Prawns:** Deep-water prawns are considered to be optimally exploited. The status of shallow-water prawns is, however, considered to be depleted, largely due to the closure of the mouth of the St Lucia Estuary blocking the recruitment of shallow-water prawns to the Thukela Bank.
- **Seaweeds:** Kelp resources are considered optimally exploited and stable in most areas, although some areas offer the opportunity for greater harvesting. Other seaweed resources generally also offer opportunities for increased harvesting.
- **Sharks:** Concerns around the stock status and harvesting rates remain for most shark resources. A paucity of reliable data for both directed catch and by-catch results in high levels of uncertainty around stock status for most shark resources.
- **Small invertebrates and new fisheries:** Despite ongoing and increased harvesting of white mussels in recent years, an ongoing shortage of data results in the status of, and fishing pressure on, this and other small invertebrate resources remaining uncertain. A number of potential new fisheries are currently under investigation, including octopus, whelks and crabs, redbait, and redeye round herring in KwaZulu-Natal.
- **Small pelagic fishes:** Small pelagic fishes are characterized by high levels of natural variability. Sardine stocks remain at a low level, likely in response to some years of poor recruitment and to unfavourable anomalous environmental conditions on the South Coast in recent years. Anchovy stocks are currently high, and it is thought that a number of interacting factors are contributing to the under-catches of the Total Allowable Catch in recent years.
- **South Coast rock lobster:** The South Coast rock lobster resource is considered to be in an optimal to depleted state. In order to ensure rebuilding of the stock, fishing pressure on this resource is being maintained at light to optimal levels.
- **Squid:** The squid resource is currently estimated to be at around 30% of its pre-fished level, and the resource is not as productive as was previously thought. Fishing effort has been adjusted to be appropriate to this new perception of the resource.
- **Tunas and swordfish:** Stock assessments and country allocations for tunas and swordfish are the responsibility of the relevant Regional Fisheries Management Organisations. The status of yellowfin tuna (Indian and Atlantic Oceans), bigeye tuna (Atlantic Ocean) and Southern bluefin tuna (Indian and Atlantic Oceans) remain of concern.
- **West Coast rock lobster:** The West Coast rock lobster resource remains heavily depleted, with stocks currently being at only 2.5% of pre-fished levels. There is growing concern regarding apparently increasing levels of illegal harvesting of the West Coast rock lobster resource.


Fishing pressure
Heavy
Optimal
Light
Unknown
St Joseph shark
Oysters (Southern Cape)
Mako sharks
Requim sharks
Skates (various)
Smooth-hound shark
Abalone
Silver kob
Elf
Harders
Soupfin shark
Yellowfin tuna (In. and Atl.)
Bigeye tuna (Atl.)
Dusky kob
Red steenbras
White steenbras
Bigeye tuna (Ind.)
Cape horse mackerel
Oysters (KZN)
White mussel
Shallow-water hake
Deep-water hake
Kingklip
Squid
Monkfish
Snoek
Patagonian toothfish
Yellowtail
Blue shark
Carpenter
Slinger
Prawns (deep-water)
Albacore tuna (Ind. and Atl.)
Swordfish (Ind. and Atl.)
Prawns (shallow-water)
Southern bluefin tuna (Ind. and Atl.)
West Coast rock lobster
Kelp
South Coast rock lobster
Agulhas sole
Anchovy
Hottentot seabream
Redeye round herring
Seaweeds (non-kelp)
Moratorium
Santer
Geelbek
Seventy-four
Unknown
Abundant
Optimal
Depleted
Heavily Depleted
Stock status

About the report: The Science of Status

The purpose of this report is to make available information related to the current status of South Africa's major exploited marine fishery resources, and largely reflects the work of the Fisheries Research and Development Chief Directorate up to and including 2013.

A quick-view assessment appears at the beginning of each section, is colour-coded for ease of reference, and provides an indication of stock status and fishing pressure. The first line indicates the present status of the resource, which 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. The aim of sustainable management is to have resources that are in an optimal state and that are fished at optimal levels. However, historical over-fishing may have reduced some stocks to depleted or heavily depleted levels, and rebuilding these stocks could be attempted by reducing fishing pressure. Such rebuilding can take several years or even decades as the rate of recovery is dependent both on the biology of the species concerned and on natural recruitment fluctuations. Additionally, short-lived species (e.g. anchovy and squid) typically show high levels of recruitment variability that can result in substantial inter-annual fluctuations in population size; these could lead to the status of that resource changing from being depleted in one year to being optimal in the next. Five categories are defined for stock status, ranging from 'Abundant' though to 'Heavily depleted', and including an 'Unknown' category for which there are insufficient or conflicting data to enable an accurate estimate to be made. Four categories of fishing pressure are defined, from 'Light' though 'Optimal' to 'Heavy', and again including an 'Unknown' category for data-poor resources. The definitions used to assign a resource to a status or category and fishing to a pressure category are given in the following tables:

Stock status

Category	Abundant	Optimal	Depleted	Heavily depleted	Unknown
Definition	$B > B_{MSY}$	$B \approx B_{MSY}$	$B < B_{MSY}$	$B << B_{MSY}$	$B = ?$

where B is the present biomass level (or population size) and B_{MSY} is that biomass level at which maximum sustainable yield (MSY) is obtained.

Fishing pressure

Category	Light	Optimal	Heavy	Unknown
Definition	$F < F_{MSY}$	$F \approx F_{MSY}$	$F > F_{MSY}$	$F = ?$

where F is the present fishing pressure and F_{MSY} is that fishing pressure level at which MSY 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, 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 in the Far East. 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 in the past, and new experimental allocations were awarded from 2012 to 2015. The recreational sector also caught abalone for many years, but due to illegal fishing and the decline in the resource, this component of the fishery was suspended in 2003/2004.

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

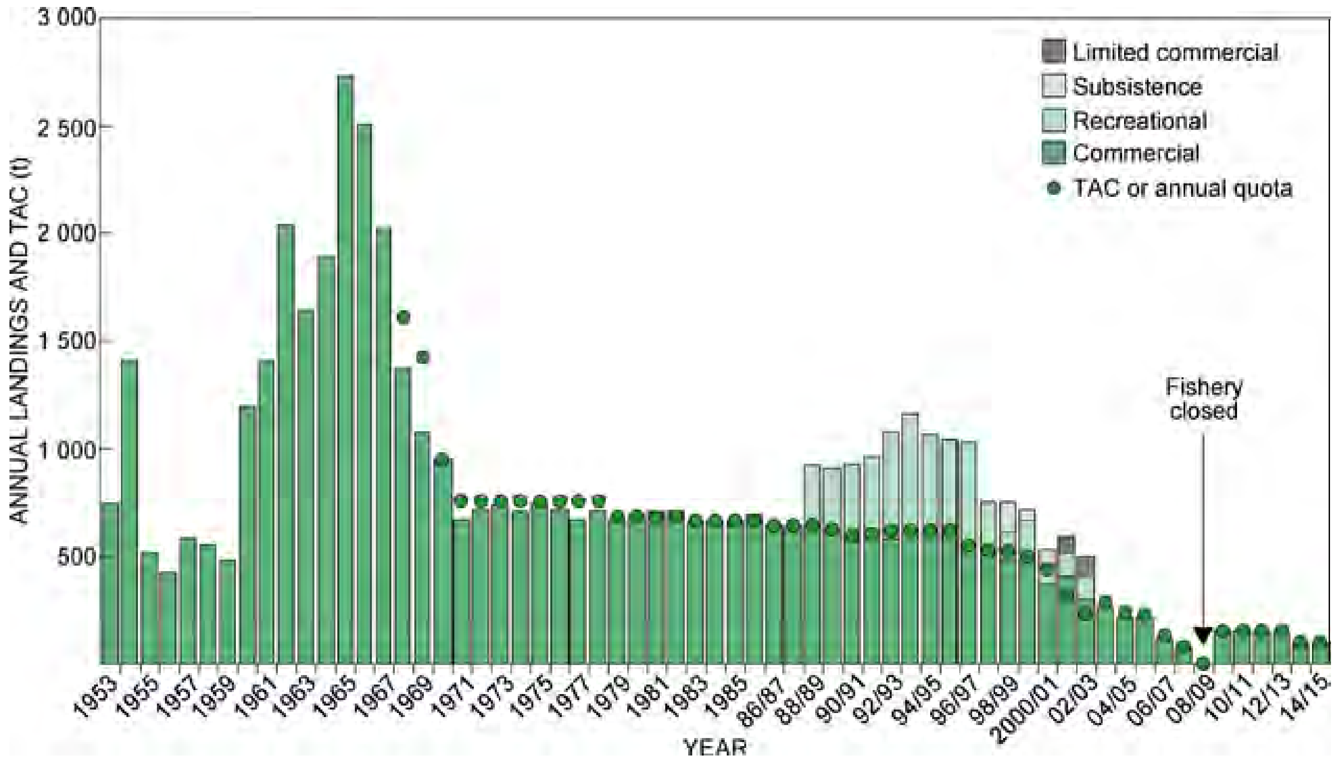


Figure 1: TAC and recorded (legal) annual landings for the abalone fishery from 1953 to 2014/2015. Landings for the recreational sector are only available since 1988/1989. Note that the substantial recent illegal catches are not shown

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, 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, introduce co-management of the resource and improve 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 regard to the size of abalone taken, and around two-thirds of confiscated abalone

Figure 2: Distribution of abalone *Haliotis midae* (insert) and abalone fishing Zones A–G, including TURF sub-zones.The recently concluded-experimental fisheries (2010/2011–2013/2014) on the western and eastern sides of False Bay and in the Eastern Cape are also shown. These areas within False Bay, provisionally included in the commercial fishery for next season, are referred to as Sub-zone E3 and Sub-zone D3

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, with TAC allocations of 150 t in the 2009/2010 and 2010/2011 seasons, which were conditional on a 15% per annum reduction in poaching. This was based on a management objective for the sustainable utilisation and recovery of the abalone resource which was 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 2009/2010, i.e. by the 2024/2025 season.

The required reduction in illegal harvesting has not been achieved. In fact, indices suggest a continued and substantial increase in poaching. Some six years after the re-opening of the fishery, estimates indicate that poaching is roughly 5 times higher.

In addition, the long-term rights that were allocated in 2003/2004 expired in July 2014 and exemptions from section 18 of the MLRA were granted to abalone right-holders until February 2016.

Research and monitoring

Data from both the fishery and directed research surveys are used to assess the abalone resource. The commercial fishery is monitored by recording landings at slipways, catch returns by right-holders and monitoring of the size of abalone caught. Commercial catch data are available from 1953, and catch per unit effort (CPUE) data from 1980.

Data on the recreational fishery were collected by means of telephone surveys and validated by recording the details of catch and effort at dive sites from 1992 to 2002. These data provided estimates of total catch, CPUE and trends in the size of abalone harvested.

Data on abalone abundance have been derived from fishery independent abalone surveys (FIAS) since 1995. The target each year is that 20 fixed-line transects are surveyed in each of five of the seven fishing zones by means of diving with scuba (the only exception being Zone F in which 16 transects are sampled) (Figure 2). The number and size of all abalone larger than 100 mm shell length are recorded to provide an index of abundance. Surveys are concentrated in the shallow (2–5 m) depth range, i.e. on the "inshore" component of the resource, since earlier findings indicated that the highest abalone densities occurred within the 0–5 m depth range. FIAS surveys of the deeper ("offshore") component of the resource are undertaken in Zones A–D, but these were of lower priority and received less attention in earlier years. However, there has been increased sampling of the deeper component since 2009, with a target of 12 deep transects surveyed annually in each of Zones A–D. Survey results show substantial declines in mean density since 1995 in Zones A–D (Figure 3).

Surveys are also undertaken around Dyer Island and the Betty's Bay Marine Protected Area (MPA). Surveys undertaken at Betty's Bay in 2012 indicated that the mean density of adult

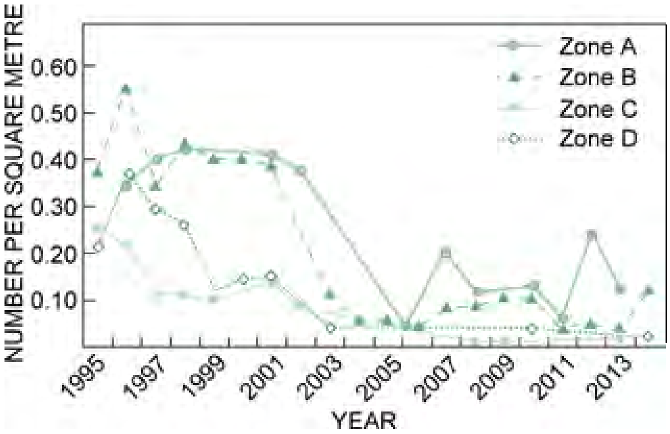


Figure 3: Mean densities of abalone in Zones A–D recorded during Fishery-independent abalone surveys from 1995 to 2014

abalone had dropped to 1% of the level recorded in the 1990s. Surveys undertaken at Dyer Island in 2013 indicated some increase in the mean density since the closure in 2004, although the 2013 density estimate is still considered to be at a very low level with only 4% of the abalone above minimum legal size (MLS). This indicates that there has been little recovery over this approximately 10-year period, which is consistent with reports of continued illegal fishing of abalone around the island.

Recruitment surveys undertaken annually from 1988 to 1993 provided evidence of a decline in urchins and juvenile abalone in Zones C and D, which was linked to the simultaneous increase in the abundance of West Coast rock lobster. A collaborative survey in Zones B and C undertaken in 2002 provided information on total population size structure and, in particular, further information on the decline in juvenile recruitment in Zone C compared to Zone B. This survey was repeated in 2015. Overall declines in mean density were observed in both zones since 2002. No recruits (shell lengths 15–45 mm) were found in Zone C during the 2015 survey, confirming that there has been no improvement in recruitment strength in this zone. An 80% decline in the density of juvenile recruits was observed in Zone B in 2015 compared to 2002.

The illegal sector is monitored by means of recording and sampling the confiscated abalone to obtain estimates of poaching trends, total illegal take and size per zone. Compliance efforts are also factored in for improved estimates of poaching trends.

In the main fishing areas on the South Coast, the resource is assessed by means of a spatially explicit age-structured production model using commercial CPUE, abundance estimates from the FIAS surveys, and catch-at-age information. The model also estimates the illegal catch, and the reduction in recruitment of juvenile abalone due to ecosystem changes.

The areas along the West Coast are not subject to such model analyses because of data limitations, and advice for these zones is based on decision rules in response to trends in CPUE from the commercial fishery, density from research surveys (Zone F) and size information. Some progress in implementing a plan for refining the decision rules has been achieved with the development of operating models for testing refined rules for Zone F.

Controlled experimental fisheries for abalone were completed (2010/2011–2013/2014) in False Bay and the Eastern Cape Province, areas that are not presently part of the commercial fishery (experimental areas are shown in Figure 2). The purpose of these experiments was to determine the spatial distribution and abundance of the resource and whether these areas might support sustainable fisheries in the future. Based on the outcome of the experimental fishery along the western side of False Bay, a1.5 t catch allocation was recommended for the extension of the Zone E area, from Millers Point, north to Muizenberg (new Sub-zone E3) (Figure 2). Based on the outcome of the experimental fishery along the eastern side of False Bay, a 3 t catch allocation was recommended for the area from Cape Hangklip to the Steenbras River (new Sub-zone D3) (Figure 2). As these recommended allocations were based on data collected over a short period only, they should be regarded as provisional and will very likely require revisions for the following season.

Priority research areas for the future include extending the full population surveys geographically including the area along the eastern side of False Bay and studies on abalone aggregation dynamics and the extent to which the potential of abalone to reproduce may be affected by the density of abalone in an area. Further improvements in illegal catch estimates and continued refining of the decision rules used for the assessment of the resource in the fishing zones along the West Coast (Zones E–G) are also priorities.

Current status

Poaching trends

Recommendations for the 2009/2010 and 2010/2011 seasons were based on a recovery strategy for abalone that recommended a target to recover the resource to 40% of its estimated pre-exploitation spawning biomass over 15 years. Analyses indicated this to be possible only if there were to be a 15% per annum reduction in the (then) estimated levels of poaching throughout the 15-year recovery period.

The requirement to reduce poaching by 15% per annum was a pivotal component of the recovery plan. Data from various sources were used to assess poaching trends.

DAFF: Directorate Compliance data on confiscations and inspection ('policing') effort suggest that poaching has been increasing recently and is roughly 5 times greater than some six years ago when the fishery was reopened. Increasing trends were estimated for the region overall (Figure 4), as well as for Zones A–D and Zones E–G when analysed separately. Estimated poaching levels are thus well above the targeted poaching level required under the abalone recovery plan.

An analysis of international trade data of imports of *H. midae* into key importing countries provided by TRAFFIC estimated that there was a net increase of around 80% in the number of abalone poached over five years (2010–2014, inclusive), compared to the annual average over the previous two years (2008 –2009) (Figure 5). This trend broadly corroborates the inferences from the DAFF Compliance data of a recent increase in abalone poaching.

It is important to appreciate that the increase in poaching is despite maximal efforts by DAFF's Compliance Directorate and other sectors, indicating that the resources allocated to them are inadequate to achieve a reduction in poaching.

Zones A and B

Current spawning biomasses and future projections are shown in Figure 6. Results of the 2015 assessment show that the resource has declined further in both zones from 2013 to 2015. Projections into the future show continuing resource decline at current estimated levels of poaching, even if there is no legal harvesting (solid line). In addition to the base case projection that assumes poaching continuing at current levels with no commercial TAC (solid line), extra projections were included in Figure 6 for illustrative purposes, to show spawning biomass trajectories if:

a) the current TAC remains allocated but poaching were to be completely stopped (bold dashed line);
b) the current TAC remains allocated and poaching continues at current levels (dashed line);
c) under the current TAC, the reduction in poaching that is required to keep the biomass at its present level into the future (dotted line), i.e. to meet a sustainability objec-

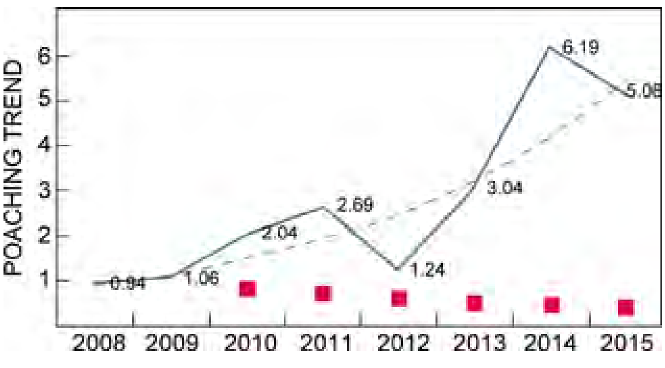


Figure 4: The solid line is the index of the annual level of poaching from a non-linear analysis of the DAFF: Compliance data on number of abalone confiscations and policing effort for the whole of the South Coast normalised to its 2008–2009 model year average values. The squares reflect the 15% annual decrease in poaching sought under the current abalone recovery plan, while the dashed line represents the poaching trend from a model assuming a steady exponential relationship with time. Note that only data for the first few months of 2015 were available for these analyses, and consequently the steady exponential trend analysis down-weights that year compared to the others.

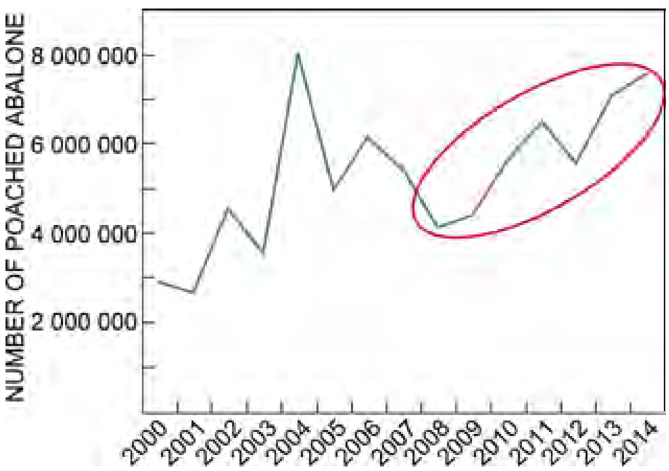


Figure 5: Estimated number of abalone poached based on international trade data for the calendar years 2000–2014, with the period (years) for current review of the recovery plan encircled. Data supplied by TRAFFIC.

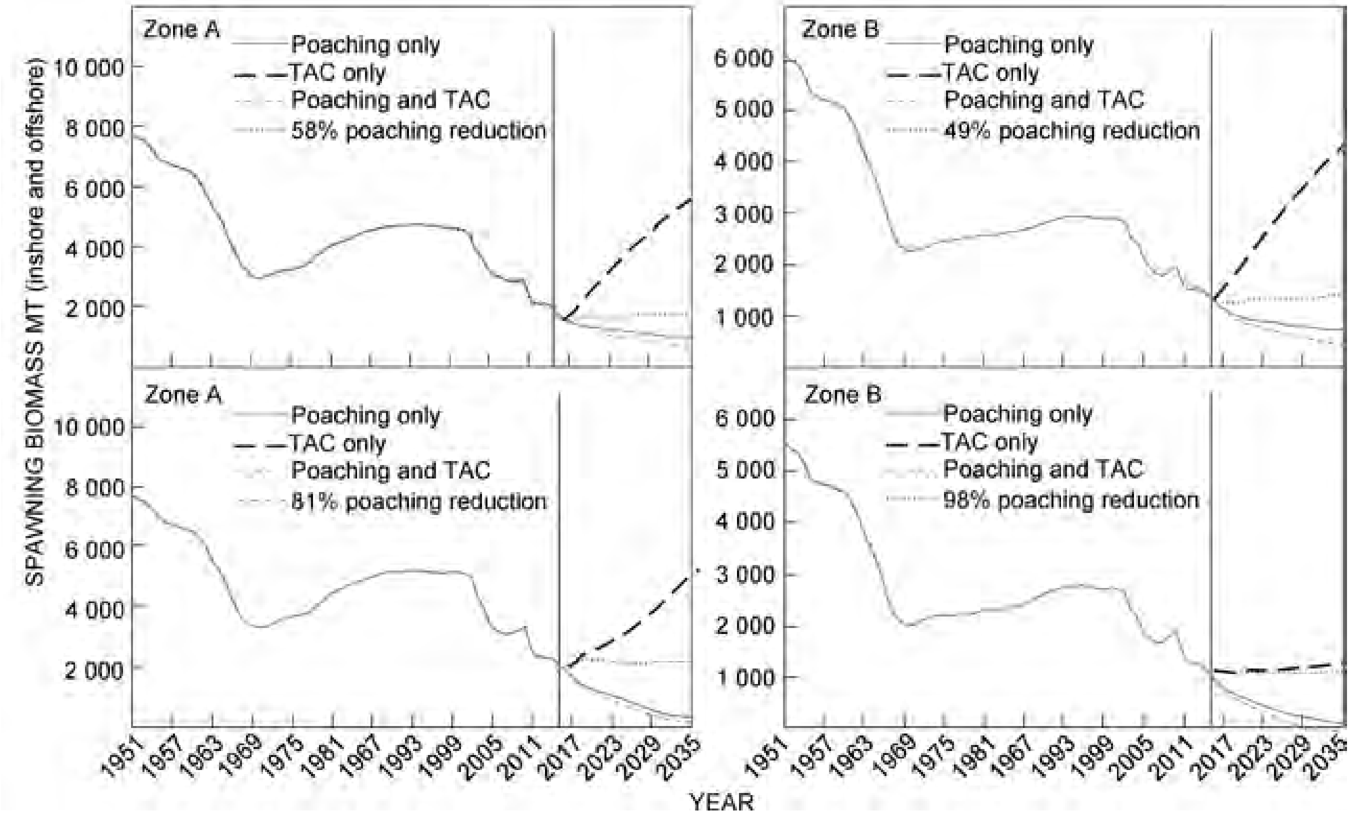


Figure 6: Total (inshore + offshore) spawning biomass trajectories shown for Zones A and B. The 20-year projections shown (after the vertical line) represent four different scenarios for future commercial and poaching catches. Unless a zero amount was assigned, future poaching levels were assumed to remain at the current estimated level (average of 2014 and 2015 estimates) and future commercial catches in each of these two zones were set to the 2014/2015 season's TAC of 25 t.The top two plots show projections when no Allee effect is taken into account, while the bottom two plots include an Allee effect. In each plot, the required reduction in poaching necessary to keep the resource stable at its present level under the 2014/2015 TAC is also shown, with the required reduction indicated in the legend

tive (though not the agreed resource recovery objective mentioned in a previous section).

In summary, the reduction in the level of poaching required under the agreed recovery plan has not been achieved. As a result, under current estimates of poaching, spawning biomass projections show continuing declines. Model results with an Allee effect included (the bottom plots in Figure 6) show even more pessimistic projections. Given the current low densities shown in the FIAS survey transects (<10 abalone per 60 m^2 transect), this more negative scenario should be considered a plausible one.

Recommendations have been made that commercial catch allocations in each of Zones A and B should be zero.

Zones C and D

Spawning biomass projections based on current estimates of poaching show continuing declines in resource abundance in these zones. In addition to the effects of poaching, the resource in these zones has been severely reduced by the lobster-urchin effect on abalone recruitment. Full population surveys that were undertaken jointly by the abalone industry and DAFF in 2015 confirmed that there was no recovery in the recruitment of juvenile abalone in Zone C with similar implications for Zone D. This, together with the fact that the populations in these two zones are estimated to be below the 20% limit reference point set out in the management objectives, resulted in a zero commercial catch allocation being maintained in these zones.

Zones E, F and G

Based on an inspection of commercial catch and survey data, application of a set of decision rules and consid-

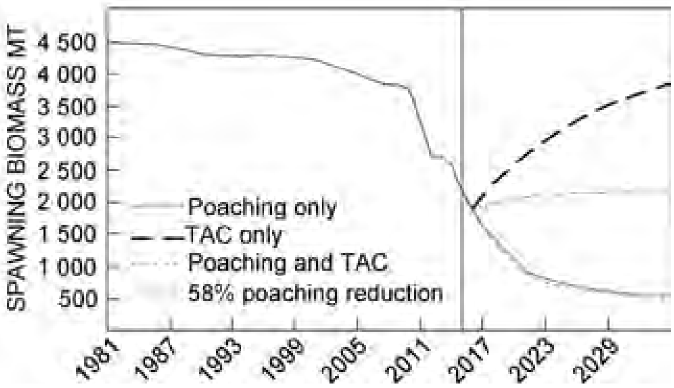


Figure 7: Spawning biomass trajectories shown for Zone F for the best fitted operating model (K = 4 500 t, average annual poaching since 2008 = 350 t). The 20-year projections shown (after the vertical line) represent four different scenarios for future commercial and poaching catches. Unless a zero amount is assigned, future poaching levels are assumed to remain at the current estimated level (average of 2014 and 2015) and future commercial catches are set to the current TAC of 16 t. The required reduction in poaching necessary to keep the resource stable at its present level under the current TAC is also shown, with the required reduction indicated in the legend

Table 1: Total allowable catches (TACs) for the abalone fishery per fishing zone for the past three seasons (2012/2013–2014/2015)

Season	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	TAC (t)
2012/2013	50	50	0	0	12	20	18	150
2013/2014	25	25	0	0	12	16	18	96
2014/2015	25	25	0	0	12	16	18	96

eration given to the high poaching levels estimated along the West Coast over recent years, 10% reductions in catch allocations were recommended for Zones E and G in the 2015 assessment. While the application of the current decision rules suggests no change to last year's catch allocation in Zone F, spawner biomass projections based on the newly developed operating models show that current poaching levels, if continued, would not be sustainable (solid line in Figure 7). However, these model results also suggest that the resource in Zone F is less depleted than in Zones A–D. While the catch allocation for Zone F may remain unchanged in the 2015/2016 season, it should be reduced to zero for the next season, unless there is a demonstrable reduction in poaching that is sufficient to allow for sustainable legal utilisation.

It is important to note that the decision rules that have been used for recommending catch levels for Zones E–G are not as scientifically refined as the procedures used for Zones A–D and therefore result in greater uncertainty in recommendations of catch limits. In addition, the juvenile recruitment in Zones E–G is sporadic and therefore the resource productivity in these zones has historically been much lower than in the South Coast Zones (A–D). A refining of the decision rules taking these concerns into consideration is underway (Table 1).

Ecosystem interactions

Since the early 1990s, ecological changes have severely disrupted normal abalone recruitment patterns in two of the major fishing zones, i.e. Zones C and D. These involved the large-scale incursion of West Coast rock lobsters into Zones C and D. The lobsters have now altered the ecosystem by consuming large numbers of sea urchins as well as 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 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, so that Dyer Island should continue as a closed area.

Further reading

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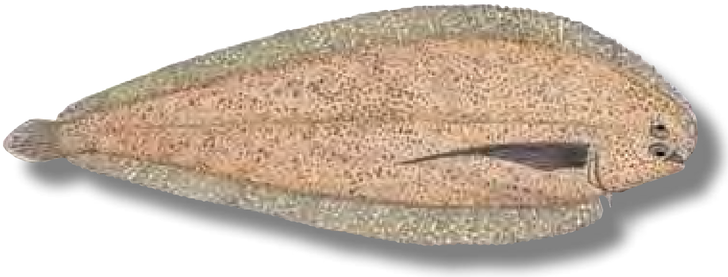
Useful statistics

TACs and catches for the abalone fishery for the past 20 seasons (1993/1994–2012/2013)

Season	TAC (t)	Total commercial catch (t)	Total recreational catch (t)
1993/1994	615	613	549
1994/1995	615	616	446
1995/1996	615	614	423
1996/1997	550	537	429
1997/1998	523	523	221
1998/1999	515	482	127
1999/2000	500	490	174
2000/2001	433	368	95
2001/2002	314	403	110
2002/2003	226	296	102
2003/2004	282	258	0
2004/2005	237	204	0
2005/2006	223	212	0
2006/2007	125	110	0
2007/2008	75	74	0
2008/2009	0	0	0
2009/2010	150	150	0
2010/2011	150	152	0
2011/2012	150	145	0
2012/2013	150	*	0
2013/2014	96	93	0
2014/2015	96	95	0

*Note that data for the 2012/2013 season were not yet complete at the time of preparation

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 8) distributed between 10 and 120 m depth, although they have occasionally also been caught in deeper water during research surveys (Figure 8). The average size caught annually by commercial vessels ranges between 32 cm and 33.6 cm.

The Agulhas sole resource is a small but commercially important component of the mixed-species inshore trawl fishery on the South-East Coast. The inshore trawl fleet currently comprises 18 active vessels, of which seven primarily target the sole resource but also rely on hake bycatch, while the remainder of the fleet targets primarily hake. There are currently 16 right-holders operating in the inshore trawl sector and the fishery sustains some 1 100 direct jobs. The current annual TAC is worth approximately R36 million.

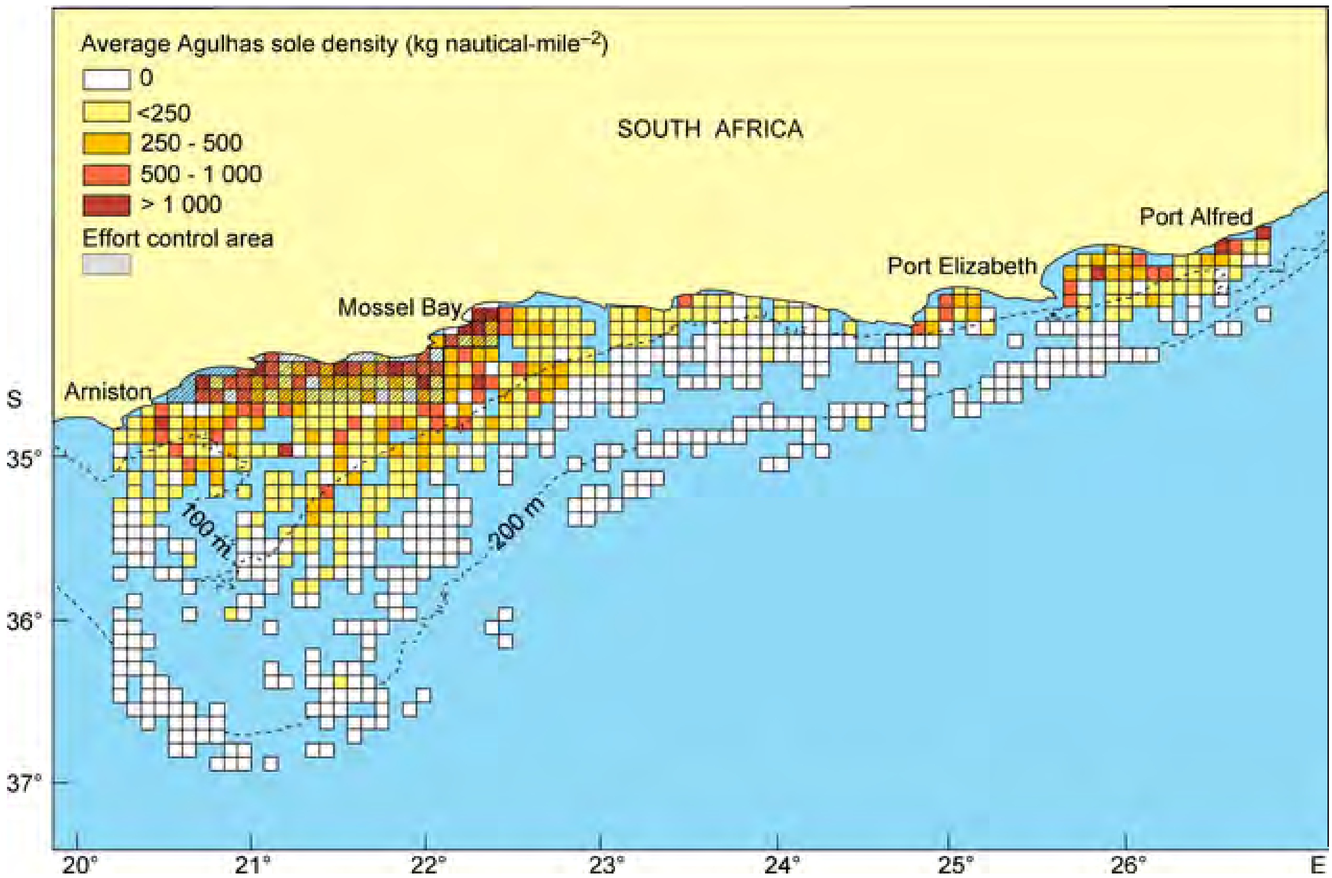


Figure 8: Distribution of Agulhas sole inferred from data collected during demersal research surveys. Data are illustrated as the average density per research grid block over the period 1986–2015

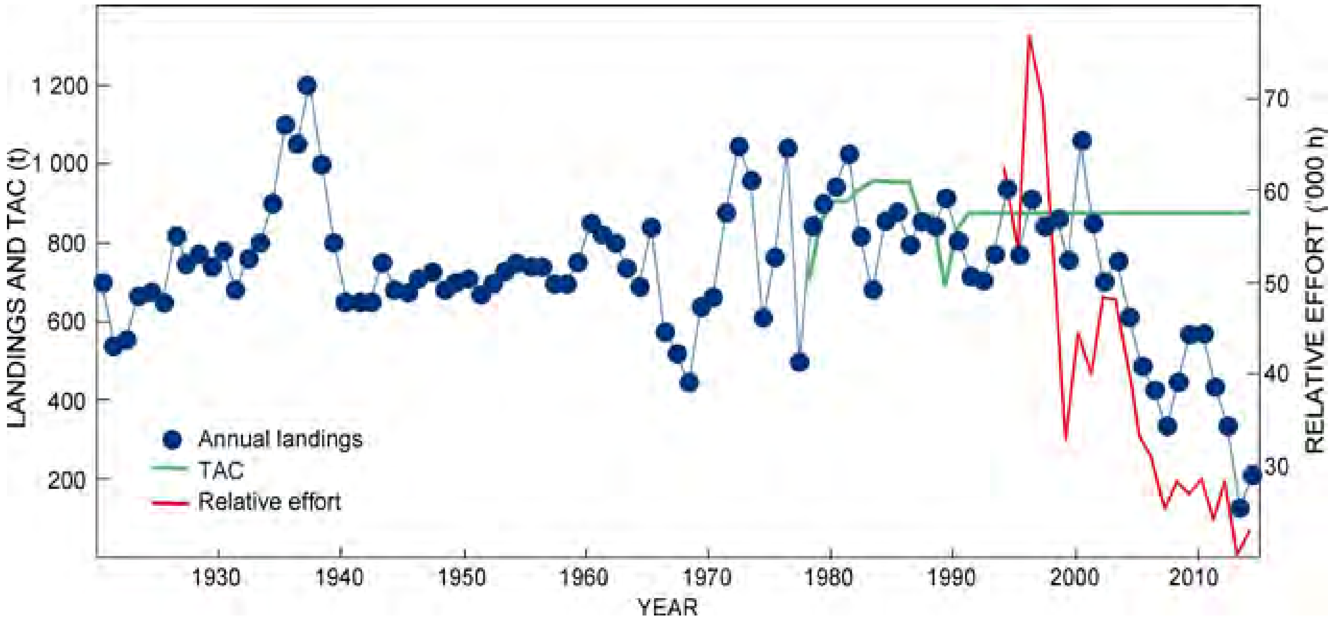


Figure 9: Annual landings, TACs and relative effort in the Agulhas sole fishery on the South-East Coast of South Africa, 1920-2014. Note that catches in excess of the TAC are generally a result of "roll-overs" where a portion of the catch in a given year has been added to the previous year's quota for various reasons

History and management

The Agulhas sole resource has been fished since the end of the 19th century and was one of the first fish stocks to be managed in South Africa. Exploitation of Agulhas sole was the economic base for the early fishery on the Cape South Coast and was the driving force for the development of the coastal fishing fleet. In the early years fishing was directed largely at Agulhas sole, but the fishery gradually shifted to targeting a number of additional species, including hake and various linefish species, by the late 1970s. The first formal attempt at managing the Agulhas sole fishery was made in 1935, with the introduction of a 75 mm minimum mesh size for bottom trawl nets. The inshore trawl fishery was formally defined as a management unit (i.e. the Hake and Sole Inshore Trawl sector) separate from the Hake Deepsea Trawl sector in 1978. An annual TAC of 700 t was first introduced in 1978, and individual quotas were introduced in 1982. The TAC remained fairly stable thereafter, varying between 700 t and 950 t between 1982 and 1992, and has subsequently been maintained at 872 t (Figure 9). 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 the section on Cape hakes).

There is substantial interannual variability in the time-series of annual catches (Figure 9), thought to be driven primarily by environmentally-induced fluctuations in Agulhas sole availability, linked to strong north-westerly fronts. Further, a number of factors have influenced the performance of the inshore trawl fishery: boat limitation; fleet rationalisation and the prevention of within-season trading of quota allocations.

The "dual quota" nature of this fishery (i.e. targeting both hake and Agulhas sole) is key to the economics of the sector. Larger ("hake specialist") inshore vessels must catch a certain ratio of hake:sole on the sole grounds in order to make fishing economically viable. When hake abundance decreases inshore (<100 m) then the larger vessels either fish offshore or the inshore hake quota is moved to an offshore vessel within the fleet and the Agulhas sole portion of the allocations is lost to the sector. Landings of Agulhas sole declined substantially over the period 2001–2007, with a slight increase in 2008–2010, but still well below the TAC (Figure 9). This decline has been attributed to a reduction in the overall effort (illustrated by the 'relative effort' in Figure 9) deployed by the fishery, rather than to a decline in the abundance of the resource. The reduction in effort is primarily a result of an appreciable reduction in the number of active inshore vessels in the fishery over time (50 in 1979, decreasing to 30 in 2006 and 18 in 2011). The reasons for this reduction in effort are complex, but are largely attributable to the market/economic forces discussed earlier, in addition to companies not replacing old/damaged vessels due to the limited availability (and substantial costs) of suitable replacement vessels, compounded by uncertainty regarding future long-term rights allocations (scheduled for 2016).

An additional, provisional measure that has recently been incorporated into the management approach for the resource is an effort-limitation scheme applied to the central part of the sole grounds. This measure is a response to a possible decline in resource abundance (see "Current status" below), indicated by the only reliable index of sole abundance, the commercial CPUE.

Research and monitoring

Abundance estimates for Agulhas sole are derived from demersal research surveys conducted on the South-East Coast using the swept-area method. These surveys are designed to estimate the abundance of hakes, although other demersal species (including Agulhas sole) are included in the data collection. The surveys are based on a pseudo-random stratified sampling design, where the survey area is sub-divided into a

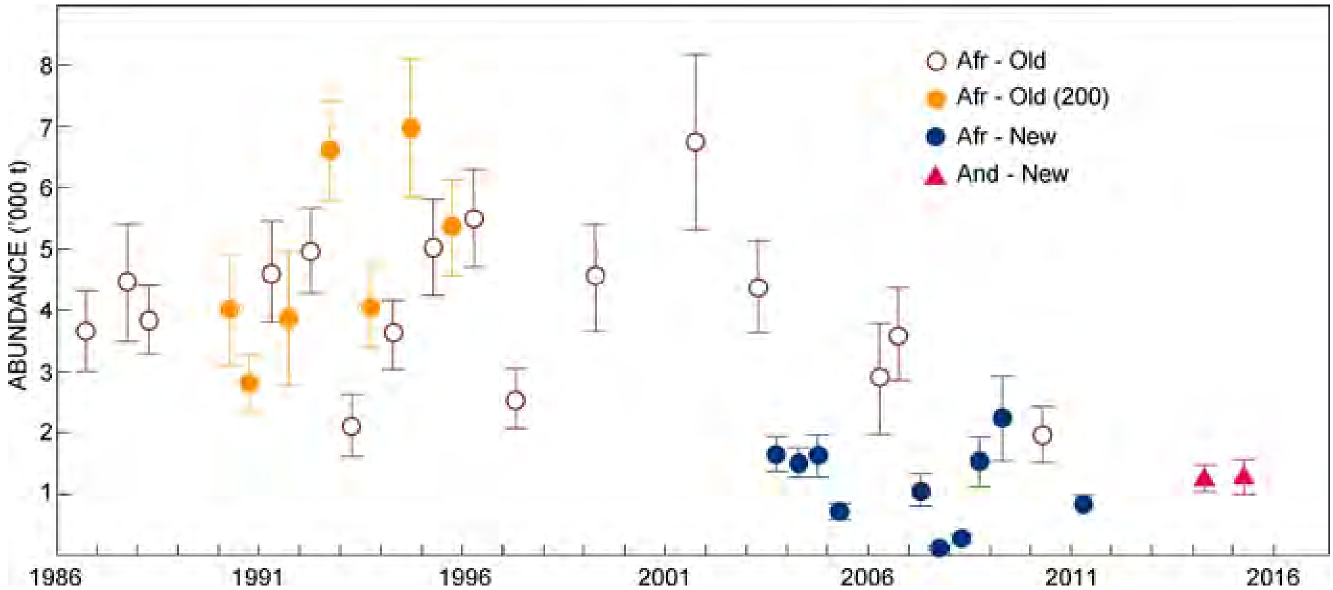


Figure 10: Spring and autumn demersal survey abundance estimates (± 1 SE) for the Agulhas sole resource on the South-East Coast of South Africa. The various vessel-gear combinations (see text) are illustrated as "***Afr***" (RS *Africana*), "*And*" (MV *Andromeda*), "Old" (old gear) and "New" (new gear). Note that the abundance estimates are not directly comparable across the different vessel-gear combinations. Surveys that only extended to the 200 m isobath are also indicated

number of depth strata with the number of sampling locations within each stratum being proportional to the area of the stratum. The full survey area extends to a far wider distribution than the 100 m isobath, which is where Agulhas sole are primarily distributed. Thus, the sole population is not comprehensively sampled, and the resulting sole abundance indices should therefore be interpreted with caution. In 1989, the autumn survey was conducted within the 200 m isobath and it was decided that either the autumn or spring survey would be "shallow" in order to better estimate the abundance of many inshore species (including Agulhas sole and chokka-squid). A further six shallow surveys were completed in spring from 1990 to 1995. However, since then, spring surveys have been intermittent, with the last one conducted in 2008. Therefore, the autumn surveys provide the longest time-series, with the caveat that they generally extended to 500 m, and more recently 1 000 m (Figure 10).

The trawl gear used for the surveys was changed in May 2003 to enable sampling of slightly rougher grounds, as well as to minimize the "herding" effect that was considered to introduce noise into the time-series of abundance data. Due to the differences in the gear configuration, abundance indices from surveys using the new gear are not directly comparable to those from surveys using the old gear, so they are illustrated separately in Figure 10. Surveys have generally been conducted on board the research vessel RS *Africana*, but due to an extended period of repairs to this vessel, no South-East Coast surveys were conducted in 2012 and 2013, and the 2014 and 2015 surveys were conducted on a commercial vessel (the MV *Andromeda*) using the new gear.

Four intensive Agulhas sole-directed surveys have been conducted (September 2006, April 2007 and 2008 and September 2008) to improve temporal and spatial coverage of the population and allow a revised assessment of the resource. Unfortunately, budgetary constraints have precluded further Agulhas sole-directed surveys, and it is not possible to draw definitive conclusions from only four surveys conducted over a period of three years.

A modelling approach was first used in 1989 to assess the status of the resource. Concerns regarding the reliability of the assessment model were raised during the early 1990s. However, financial and capacity constraints have prevented the collection of the data required to address these concerns. The fishery has consequently been managed using a constant catch strategy (an annual TAC of 872 t) since 1992, with only a commercial CPUE index of abundance being used to monitor the status of the resource.

Current status

Survey-derived abundance indices show considerable variability (Figure 10). Within-year differences between survey abundance indices in some years (e.g. 1993 and 1994) are too large to be attributed to changes in absolute abundance, and they are thought to reflect primarily environmentally-induced changes in the availability of Agulhas sole to the research trawl gear during the surveys. In particular, the September 2007 and April 2008 surveys were compromised by bad weather that may have reduced the availability of Agulhas sole to the gear, resulting in artificially reduced estimates of abundance. Estimates derived using the old gear suggest that the Agulhas sole resource has remained reasonably stable over time (with a period of relatively higher abundance during the mid-to-late 1990s). The low April 2010 estimate may be an artefact resulting from bad weather that shortened the duration of the survey and may potentially have reduced Agulhas sole availability to the gear. Unfortunately, no September estimate is available to provide further information for this period. The time-series of new gear estimates is not yet sufficiently extensive to draw any conclusions concerning resource trends and has been further interrupted by the unavailability of the RS *Africana* since April 2012. Although surveys were completed in 2014 and 2015 on the MV *Andromeda*, the time-series of fishery-independent demersal survey data for Agulhas sole cannot, at present, be used to inform management.

The only remaining reliable information source that can be used to assess trends in the status of the Agulhas sole resource is a standardized CPUE index of abundance based on the seven vessels that have targeted mainly Agulhas sole in recent years. This time-series (Figure 11) suggests that the abundance of the resource remained relatively stable over time, with periods of high abundance from 2000 to 2001 and again from 2009 to 2011. Despite reduced effort levels, CPUE indices of abundance derived from sole-directed fishing on the Agulhas sole grounds have indicated a steady decline since a peak in 2009 to a level that, in 2013, was the lowest in the time-series.

While anecdotal reports of anomalous environmental conditions prevailing on the South Coast over the period 2011–2013 may, to some extent, provide a basis for this decline in the CPUE (similar declines have been observed in other species such as chokka-squid and horse mackerel), available data are insufficient to establish whether the decline reflects a change in the availability/catchability of the resource, or a true decline in population abundance/productivity. In view of this uncertainty, and recognizing that the circumstances warranted a management response, further analyses exploring the results of various management options (effort limitation was considered to be the most appropriate approach) were conducted. A Dynamic Schaefer Production Model was developed and used as a basis to project future resource abundance and expected catches under a suite of effort limitation strategies for various scenarios of the resource dynamics. The projection results indicated that the changed catchability/availability scenario was not a cause for concern, but that the risk posed by the reduced abundance/productivity scenario required limiting fishing effort exerted on the central part of the sole grounds during the 2015 fishing season at a level consistent with that realised in 2013. This strategy was implemented for the 2015 fishing season.

The updated Agulhas sole CPUE time-series show an increase in the 2014 value compared to that of 2013 (Figure 11), but this CPUE index remains well below the long-term average. The reason(s) for the CPUE decline remain unresolved, and the intention is to continue the effort limitation strategy, pending the availability of relevant data to inform future management of the resource.

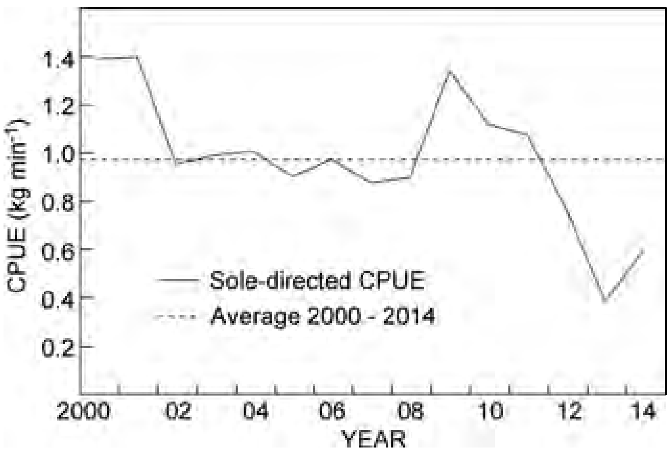


Figure 11: Standardised CPUE for Agulhas sole-directed vessels on the Agulhas sole grounds over the period 2000–2014. The dashed line indicates the average CPUE over the illustrated period

Ecosystem considerations

Measures aimed at reducing the ecosystem impacts of the hake-directed demersal trawl fisheries are contained in Sections B and C of the current permit conditions, and the regulations include clauses aimed at:

- minimising seabird mortalities through the deployment of tori lines and management of offal discharge;
- reducing damage to the seabed through restrictions on trawl gear;
- 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); and
- prevention of overharvesting of kingklip through a time-area closure on the South-East Coast near Port Elizabeth where the species aggregates to spawn, rendering it susceptible to excessive catches.

Implicit in the permit conditions are also restrictions on fishing in specified Fishery Management Areas (FMAs) and proclaimed Marine Protected Areas (MPAs). Furthermore, a procedure to limit fishing capacity in the hake trawl sectors (through matching the fishing capacity that is available to a right-holder to his/her hake allocation) has been developed jointly with industry and has been implemented (and reviewed each year) since 2008.

The Agulhas sole fishery is managed as part of the mixed-species Inshore Trawl Sector. The Agulhas sole grounds are areas of particularly high species diversity, and sole-directed fishing incurs appreciable bycatch. Although more than 100 species are caught, 20 species account for 98% of the catch, comprising a mix of linefish species (silver kob, carpenter, panga, white stumpnose and geelbek), gurnards, St Joseph, a number of skate species and other species which are already assessed and managed within the trawl fishery (hake, horse mackerel, kingklip, monkfish and squid). The majority of these bycatch species are marketable (often referred to as “joint product”), and are consequently landed rather than being discarded at sea. Considerable effort has been directed at developing a management strategy for the Inshore Trawl Sector that aims at controlling bycatch of potentially vulnerable chondrichthyan and linefish species. A co-management plan for this purpose is being developed through consultation between the South-East Coast Inshore Fishing Association (SECIFA) and academics at the University of Cape Town. The plan essentially involves DAFF setting catch limits for species of concern (ideally based on meaningful stock assessments of these species where possible), and the industry association internally managing the catches of these species among right-holders.

This plan is currently being tested using a suite of experimental catch thresholds for 10 species. Efforts are also being directed at developing stock assessments for the key bycatch species within the hake trawl fishery (both inshore and deepsea components) to enable the implementation of meaningful management measures for these species.

Further reading

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Useful statistics

Total catch (tons) of Agulhas sole per calendar year and the annual TACs (tons) for the period 1978–2014

Year	Catch (t)	TAC (t)
1978	850	700
1979	899	850
1980	943	900
1981	1 026	900
1982	817	930
1983	682	950
1984	857	950
1985	880	950
1986	796	950
1987	855	868
1988	839	868
1989	913	686
1990	808	834
1991	716	872
1992	704	872
1993	772	872
1994	938	872
1995	769	872
1996	909	872
1997	840	872
1998	859	872
1999	757	872
2000	1 060	872
2001	850	872
2002	702	872
2003	754	872
2004	612	872
2005	485	872
2006	428	872
2007	331	872
2008	448	872
2009	568	872
2010	570	872
2011	442	872
2012	338	872
2013	127	872
2014	208	872

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. *M. paradoxus* are distributed from northern Namibia to southern Moçambique, whereas *M. capensis* are distributed mainly 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. *M. capensis* are distributed over a depth range of 30–500 m with most of the population occurring between 100 and 300 m. 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. As the sizes of both species increase with depth, large *M. capensis* 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: deep-sea demersal trawl, inshore demersal trawl, hake longline and hake handline, with most of the catch being taken by the deep-sea trawl sector (Figure 12). Hakes are also caught as incidental bycatch in the horse mackerel directed midwater trawl and demersal shark longline fisheries, and to a lesser extent in the linefish sector. The inshore trawl and 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*. Although not the largest fishery in terms of tonnage (the small pelagic purse-seine fishery targeting sardine and anchovy lands the largest amount of fish at present), 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 only. Directed fishing of Cape hakes began only 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 about 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 at over 295 000 t in 1972 (Figure 12). By this time,

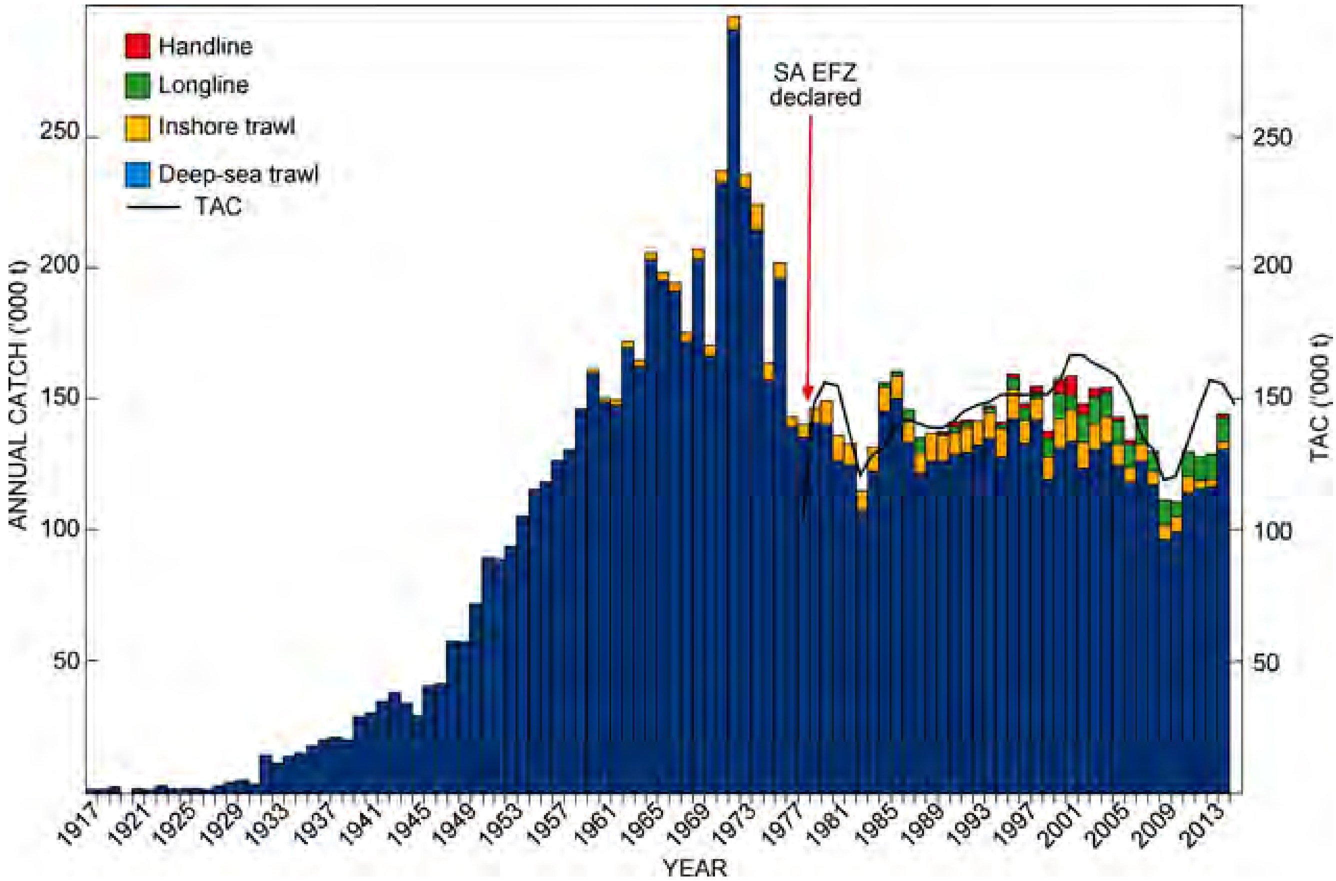

Figure 12: Annual catches of Cape hakes by the hake-directed fishing sectors. The annual TACs are also shown for the period since the onset of management of the hake resource by the SA government in 1978

effort had extended farther offshore and also into Namibian waters, with over 1.1 million t being caught in the South-East 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 this organisation. However, catch rates continued to decline, and in November 1977 the declaration of a 200 nautical mile Exclusive Fishing Zone (EFZ) by South Africa marked the onset of direct management of the South African hake resource by the South African government, and the exclusion of foreign vessels (with the exception of a few vessels operating under bilateral agreements and subject to South African regulations).

Subsequent to the declaration of the EFZ, South Africa implemented a relatively conservative management strategy in order to rebuild the hake stocks to BMSY, the biomass level that would provide the Maximum Sustainable Yield (MSY). TAC restrictions were imposed on the fishery, aimed at keeping catches below what were considered to be sustainable levels in order to promote 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 in a move to provide a sounder 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 (commercial and fishery-independent indices of abundance derived from commercial catch and effort data, and from demersal research surveys respectively). Implicit in the OMP approach is a schedule of OMP revisions (every four years) to account for possible revised datasets and understanding of resource and fishery dynamics. Assessments are routinely updated every year to check that resource indicators remain within the bounds considered likely at the time that the OMP was adopted.

As a result of the substantial overlap in distribution and the difficulty of distinguishing between the two hake species, species-specific catch-and-effort data are not available from the commercial fishery, and the two species were initially assessed and managed as a single resource. However, the development of the longline fishery during the 1990s led to shifts in the relative exploitation rates of the two species, rendering species-combined assessments of the resource inappropriate. Algorithms to apportion the commercial hake catch between the two species were developed using research survey data to enable the development of species-disaggregated assessment models. The first such model was developed during 2005 and was used in the development of the revised OMP implemented in 2006.

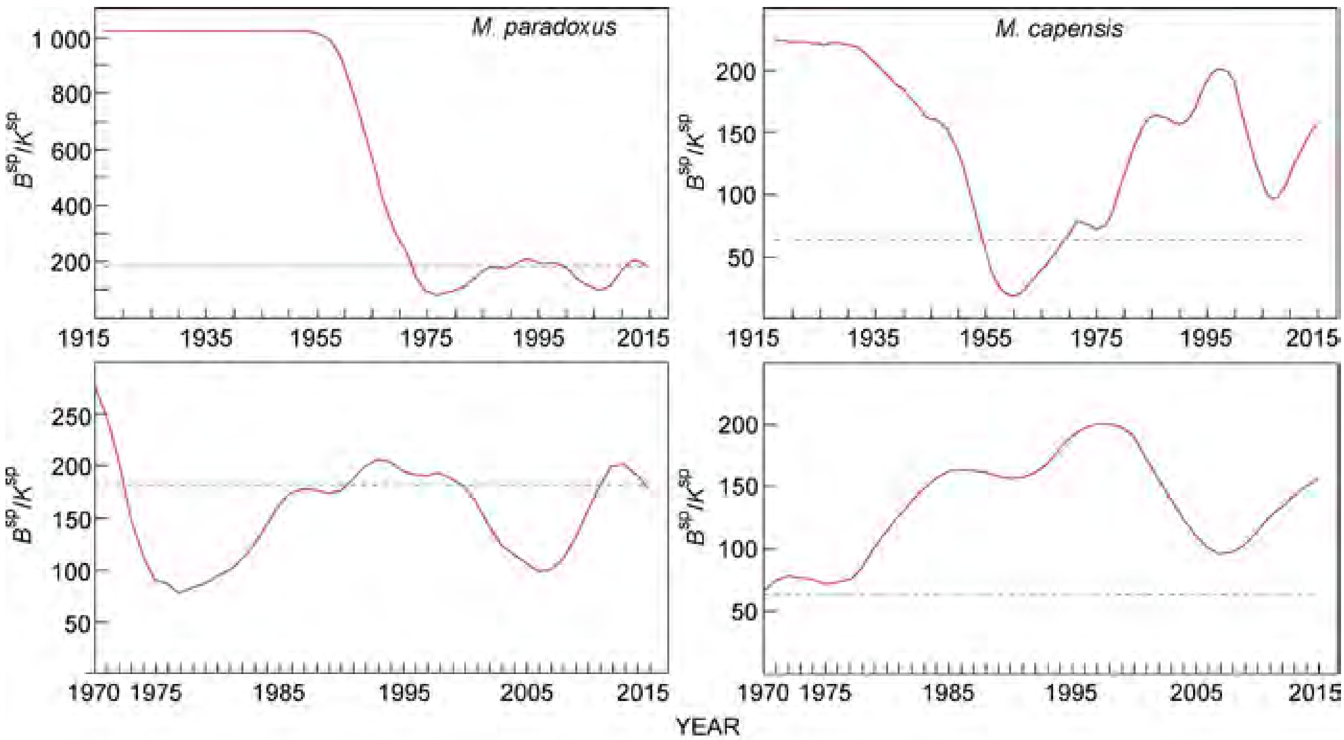

Figure 13: Female spawning biomass ('000 t) trajectories for *M. capensis* and *M. paradoxus* (solid black line) estimated by the 2015 Reference Case assessment update. The horizontal dashed line indicates B_{MSY} (the biomass estimated to yield Maximum Sustainable Yield). The lower panels illustrate the same data as the upper panels, but presented on a different time scale to clarify trends over the past few decades

The management strategies implemented since the EFZ was declared initially showed positive results with both catch rates and research survey abundance estimates (and hence TACs and annual catches) increasing gradually through the 1980s and 1990s (Figure 12). In the early 2000s, however, the hake fishery experienced declining 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} (Figure 13). 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 not known.

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% in order to provide stability for the industry. Implementation of this OMP led to substantial reductions in the TAC from 2007 until 2009 (Figure 12), but TACs subsequently increased as the resource responded positively to the recovery plan, with both commercial catch rates and survey indices of abundance turning around to show increasing trends (Figures 14 and 15). In accordance with the agreed OMP revision schedule, revised OMPs were developed in 2010 (OMP-2010) and 2014 (OMP-2014) to provide TAC recommendations for the years 2011–2014 and 2015–2018 respectively.

An important consideration in the development of the recent hake OMPs has been the certification of the South African hake trawl fishery (both the deep-sea and inshore trawl sectors) by the Marine Stewardship Council (MSC). The fishery first obtained this prestigious eco-label in 2006, and was successfully re-certified in 2010 and again in 2015. 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 certfied. Recent economic studies conducted by the Bureau of Economic Research and independent consultants have in-

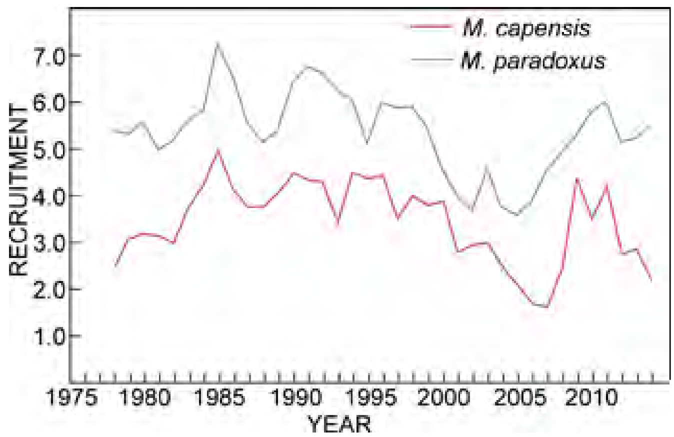

Figure 14: Standardised commercial (deepsea trawl) CPUE indices of abundance for *M. capensis* and *M. paradoxus*. Each index has been normalised to its mean.

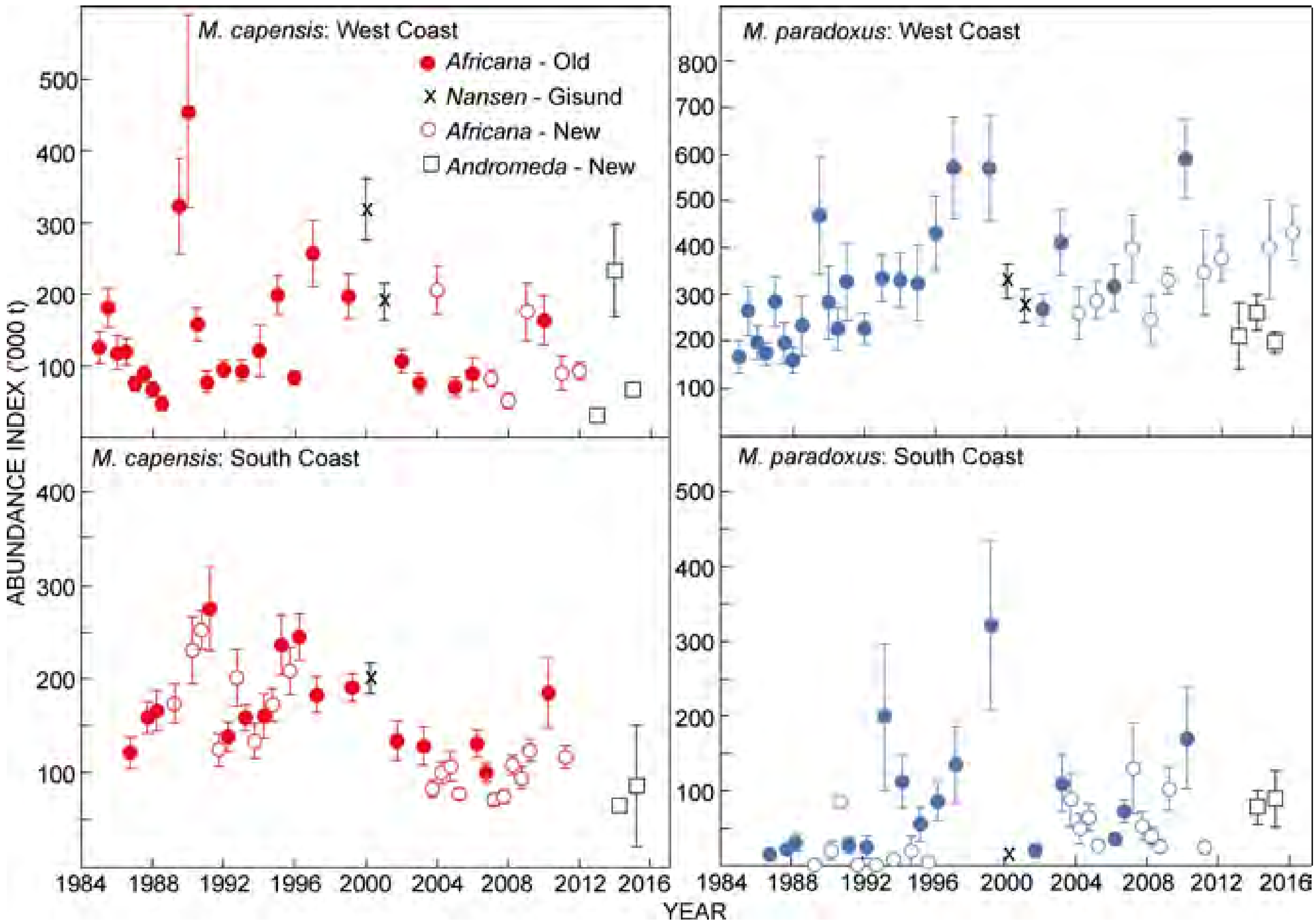

Figure 15: Survey abundance estimates (± 1 SE) for *M. capensis* and *M. paradoxus*. The various vessel – gear combinations are indicated, as are those surveys (only on the South Coast) that extended only to the 200 m isobath (the remaining surveys all extended to the 500 m isobaths). Note that estimates obtained cannot be directly compared over the various vessel and gear combinations

dicated 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 maintain it fluctuating around that level had to be taken into account.

Uncertainty remains as to the extent to which the *M. paradoxus* resource is shared between South Africa and Namibia, and the influence of catches by the two national fleets on the resource as a whole. At present, the two fisheries are managed independently, although the recently established Benguela Current Commission (BCC) aims to work towards joint management of this resource if it is established that there is sufficient sharing of the resource between the two countries to warrant this. The ECOFISH program (a joint BCC – European Union project) is currently working towards developing a joint SA – Namibia assessment of the *M. paradoxus* resource.

Research and monitoring

Fishery-independent hake abundance indices are determined from research surveys conducted on the West Coast in summer and the South Coast in autumn each year since 1984. Additional winter West Coast and spring South Coasts surveys have been conducted in some years, but budgetary and operational constraints have prevented these surveys from being routinely conducted every year. For each survey, a minimum of 100 trawl stations are selected using a pseudo-random stratified survey design. The survey area (coast to the 500 m depth contour) is subdivided by latitude (West Coast) or longitude (South Coast) and depth into a number of 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

Table 2: Results of the 2015 update of the Reference Case assessment. Note that "spawning biomass" refers to spawning females only, and "depletion" refers to the spawning biomass in a given year relative to pre-fished levels

		M. capensis	*M. paradoxus*
B_{MSY}	Spawning biomass yelding MSY; '000 t	63	181
B_{2013}	Spawning biomass in 2013 ('000 t)	142	201
B_{2014}	Spawning biomass in 2014 ('000 t)	150	192
B_{2015}	Spawning biomass in 2015 ('000 t)	156	178
B_{2013}/K	Depletion in 2013	63%	20%
B_{2014}/K	Depletion in 2014	67%	19%
B_{2015}/K	Depletion in 2015	70%	17%
B_{2013}/B_{MSY}	Spawning biomass in 2013 relative to B_{MSY}	225%	111%
B_{2014}/B_{MSY}	Spawning biomass in 2014 relative to B_{MSY}	238%	106%
B_{2015}/B_{MSY}	Spawning biomass in 2015 relative to B_{MSY}	247%	98%
MSY	Maximum sustainable yield ('000 t)	63	111

that can be sampled. Trawling is conducted during the day only to avoid bias arising from the daily vertical migration of hake (hake move off the sea floor and into the water column at night to feed). All organisms in the catch made at each trawl station are identified to species level (where possible), and in some cases also separated by gender, and the catch weight of each species is then recorded. The size composition of the catch of each species is then measured and more detailed biological analyses are conducted on sub-samples of commercially important species. Biological data and samples routinely collected include individual fish length and weight measurements, macroscopic estimation of maturity stage, gonad and liver weight measurements (the gonads often being retained for histological studies of reproductive biology), evaluation of stomach contents and extraction of otoliths (for age determination research). 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.

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 RS *Africana* because net-monitoring sensors showed that the gear was being over-spread (i.e. the opening of the net was being pulled too wide, which reduced the vertical opening and frequently lifted the foot rope off the sea bed). In selecting a new gear configuration, particular emphasis was placed on minimising the possible effect of herding on the abundance indices. This change is currently taken into account in the assessment model by the application of conversion factors estimated from experiments. Another recent (2011) change to the survey design is the extension of the survey area into deeper water (1 000 m) to encompass the full extent of the *M. paradoxus* resource. However, abundance estimates for input to assessments and the hake OMP are still calculated for the historical survey area (< 500 m) for comparability purposes. Once abundance time-series of sufficient duration are available for the extended survey area it will bepossible to incorporate these data into the assessments and OMP. Operational problems with the departmental research vessel (RS *Africana*) have prevented this vessel conducting any surveys subsequent to the 2012 summer West Coast survey. In the absence of the RS *Africana*, the research surveys have been conducted on board a commercial vessel, the MV *Andromeda*, although no autumn South Coast surveys were conducted in 2012 and 2013.

Species-specific Catch-Per-Unit-Effort (CPUE) time-series derived from commercial catch and effort data are standardised using general linear modelling techniques to account for differences in factors such as depth, area, and vessel power. These time-series (Figure 14) are then used in the assessment to provide additional estimates of resource abundance and trends.

Current status

OMP-2014 was developed in circumstances in which the *M. capensis* resource was estimated to be well above B_{MSY}, while the *M. paradoxus* resource had experienced below-average recruitment over 2009–2013, likely to result in a short-term reduction in spawning biomass, and hence reductions in the TAC in the short- to medium-term. OMP-2014 has the following general specifications:

- The 2015 and 2016 TACs are set at 147 500 t per annum (this was included to provide the industry time to "scale down" the infrastructure built up in response to the increasing TACs in preceding years).
- The 2017 and 2018 TACs are the sum of the intended species-disaggregated TACs, which are 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.
- The TAC over the period 2015–2018 may not exceed 150 000 t per annum.
- The TAC may not be increased by more than 10% or decreased by more than 5% from one year to the next.
- A "safeguard" meta-rule that 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.
- "Exceptional Circumstances" provisions that regulate the procedures to be followed in the event that future monitoring data fall outside of the range simulated in the development of the OMP.

An in-depth assessment that fits a suite of Age Structured Production Models (ASPMs) to updated data-sets is conducted every two years, timed to coincide with the four-year schedule of OMP revision. The suite of models (referred to as the 'Reference Set') is designed to encompass major sources of uncertainty, and includes the Reference Case model that is considered to provide the most plausible measures of stock status and dynamics. An update of this Reference Case model is conducted every other year to ensure that the resources have not deviated from what was predicted during the course of OMP testing. An in-depth assessment of the hake resource was conducted in early 2014 to enable the revision of the hake OMP that was scheduled for that year, and, as per the assessment cycle, an update of the Reference Case assessment was conducted in 2015. The 2015 Reference Case update encompassed updated data-sets extending to the end of 2014 for all but the survey abundance indices, which included 2015 data. The results of the assessment (Table 2, Figure 13) indicated that *M. paradoxus* spawning biomass had increased to levels above B_{MSY} over the 2012–2014 period, after which it had declined to about 98% of B_{MSY} in 2015. This result indicated that the recovery plan implicit in OMP-2010 was successful, with the *M. paradoxus* resource recovering to B_{MSY} sooner than was projected, and that the *M. paradoxus* resource could now be considered to be fluctuating around B_{MSY}.

The assessment also indicated that *M. capensis* spawning biomass remained at levels more than double B_{MSY}. Although the estimates of *M. capensis* 2014 CPUE (the South Coast component in particular) are slightly lower than was projected in the testing of OMP-2014, immediate action (revision of the OMP) is not considered necessary, although such a revision may be considered if the *M. capensis* abundance indices continue to be low.

Ecosystems interactions

South Africa has committed to implementing an Ecosystem Approach to Fisheries (EAF) management. 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 (bird-scaring 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 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 [8 km] away).
- Prevention of over-harvesting of kingklip through a time-area closure on the South-East Coast near Port Elizabeth, where the species aggregates to spawn, rendering it susceptible to excessive catches.

Explicit in the permit conditions are also restrictions on fishing in specified Fishery Management Areas (FMAs) and proclaimed MPAs.

A procedure to limit fishing capacity in the hake trawl sectors (through matching the fishing capacity that is available to a right-holder to their hake allocation) has been developed jointly with Industry and has been implemented (and reviewed each year) since 2008. This management tool has appreciably reduced the capacity in the trawl fishery in terms of the number of active vessels.

Considerable effort is being directed at developing a management strategy for the inshore trawl sector that aims at minimising bycatch of potentially vulnerable sharks 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 a number of 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 the most appropriate assessment approaches.

In order to promote the continued certification of the South African hake trawl fishery by the MSC, the hake trawl industry implemented the Trawl Ring Fence initiative in 2008 as a precautionary measure to address the issue of impacts of demersal trawling on marine benthic habitats. This voluntary initiative was a commitment by the industry to prevent the expansion of trawling into new areas until such time as an improved understanding of the impacts of bottom trawling on the sea floor has been reached. This measure was formalised in 2015 through incorporation into the permit conditions for the two trawl sectors, and will ensure that impacts on benthic habitats will not extend beyond currently fished areas. Research into the impacts of trawling on benthic habitats is being conducted through the "Benthic Trawl Experiment", a collaborative initiative between DAFF, 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 annual surveys of the "trawled" and "untrawled" sites were initiated in January 2014 and are planned to continue for five years. The surveys encompass monitoring of sediments and benthic infauna (through the use of cores and grab samples) as well as benthic epifauna using an underwater camera system.

An Ecological Risk Assessment (ERA) was conducted for the South African hake fishery in 2008 and progress was reviewed in 2011. The results of the 2011 review indicated a general improvement in the implementation of EAF considerations in the management of this fishery since the 2008 risk assessment.

Further reading

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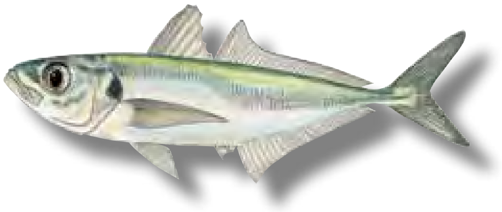
Useful statistics

Annual hake catch limits (TACs) and catches of the two hake species ('000 t) split by hake-directed fishing sector and coast (WC and SC denote West and South coasts respectively)

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							1.000							1.000	1.000
1918							1.100							1.100	1.100
1919							1.900							1.900	1.900
1920							0.000							0.000	0.000
1921							1.300							1.300	1.300
1922							1.000							1.000	1.000
1923							2.500							2.500	2.500
1924							1.500							1.500	1.500
1925							1.900							1.900	1.900
1926							1.400							1.400	1.400
1927							0.800							0.800	0.800
1928							2.600							2.600	2.600
1929							3.800							3.800	3.800
1930							4.400							4.400	4.400
1931							2.800							2.800	2.800
1932							14.300							14.300	14.300
1933							11.100							11.100	11.100
1934							13.800							13.800	13.800
1935							15.000							15.000	15.000
1936							17.700							17.700	17.700
1937							20.200							20.200	20.200
1938							21.100							21.100	21.100
1939							20.000							20.000	20.000
1940							28.600							28.600	28.600
1941							30.600							30.600	30.600
1942		0.001				0.001	34.499							34.499	34.500
1943		0.001				0.001	37.899							37.899	37.900
1944		0.002				0.002	34.098							34.098	34.100
1945		0.004				0.004	29.196							29.196	29.200
1946		0.011				0.011	40.389							40.389	40.400
1947		0.021				0.021	41.379							41.379	41.400
1948		0.059				0.059	57.741							57.741	57.800
1949		0.113				0.113	57.287							57.287	57.400
1950		0.275				0.275	71.725							71.725	72.000
1951		0.662				0.662	88.838							88.838	89.500
1952		1.268				1.268	87.532							87.532	88.800
1953		2.558				2.558	90.942							90.942	93.500
1954		5.438				5.438	99.962							99.962	105.400
1955		10.924				10.924	104.476							104.476	115.400
1956		19.581				19.581	98.619							98.619	118.200
1957		34.052				34.052	92.348							92.348	126.400
1958		51.895				51.895	78.805							78.805	130.700
1959		76.609				76.609	69.391							69.391	146.000
1960		100.490				100.490	59.410		1.000					60.410	160.900
1961		104.009				104.009	44.691		1.308					45.999	150.008
1962		109.596				109.596	38.004		1.615					39.619	149.215
1963		129.966				129.966	39.534		1.923					41.457	171.423
1964		126.567				126.567	35.733		2.231					37.964	164.531
1965		159.704				159.704	43.296		2.538					45.834	205.538

Year	TAC	*M.paradoxus*				Total	*M.Capensis*						Total	Total
		Deep-sea		Longline			Deep-sea		Inshore	Longline		Handline		(both
		WC	SC	WC	SC		WC	SC	SC	WC	SC	SC		species)
1966		154.109				154.109	40.891		2.864				43.755	197.864
1967		139.973	7.086			147.059	36.727	7.100	3.154				46.981	194.040
1968		113.890	13.958			127.848	29.710	13.950	3.462				47.122	174.970
1969		131.023	18.982			150.005	34.077	18.948	3.769				56.794	206.799
1970		113.124	11.786			124.910	29.376	11.847	4.077				45.300	170.210
1971		160.384	15.078			175.462	41.616	15.037	4.385				61.038	236.500
1972		193.694	23.382			217.076	50.239	23.314	4.692				78.245	295.321
1973		125.292	36.232			161.524	32.490	36.124	5.000				73.614	235.138
1974		97.674	45.496			143.170	25.326	45.357	10.056				80.739	223.909
1975		71.165	33.783			104.948	18.452	33.680	6.372				58.504	163.452
1976		114.268	26.005			140.273	29.626	25.925	5.740				61.291	201.564
1977		81.260	18.515			99.775	21.068	18.457	3.500				43.025	142.800
1978	103.000	107.701	4.937			112.638	19.812	2.648	4.931				27.391	140.029
1979	147.500	101.890	3.575			105.465	31.633	3.345	6.093				41.070	146.535
1980	155.700	105.483	3.676			109.159	28.045	2.784	9.121				39.950	149.109
1981	154.500	95.330	1.767			97.096	25.601	3.719	9.400				38.720	135.816
1982	136.000	88.933	5.057			93.990	24.417	6.300	8.089				38.806	132.796
1983	120.000	74.173	7.034	0.126		81.333	20.260	5.482	7.672	0.104			33.518	114.851
1984	128.000	86.045	5.718	0.200	0.005	91.968	25.210	5.217	9.035	0.166	0.011		39.639	131.607
1985	130.500	98.283	12.694	0.638	0.091	111.705	26.788	7.322	9.203	0.529	0.201	0.065	44.108	155.813
1986	138.500	107.907	11.539	0.753	0.094	120.292	25.898	4.427	8.724	0.625	0.208	0.084	39.966	160.258
1987	141.000	96.162	10.536	1.952	0.110	108.761	21.363	5.148	8.607	1.619	0.243	0.096	37.075	145.836
1988	139.900	83.606	8.664	2.833	0.103	95.206	22.976	5.852	8.417	2.350	0.228	0.071	39.894	135.100
1989	138.500	85.298	9.039	0.158	0.010	94.505	21.961	9.873	10.038	0.132	0.022	0.137	42.163	136.668
1990	138.500	84.969	13.622	0.211		98.802	18.668	9.169	10.012	0.175		0.348	38.372	137.174
1991	141.004	89.371	15.955		0.932	106.258	17.079	6.119	8.206		2.068	1.270	34.742	141.000
1992	145.000	86.777	22.368		0.466	109.610	16.510	4.094	9.252		1.034	1.099	31.990	141.600
1993	147.000	105.114	12.472			117.586	12.951	1.789	8.870			0.278	23.887	141.473
1994	148.000	106.287	8.588	0.882	0.194	115.950	17.580	2.464	9.569	0.732	0.432	0.449	31.227	147.177
1995	151.000	102.877	5.395	0.523	0.202	108.998	18.020	1.755	10.630	0.434	0.448	0.756	32.042	141.040
1996	151.000	110.460	11.080	1.308	0.568	123.416	18.715	2.209	11.062	1.086	1.260	1.515	35.847	159.263
1997	151.000	103.035	13.651	1.410	0.582	118.677	14.119	2.185	8.834	1.170	1.290	1.404	29.003	147.680
1998	151.000	113.083	11.703	0.505	0.457	125.748	14.570	2.450	8.283	0.419	1.014	1.738	28.474	154.222
1999	151.000	89.147	13.435	1.532	1.288	105.402	14.614	1.912	8.595	1.272	2.856	2.749	31.997	137.399
2000	155.500	97.417	9.920	2.706	3.105	113.148	20.285	3.610	10.906	2.000	1.977	5.500	44.278	157.426
2001	166.000	101.990	11.016	2.045	0.370	115.421	15.606	5.141	11.836	1.750	1.347	7.300	42.980	158.401
2002	166.000	91.720	15.445	4.469	1.585	113.218	13.211	3.140	9.581	2.391	2.546	3.500	34.369	147.587
2003	163.000	95.143	21.107	3.305	1.252	120.807	10.233	3.926	9.883	2.526	3.078	3.000	32.646	153.453
2004	161.000	86.916	30.746	2.855	1.196	121.713	11.315	4.024	10.004	2.297	2.731	1.600	31.971	153.684
2005	158.000	87.540	25.051	3.091	0.472	116.154	7.727	4.195	7.881	2.773	3.270	0.700	26.546	142.700
2006	150.000	83.840	22.133	3.241	0.485	109.699	9.657	2.494	5.524	2.520	3.227	0.400	23.823	133.522
2007	135.000	96.332	15.825	2.512	3.021	117.690	12.537	1.420	6.350	2.522	2.522	0.400	25.751	143.441
2008	130.532	88.290	14.940	2.255	0.809	106.294	11.085	2.567	5.496	1.937	1.893	0.231	23.209	129.503
2009	118.578	69.716	13.269	2.410	1.069	86.464	10.783	2.431	5.639	2.828	2.520	0.265	24.466	110.930
2010	119.831	70.156	17.863	2.045	0.370	90.434	9.738	1.649	5.472	1.750	1.347	0.275	20.232	110.666
2011	131.780	76.744	20.447	3.261	0.905	101.357	15.505	1.543	6.013	2.705	2.009	0.185	27.960	129.317
2012	144.671	82.362	19.356	3.572	2.963	108.253	11.970	1.776	3.223	0.829	1.840	0.001	19.639	127.892
2013	156.075	75.616	32.398	6.302	1.312	115.628	7.787	0.636	2.920	1.537	0.166	0.022	13.068	128.696
2014	155.280	76.240	46.146	6.938	0.512	129.836	7.381	0.597	2.965	1.692	0.065	1.390	14.090	143.926
2015	147.500	78.133	47.292	7.110	0.525	133.060	7.565	0.612	3.039	1.734	0.066	1.425	14.441	147.501

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. They are replaced by the very similar Cunene horse mackerel *T. tracea* and African horse mackerel *T. delagoa* to the north and east respectively.

Horse mackerel as a group are recognised 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 length and become sexually mature at about three years of age when they are roughly 20 cm long. They feed primarily on small crustaceans, which they filter from the water using their modified gillrakers.

Historically, large surface schools of adult Cape horse mackerel occurred on the West Coast and supported a purse-seine fishery that made substantial catches. These large schools have since disappeared from the South African west coast, but still occur off Namibia where horse mackerel are the most abundant harvested fish. Off South Africa, adult horse mackerel currently occur more abundantly off the South Coast than the West Coast.

Adult Cape horse mackerel are caught as incidental bycatch by the demersal trawl fleet and as a targeted catch by the midwater trawl fleet, mainly on the South Coast. In addition, the pelagic purse-seine fleet catches juvenile horse mackerel, largely on the West Coast, as incidental bycatch during directed fishing for small pelagic fish (primarily sardine and anchovy). Horse mackerel yield a low-value product and are a source of cheap protein.

History and management

Purse-seine catches of adult Cape horse mackerel on the West Coast peaked at 118 000 t in the early 1950s (Figure 16) and declined to negligible levels by the late 1960s. In the 1990s, purse-seine catches of Cape horse mackerel (now comprising largely juvenile fish) again showed an increasing trend, reaching 26 000 t in 1998. This increase raised concerns as to

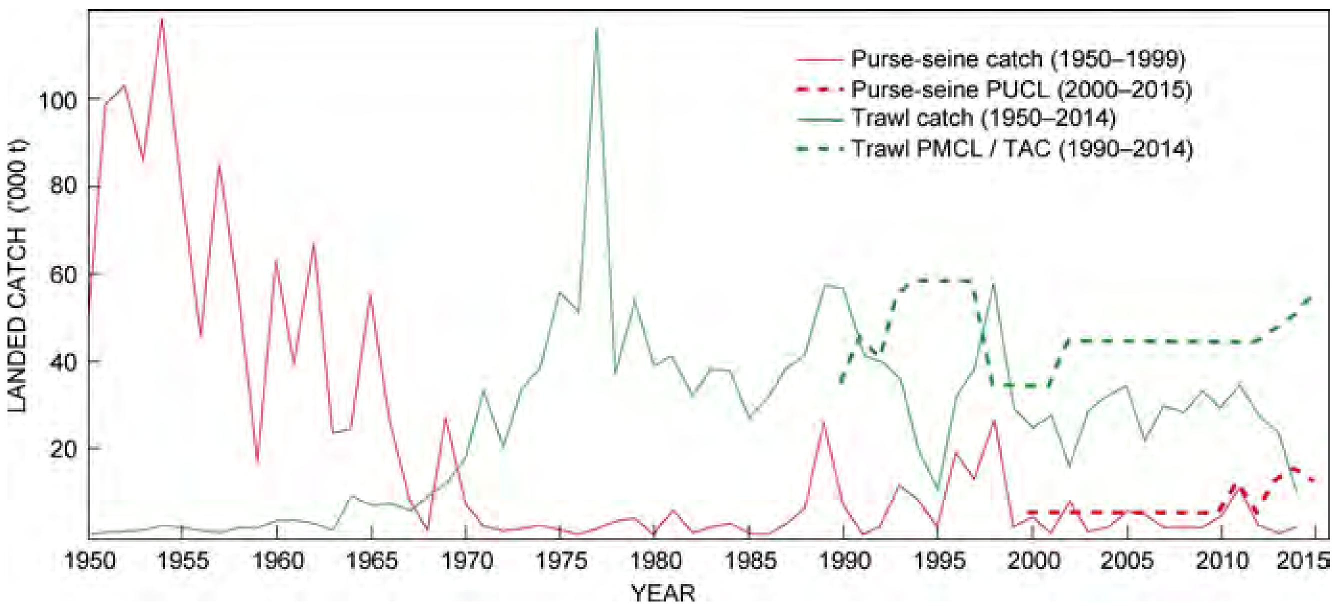


Figure 16: Annual horse mackerel catches and regulatory catch limits ('000 t) by the trawl (midwater and demersal combined) and purse-seine fisheries

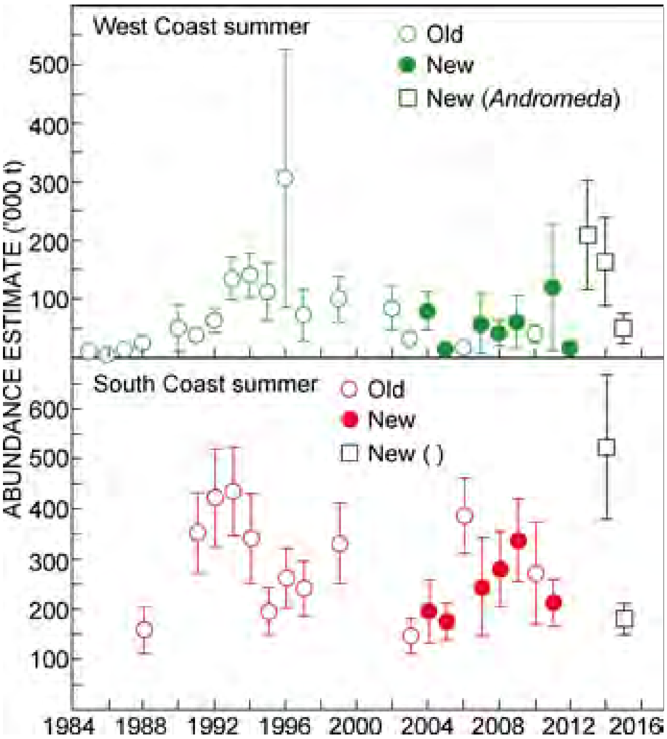


Figure 17: Time-series of horse mackerel abundance estimates (±1 SE) derived from demersal swept area research surveys. Time-series are illustrated separately for summer West Coast and autumn South Coast surveys. The various vessel-gear combinations are indicated as "Old" (RS *Africana* using old gear), "New" (the *Africana* using the new gear configuration) and "New (*Andromeda*)" (the commercial vessel MV *Andromeda* using the new gear configuration)

the likely effects of large catches of juvenile Cape horse mackerel on the trawl fishery for adults. Analyses exploring this potential impact indicated a pronounced yield-per-recruit effect, leading to the introduction of an annual 5 000 t Precautionary Upper Catch Limit (PUCL) for horse mackerel in the purse-seine fishery in 2000. Subsequent to this measure being implemented, the average annual horse mackerel catch by the purse-seine fleet has been 3 400 t. The 5 000 t annual PUCL was changed to a "PUCL3" 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 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 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 93 000 t in 1977. Following the declaration of the South African Exclusive Fishing Zone (EFZ) in 1977, foreign participation in the fishery was controlled and catches stabilised at between 25 000 t and 40 000 t per annum. When foreign fleets were finally phased out in 1992, annual catches (now by South African vessels only) declined to below 10 000 t in 1995 and 1996. 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 16), which has fluctuated between 11 000 t and 33 000 t since the 2000 fishing season.

Annual Total Allowable Catch (TAC) restrictions for the trawl fishery (both demersal and midwater components) were set for the years 1990 and 1991 using assessments of the resource based on Catch Per Unit Effort (CPUE) data derived from the Japanese fleet, combined with survey biomass and egg abundance indices. With the phasing out of the foreign fleets in 1992, the Japanese CPUE time-series was terminated and this modelling approach was no longer appropriate. A Precautionary Maximum Catch Limit (PMCL) of 40 000 t was set for 1992. Thereafter, a Yield-per-Recruit modelling approach was adopted on which to base PMCLs until 1999, when an Age-Structured Production Model (ASPM) of the resource was developed. Biomass projections using the model indicated that a PMCL of 34 000 t for the trawl fishery combined with the 5 000 t PUCL for the purse-seine fishery would be appropriate, and these catch restrictions were imposed for the 2000 fishing season. The trawl PMCL was increased to 44 000 t for 2001, and was maintained at that level until 2012. Between 2002 and 2012, the trawl PMCL has been separated into a 12 500 t reserve to account for incidental bycatch of horse mackerel in the hake demersal trawl fishery, and a 31 500 t allocation for the directed midwater trawl sector.

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

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 in April-May each year (Figure 17). 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 bottom 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 bottom 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. Dedicated horse mackerel surveys employing both

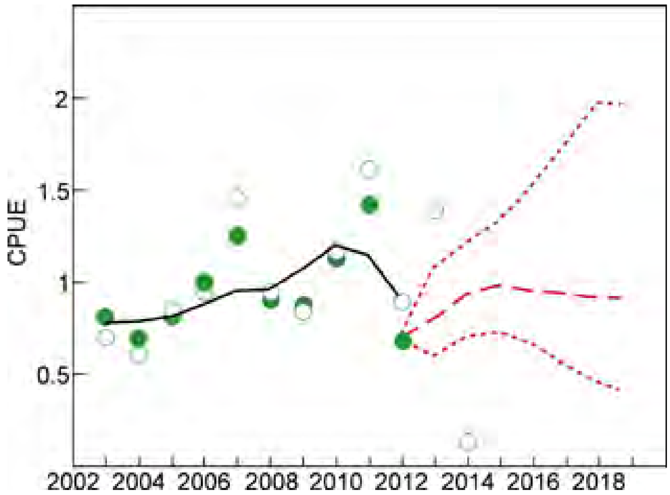


Figure 18: Horse mackerel CPUE. The most recent (2015) updated series of standardised, observed CPUE (circles) is illustrated relative to the 2014 updated series (dots) to which the 2014 assessment model was fitted (black line). The projected (future) CPUE estimated using the 2014 assessment model is shown in median terms (dashed line) with the associated 95% confidence intervals (dotted lines). The observed CPUE in 2014 is clearly well below the bounds predicted by the 2014 assessment

demersal trawl and hydro-acoustic techniques in combination may enable the quantification of the level of error inherent in the estimates of horse mackerel abundance derived from the hake-directed surveys. Plans to further this research have been unsuccessful due to budgetary and ship-time constraints, but a dedicated horse mackerel survey using both swept-area and hydro-acoustic techniques is planned for 2016.

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

Current status

An updated assessment of the horse mackerel resource was conducted during 2015, encompassing data extending to the end of 2014. The data included a revised commercial CPUE time-series (derived from the application of a delta lognormal model to account for the large proportion of zero catches in recent years). The assessment was conducted in circumstances where the only reliable index of horse mackerel abundance (the commercial CPUE) was at a level in 2014, which was appreciably lower than the bounds projected by the previous horse mackerel assessment (Figure 18), having declined from a relatively high level the previous year. Available data are insufficient to inform on whether the low CPUE reflects a decline in availability or an increase in natural mortality that has resulted in a decline in resource abundance.

Preliminary analyses indicated that the reduction in the TAC resulting from the application of the midwater control rule would not, in isolation, provide a satisfactory management response in the event that the low 2014 CPUE reflects a decline in resource abundance. Extended analyses exploring alternative management responses indicated that an effort restriction applied to the midwater trawl fleet, additional to the TAC reduction, would ensure that the resource would not be subjected to unsustainable fishing pressure in the event that it has in fact declined in abundance (i.e. fishing effort cannot be increased in an attempt to increase catches in circumstances of low catch rates). In the event of the alternative possibility (i.e. a reduction in availability), this management approach will enable increased catches in the event that catch rates recover/increase in the short term.

Accordingly, the midwater trawl horse mackerel TAC was decreased to 38 658 t for 2016, from 41 927 t in 2015. An effort management scheme has also been applied to the midwater fleet, aimed at restricting fishing effort in 2016 to the average of the annual levels exerted by the fishery over the period 2010–2013. An additional, precautionary measure to be implemented in 2016 is a reduction in the PUCL3 (from 15 589 t to 12 500 t) applied to incidental catches of juvenile horse mackerel by the small pelagic purse-seine fleet.

Ecosystem interactions

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

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

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

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 as yet been unsuccessful.

Further reading

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

Merkle D, Coetzee J. 2007. Acoustic estimation of juvenile horse mackerel 1997–2006. Marine and Coastal Management. South Africa. MCM/2007/MAY/SWG-PEL/02. 8 pp.

Useful statistics

Annual catches of horse mackerel by the trawl (midwater and demersal combined) and pelagic purse-seine fisheries. The relevant catch limits are also provided

	Catch ('000 t)		PMCL/TAC/PUCL ('000 t)			Catch ('000 t)		PMCL/TAC/PUCL ('000 t)	
Year	Trawl	Purse-seine	Trawl	Purse-seine	Year	Trawl	Purse-seine	Trawl	Purse-seine
1950	0.445	49.900			1983	38.332	2.100		
1951	1.105	98.900			1984	37.969	2.800		
1952	1.226	102.600			1985	27.278	0.700		
1953	1.456	85.200			1986	31.089	0.500		
1954	2.550	118.100			1987	38.475	2.834		
1955	1.926	78.800			1988	41.482	6.403		
1956	1.334	45.800			1989	56.892	25.872		
1957	0.959	84.600			1990	56.717	7.645	35.000	
1958	2.073	56.400			1991	41.658	0.582	45.000	
1959	2.075	17.700			1992	39.888	2.057	40.000	
1960	3.712	62.900			1993	35.997	11.651	55.000	
1961	3.627	38.900			1994	20.028	8.207	58.000	
1962	3.079	66.700			1995	10.790	1.986	58.000	
1963	1.401	23.300			1996	31.697	18.920	58.000	
1964	9.522	24.400			1997	38.135	12.654	58.000	
1965	7.017	55.000			1998	57.680	26.680	34.000	
1966	7.596	26.300			1999	29.520	2.057	34.000	
1967	6.189	8.800			2000	24.639	4.503	34.000	5.000
1968	9.116	1.400			2001	28.044	0.915	34.000	5.000
1969	12.252	26.800			2002	15.961	8.148	44.000	5.000
1970	17.872	7.900			2003	28.872	1.012	44.000	5.000
1971	33.329	2.200			2004	32.087	2.048	44.000	5.000
1972	20.560	1.300			2005	34.285	5.627	44.000	5.000
1973	33.900	1.600			2006	22.190	4.824	44.000	5.000
1974	38.391	2.500			2007	29.841	1.903	44.000	5.000
1975	55.459	1.600			2008	28.221	2.280	44.000	5.000
1976	50.981	0.400			2009	33.124	2.087	44.000	5.000
1977	116.400	1.900			2010	29.073	4.353	44.000	5.000
1978	37.288	3.600			2011	34.258	10.990	44.000	12.000
1979	53.583	4.300			2012	27.520	2.199	44.000	5.000
1980	39.139	0.400			2013	24.100	0.596	47.150	12.595
1981	41.217	6.100			2014	9.880	1.868	50.165	15.000
1982	32.176	1.100			2015			54.427	12.233

Kingklip

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

Introduction

Kingklip *Genypterus capensis* belongs to the cusk-eel family (Ophidiidae) and is a deep-water 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 their distribution extends even further eastwards). Kingklip are found at depths between 50 m and 800 m (Figure 19), generally in rocky areas on the continental shelf and shelf edge. Juveniles feed on benthic fish, crustaceans and squid, whereas the diet of the adults consists almost entirely of demersal fish. Kingklip move further offshore (and deeper) as they get older, with juveniles largely restricted to depths shallower than 200 m. The question of whether there are separate stocks of kingklip on the West and South coasts remains unresolved, and current management assumes a single stock distributed around the coast of South Africa, separate from the stock in Namibian waters. They are relatively slow-

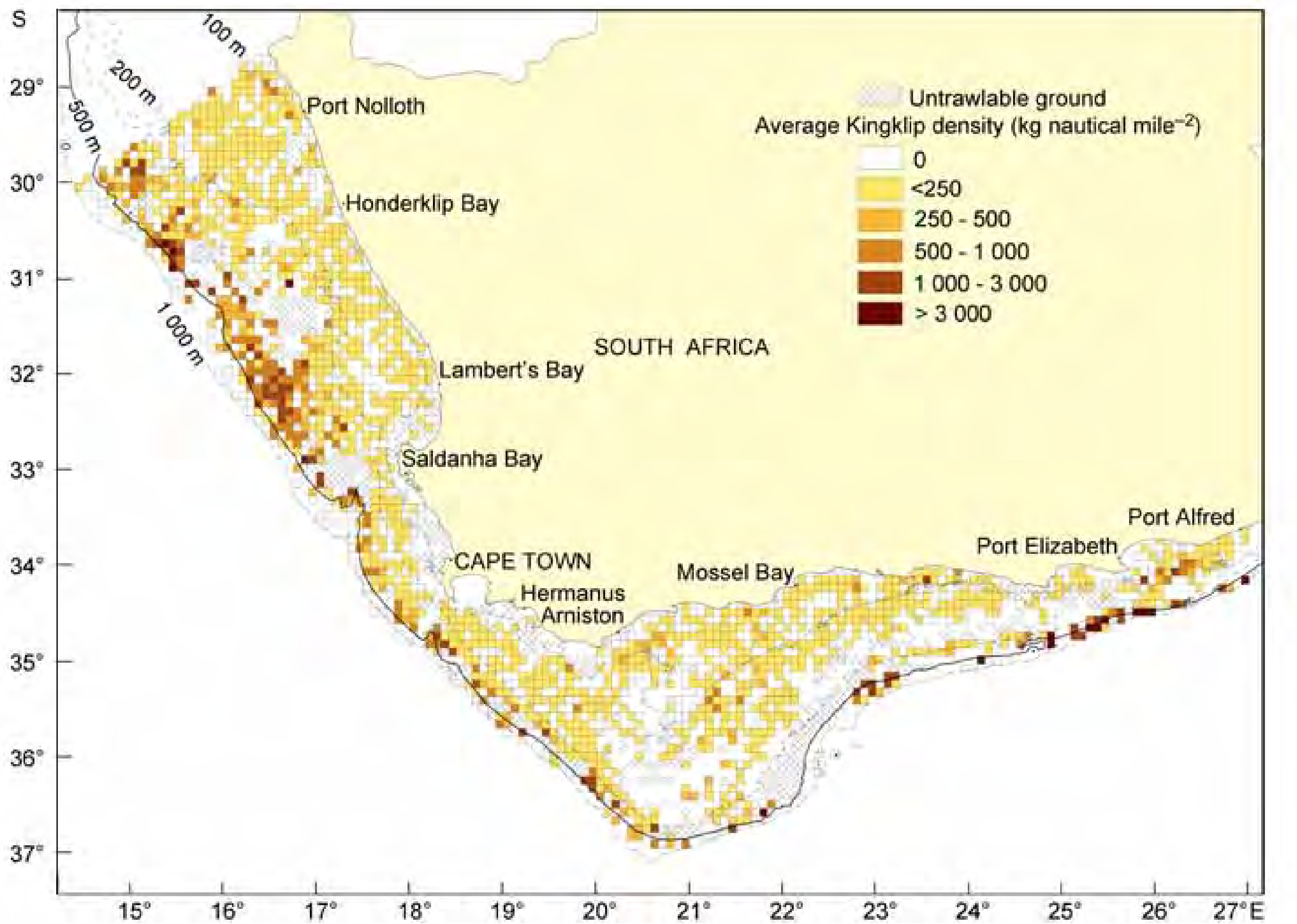

Figure 19: Distribution of kingklip in Cape waters, derived from demersal research surveys. Average densities calculated from survey catches over the period 1984–2015 are illustrated per sampling grid block

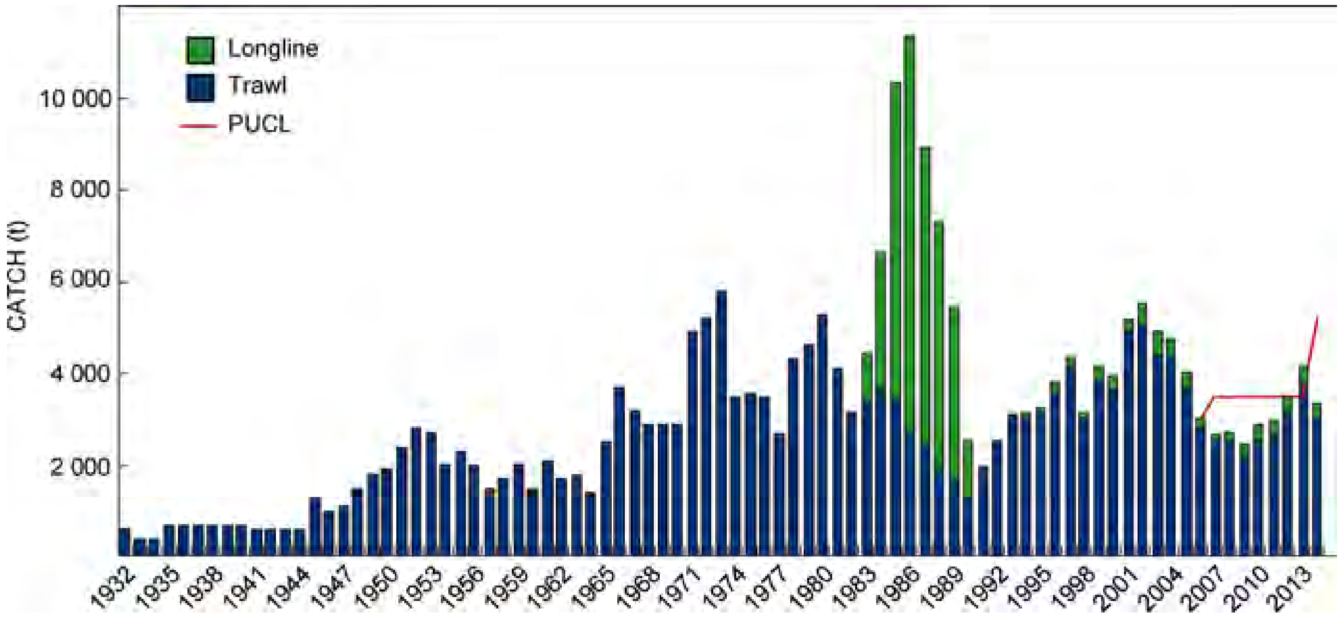

Figure 20: : Annual catches of kingklip (tons) made by the trawl and longline fisheries, as well as the Precautionary Upper Catch Limit (PUCL) that was introduced in 2006. Note that the 1983 – 1990 longline catches were made by a kingklip-directed fishery, while longline catches subsequent to 1993 are incidental by-catch in the hake-directed longline fishery that was established in 1994

growing and long-lived, 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. Males also appear to mature later on the West Coast than on the South Coast. Length-at-50% maturity for male fish on the West Coast is approximately 65.5 cm (~5 years) and on the South Coast at 62 cm (~4 years). The length-at-50% maturity for females is 81 cm and 72.5 cm on the West and South coasts respectively. These equate to ages of 6.5 years on the West Coast and 5.6 years on the South Coast. Spawning takes place on both coasts, generally from autumn to spring, with peak spawning between June and September. Kingklip form large aggregations to spawn and the largest known aggregation is on the South-East 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 is of appreciable economic importance to several South African fisheries. Kingklip is currently mostly caught as incidental bycatch in the hake trawl and hake longline sectors.

History and management

Trawl bycatches of kingklip fluctuated between 400 t and 700 t in the 1930s and 1940s (Figure 20), and then increased steadily to a peak of 5 800 t in 1973. Catches then fluctuated between about 3 000 t 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 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, rapid increase in catches by the hake trawl sectors followed, reaching a peak of 5 026 t in 2002. This peak corresponded to 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 3 000 t PUCL in 2006 (Figure 20), which has subsequently been retained as the primary regulatory measure for the resource. This PUCL is a “global” catch limit that applies to the hake-directed sectors (trawl and longline) in which kingklip is caught as bycatch. Efforts to ensure that the PUCL is not exceeded have followed a co-management approach, with the Department interacting closely with the relevant fishing associations.

The results of the first assessment of the kingklip resource conducted in 1992 indicated that the resource was severely depleted. A subsequent assessment undertaken in 2002 used a deterministic 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.

The PUCL was increased in 2007 to 3 500 t and subsequently was maintained at this level until 2013 (Figure 20). 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 coasts 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-exploited. The 2008 updated assessment suggested further analyses were required before an alteration to the PUCL could be considered. Additionally, a seasonal 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 Replacement Yield (RY)

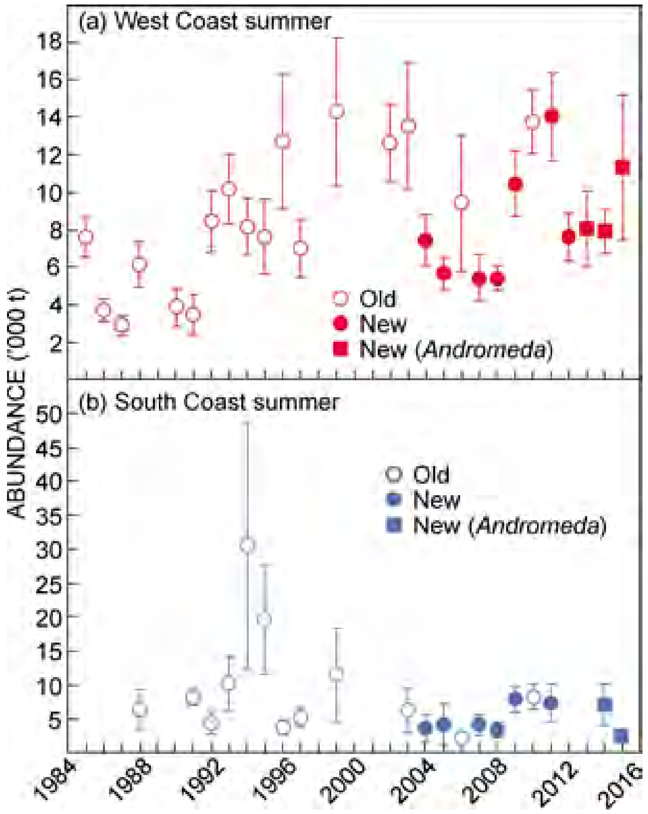

Figure 21: Estimates of kingklip abundance (± 1 SE) derived from the fishery-independent demersal research surveys conducted separately on the West (summer) and South (autumn) coasts each year. The various vessel-gear combinations are indicated as "Old" (RS *Africana* using old gear), "New" (the RS *Africana* using the new gear configuration) and "New (*Andromeda*)" (the commercial vessel MV *Andromeda* using the new gear configuration)

assessment of the resource conducted during 2013, and this level was maintained for the 2015 fishing season (Figure 20).

Research and monitoring

Abundance estimates for kingklip (Figure 21) 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 three, stocks of kingklip; one on the West Coast, one on the South Coast and possibly a third stock in an intermediate location on the central Agulhas Bank. Differences in growth and size/age-at-maturity estimates obtained from West and South coast fish could be considered to provide some support for at least the two-stock hypothesis, but it must be recognised that such differences can be realistically obtained from a single breeding stock where the offspring move to different areas with different environmental conditions. A genetic study conducted in 2005 using analyses of allozyme markers indicated a single genetic stock. Two research projects investigating kingklip stock structure have recently been initiated. The first study is employing advanced genetics techniques (analyses of both microsatellites and mitochondrial DNA), while the second project is exploring the use of parasites as biotags.

Current status

The assessment of the kingklip resource conducted in 2013 employed a Bayesian RY approach, and indicated that the resource had gradually increased in abundance on both the West and South coasts over the period 2008–2012 (average annual increases of about 3% and 2% respectively). The results suggested that, in median terms, a catch limit of 5 938 t could be sustainable. Given the relatively simple nature of the analysis, however, a precautionary approach was adopted and a conservative catch limit of 5 264 t was set for 2014. Following concerns from various stakeholders regarding the status of the South Coast component of the resource relative to reference points related to Maximum Sustainable Yield (MSY), an update to the RY model was conducted in 2014. The results indicated that the South Coast component of the resource, if treated as a separate stock, was at about 40% of pre-exploitation biomass, suggesting a status close to the biomass yielding MSY. This result, considered together with the general increasing trend in the survey-derived abundance indices apparent at that time (Figure 21), suggested that current fishing mortality is less than that corresponding to MSY, Fishing Mortality Produce MSY Level (FMSY).These results thus provided no basis to alter the existing PUCL, which was therefore maintained at 5 264 t for the 2015 fishing season.

Ecosystem interactions

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

Further Reading

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

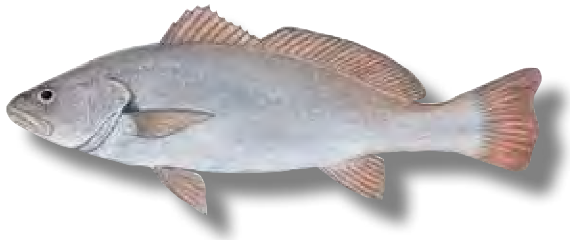
Useful statistics

Annual catches of kingklip in the demersal trawl fishery for the period 1932–2014, the longline fishery for the period 1983–2014, and the PUCL that was introduced in 2006. Catches are separated by coast: 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

	Catch (t) - trawl			Catch (t) - longline			
Year	WC	SC	Total	WC	SC	Total	PUCL
1974	2 532	956	3 488				
1975	2 600	982	3 582				
1976	2 519	952	3 471				
1977	1 953	737	2 690				
1978	2 551	1759	4 310				
1979	3 080	1532	4 612				
1980	4 415	878	5 293				
1981	3 149	963	4 112				
1982	2 410	721	3 131				
1983	2 246	1 169	3 415	842	200	1 042	
1984	2 558	1 034	3 592	1 881	1 159	3 040	
1985	1 750	1 650	3 400	1 314	5 656	6 970	
1986	2 287	399	2 686	1 231	7 453	8 684	
1987	2 083	392	2 475	1 948	4 504	6 452	
1988	1 519	408	1 927	2 091	3 311	5 402	
1989	1 407	223	1 630	1 607	2 209	3 816	
1990	1 002	266	1 268	557	708	1 265	
1991	1 271	680	1 951	0	0	0	
1992	1 884	676	2 560	0	0	0	
1993	2 207	884	3 091	0	0	0	
1994	1 445	1 560	3 005	92	48	140	
1995	1 863	1 275	3 138	65	48	113	
1996	1 596	1 981	3 577	170	60	230	
1997	1 972	2 128	4 100	155	120	275	
1998	1 632	1 366	2 998	53	87	140	
1999	2 104	1 737	3 841	141	171	312	
2000	2 176	1 472	3 647	199	103	302	
2001	2 678	2 233	4 911	183	57	240	
2002	2 407	2 617	5 025	312	202	514	
2003	1 870	2 558	4 427	317	160	477	
2004	1 823	2 538	4 361	266	141	407	
2005	1 792	1 853	3 646	255	121	376	
2006	1 475	1 321	2 797	125	109	234	3 000
2007	1 246	1 256	2 502	84	105	189	3 500
2008	1 161	1 352	2 513	113	85	198	3 500
2009	1 206	1 002	2 208	132	137	269	3 500
2010	1 451	1 091	2 542	114	226	340	3 500
2011	1 682	972	2 654	107	227	334	3 500
2012	1 874	1 263	3 137	93	285	378	3 500
2013	1 783	2 011	3 794	66	284	350	3 500
2014	1 554	1 480	3 034	17	312	329	5 264

Linefish



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

Introduction

Linefishing in South Africa is defined as the capture of fish with hook and line, but excludes the use of longlines. Together, the three sectors of the linefishery (commercial, recreational and subsistence) target between 95 and 200 of South Africa's 2 200 marine fish species. Species targeted in the linefishery display diverse life-history strategies, including many tactics that cause populations to be particularly vulnerable to overfishing, including long lifespans (>20 years), estuarine-dependence, sex change and aggregating behaviour. Many of the species are endemic to South Africa and are not shared with our neighbours. Target species include temperate reef-associated seabreams (such as roman *Chrysoblephus laticeps*, hottentot seabream *Pachymetopon blochi*, santer and slinger *Chrysoblephus puniceus*), coastal migrants (such as geelbek *Atractoscion aequidens* and dusky kob) and nomads (such as snoek and yellowtail). 90% of the current catch is made up of the aforementioned eight species (Table 3).

Linefish species are typically predatory in nature, and include a number of apex predators such as sharks, groupers, tunas and red steenbras. 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. This complicates the management of these resources.

The commercial linefishing sector is exclusively boat-based. The total number of registered vessels operating in this sector was estimated at 700 in the late 1990s, which accounted for 37% of all boats operating in marine fisheries in South Africa. From 2006 until the end of 2013, 455 boats have been in operation. Linefishing is a low-earning, labour-intensive industry, important from a human livelihood point of view. Employing an estimated 27% of all fishers, it has the lowest average employment income of all South African fisheries. Although the commercial linefishery has the largest fleet, it contributes only 6% of the total estimated value all South African marine fisheries.

After the introduction of the towable skiboat in the late 1940s, the recreational boat-based sector expanded rapidly, with an estimated minimum number of 4 000 vessels. Landings from this open-access recreational fishery are not reported throughout the region, and for some areas and species the total catch from this sector could be equivalent to that reported by the commercial sector. The recreational linefishery has by far the largest number of participants (more than 450 000) of all fishery sectors in South Africa and consequently has great economic value. This is especially important to coastal regions

Table 3: Annual catch (t) of linefish species from 2000 to 2013

Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Snoek	6 543	6 839	3 837	4 532	7 278	4 787	3 529	2 765	5 223	6 322	6 360	6 205	6 809	6 690
Yellowtail	320	327	242	329	883	739	310	478	313	330	171	204	382	712
Kob	547	416	392	272	360	324	400	421	358	442	419	312	221	157
Carpenter	441	285	231	177	228	184	159	265	226	282	263	363	300	481
Slinger	186	139	101	88	184	169	192	157	194	186	180	214	240	200
Hottentot seabream	234	109	79	106	254	168	87	128	120	184	144	216	160	173
Geelbek	894	395	315	513	672	580	419	448	403	495	408	286	337	263
Santer	76	69	48	48	87	84	79	84	82	66	69	62	82	84

dependent on the tourist trade, but also to industries associated with the small craft, outboard motor, fishing tackle and bait trades.

The small-scale/subsistence sector was legally created to recognise those fishers who depend on marine living resources for direct food security, usually very poor coastal communities or those using simple traditional methods. There are an estimated 30 000 small-scale fishers active along the South African coastline, 85% of whom harvest linefish. The small-scale fishers will be organised into co-operatives that target a 'basket' of species that includes many linefish resources.

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 quite 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 (more than 3 boats per kilometre of coastline). The sharp increase in fishing effort, together with the increase in operational range through the introduction of motorised skiboats on trailers, the rapid development in fishing technology (echosounders, nylon line, etc.) and the additional offtake by other fleets such as trawl and purse-seine, led to overfishing of most of the linefish resources around the coast during the last quarter 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 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 utilisation, a Linefish Management Protocol (LMP) was developed in 1999 in order to base regulations in the linefishery on quantifiable reference points. This remains the basis of linefish management.

A number of regulations were put in place to manage fishing pressure on linefish resources. Due to the large number of users, launch sites and species targeted, and 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 recreational fishery is managed by a number of output restrictions, such as size and bag limits, closed areas and seasons. The small-scale/subsistence fishery is in its implementation phase and will be managed through a combination of these. The level of commercial effort was reduced to the levels stipulated in the declaration of the emergency when linefish rights were allocated in 2003 (for the medium-term) and in 2005 for the long-term fishing rights. The TAE was set to reduce the total catch by at least 70%, a reduction that was deemed necessary to rebuild the linefish stocks. There has also been a reduction in recreational fishing pressure through the implementation of more realistic species-specific daily bag and size limits since 2005.

Although this appears to be a substantial reduction in the 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 ves-

Table 4: Annual Total Allowable Effort (TAE) and activated effort per linefish management zone from 2006 to 2012.

Total TAE boats (fishers). Upper limit: 455 boats or 3 450 crew			Zone A: Port Nolloth to Cape Infanta		Zone B: Cape Infanta to Port St Johns		Zone C: KwaZulu-Natal	
Allocation	455 (3 182)		301 (2 136)		103 (692)		51 (354)	
Year	Allocated	Activated	Allocated	Activated	Allocated	Activated	Allocated	Activated
2006	455	385	301	258	103	78	51	49
2007	455	353	301	231	103	85	51	37
2008	455	372	301	239	103	82	51	51
2009	455	344	300	222	104	78	51	44
2010	455	335	298	210	105	82	51	43
2011	455	328	298	207	105	75	51	46
2012	455	296	298	192	105	62	51	42

sels 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. (Table 4).

The policy for the small-scale fisheries sector is currently in the process of being implemented. A large number of species, the majority of which are part of the linefishery, will be shared between the small-scale sector and the commercial and recreational sectors. To achieve this without compromising recovery of these valuable stocks, a comprehensive revision of the LMP is underway.

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 observers confirmed recorded catch-and-effort data and collected size frequencies per species from the boat-based fishery at access points around the country. A comparison between this information and the data handed in by the fishery confirmed the accuracy of the National Marine Linefish System (NMLS) catch data, which is based on mandatory catch reports by the fishery.

With the increased focus on formalising the small-scale and subsistence fishery around the country, a national, shore-based monitoring programme for this fishery has been designed and implemented. Data from this programme are used to investigate whether current fishing effort and catch are sustainable and will aid in determining management measures for the 'basket' of resources allocated for this fishery. Thus far, the data have been used to assess the stocks of seven of the most important target species along the Eastern Cape coast. Spawner-biomass per recruit analyses revealed that two of these species (bronze bream and stone bream) are sustainably fished, but the population status of dusky kob is estimated to be at exceptionally low levels (1.3% of pristine spawner biomass). These assessments need to be considered when the small-scale fishery is implemented, as recovery of these stocks is critical to growing the potential revenue for fishers reliant on these resources.

In addition to fisheries-dependent data, which can only provide indirect measures of resource status, novel 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 (BRUV) technique will be used during a nationwide investigation of fishing hotspots and MPAs to determine fish abundance, species composition and size frequencies of reef-associated linefish.

The biology of the fish caught in the linefishery has been remarkably well studied, even more so when considering the large variety of target species in comparison with other fisheries. It is also this variety, however, that makes information on linefish difficult to access, both for researchers and for the general public. The recently published linefish species profiles contain updated information on life-history, ecology and population status of 139 linefish species (see section on Further Reading).

MPAs have the potential to enhance and sustain surrounding fisheries. A recent study done by DAFF has shown that, in some instances, this can be achieved without the commonly predicted negative effects on the fishery, in particular for depleted temperate reef fish stocks with complicated life histories. The results showed that catch rates in areas outside of a newly established MPA increased slowly at first and then more rapidly due to the export of larger fish and, five years later, spill-over of eggs and larvae.

Due to the depleted status of the stocks there is little scope to increase fishing effort on the linefishery in the near future, yet it is likely that profitability of the fishery could be increased. For example, to compete with imports of similar species from industrial fisheries in South America, Asia and New Zealand would be possible with improved handling and cooling protocols for some resources. In addition, a deeper understanding of the interactions between the linefishery and other fisheries, aquaculture, and fish imports is required.

Assessing the status of linefish stocks has been a priority in recent years, but is difficult due to the multi-species, multi-area nature of the fishery. Drawing on the enormous body of data contained in the NMLS, the largest spatially-referenced marine dataset in the world, a novel method to standardise CPUE data, used as an index for stock abundance, has been developed. Simulation testing of this approach with computer-generated data has proved that this method outperforms existing methods, laying the foundation for the first comprehensive stock assessment framework for the linefishery with state-of-the-art modelling techniques. The new framework has allowed recent assessment of stocks of four of the eight most important species, namely slinger *Chrysoblephus puniceus*, carpenter *Argyrozona argyrozona*, hottentot seabream *Pachymetopon blochi* and silver kob *Argyrosomus inodorus*. An assessment of geelbek *Atractoscion aequidens* is underway. The remaining species will be assessed comprehensively in the near future. The new framework has been incorporated in a proposed update of the LMP.

Rarer species that are caught infrequently and are subject to stringent bag and size limits are notoriously difficult to monitor. A novel approach based on encounter probabilities in the catch has been applied to two species, the red steenbras and the dageraad. Application of this fairly robust method confirms the continuous decline of these once abundant species to critically low levels. These two species are now not only of serious concern from a fishery sustainability perspective, but also of conservation concern, having been included on the IUCN Red List of Threatened Species as endangered.

Current status

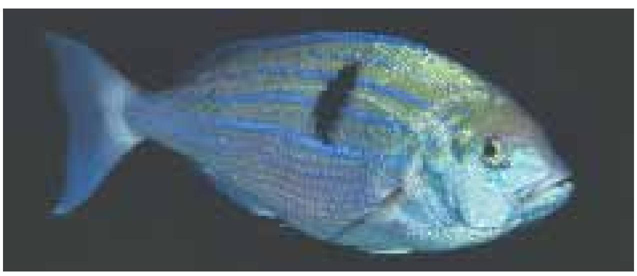
If the linefishery can be carefully managed to return to more sustainable levels, it has the potential to become one of the most ecologically and economically viable fisheries in South Africa, due to the following factors: (i) the fishing method can be highly selective and bycatch of undersized fish and unwanted species can be avoided; (ii) the labour-intensive, low-technology and 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 minimal impact on the broader ecosystem.

The first results of the new stock assessments indicate that the drastic reduction of fishing effort from 2003 resulted in the partial recovery of some species, such as the slinger, hottentot seabream and carpenter. However, other important stocks such as silver kob are still being overfished, due to the cumulative impact of the linefishery and the commercial inshore-trawl fishery on this species. Although not comprehensively assessed yet, the abundance trends of snoek and yellowtail suggest that these species are optimally exploited, but there is considerable inter-fishery conflict around these species which are also caught by a number of other fisheries (i.e. trawl and hake handline fishery in the case of snoek and tuna-pole and beach-seine net fisheries in the case of yellowtail). Moreover, the variable quality of the linefish catch and the inconsistent local availability of these nomadic species hampers the optimal use of the local product. Consequently, considerable quantities of these fishes are imported from Asia and South America.

The recovery of endangered species such as seventy-four, red steenbras and dageraad, hinges increasingly on the protection of juveniles and spawning stock of these species inside MPAs and offshore refugia. For some of these fish, even the rigorous enforcement of all existing regulations might not be sufficient to induce a recovery and more drastic measures might need to be taken to save these species.

Some of the most important species for shore and estuarine-based subsistence fishing, such as spotted grunter and dusky kob, are collapsed already. Rebuilding these stocks will be crucial for the small-scale fishing communities that rely on these resources.

The new assessment framework will enable tracking of the stock trajectories of the most important linefish species, providing a strong foundation for scientifically based sustainable management. Nevertheless, other stock status indicators such as standardised CPUE, a change in the proportion of a particular species in the catch, and even the concern of the majority of stakeholders about the status of a particular species, can inform management actions to safeguard the sustainability of the stocks for future generations of fishers



Ecosystem interactions

Given the relatively selective nature of linefishing, the bycatch in the linefishery is negligible. However, fishing with rod and line on high-biodiversity habitats such as temperate or tropical reefs will yield a range of species, some of which it is undesirable to catch because of their highly depleted status (such as the dageraad, the red steenbras and the seventy-four, as well as a number of shark and grouper species). Although captured fish can be released, there might still be significant mortality due to barotrauma and hook damage. Temporal (closed season, night fishing restrictions) and spatial (MPAs) management might be the only way to mitigate against these undesirable effects of multi-species linefishing.

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 is linked to the status of the estuaries. Reduced or regulated freshwater input, coastal development and pollution are altering estuarine habitats and threaten the wellbeing of the dependent fish populations.

Further Reading

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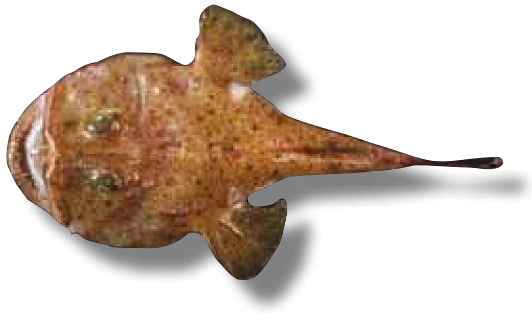
Monkfish



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

Introduction

The monkfish species occurring in southern African waters is *Lophius vomerinus*, commonly known as the Cape monkfish or 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, spending most of their time lying on the sea

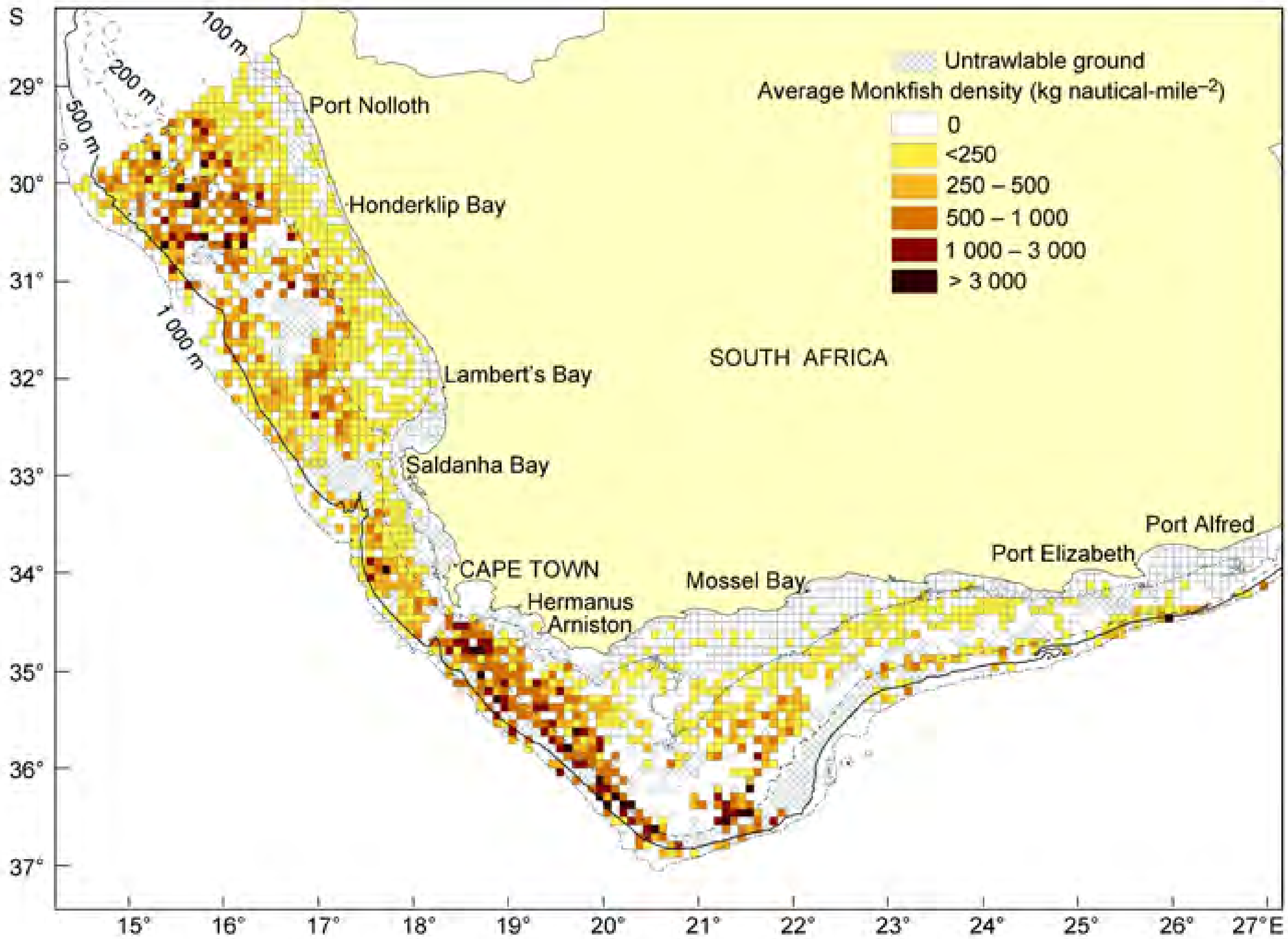


Figure 22: Distribution of monkfish in South Africa, derived from demersal research surveys. Average densities calculated from survey catches over the period 1984–2015 are illustrated per sampling grid block

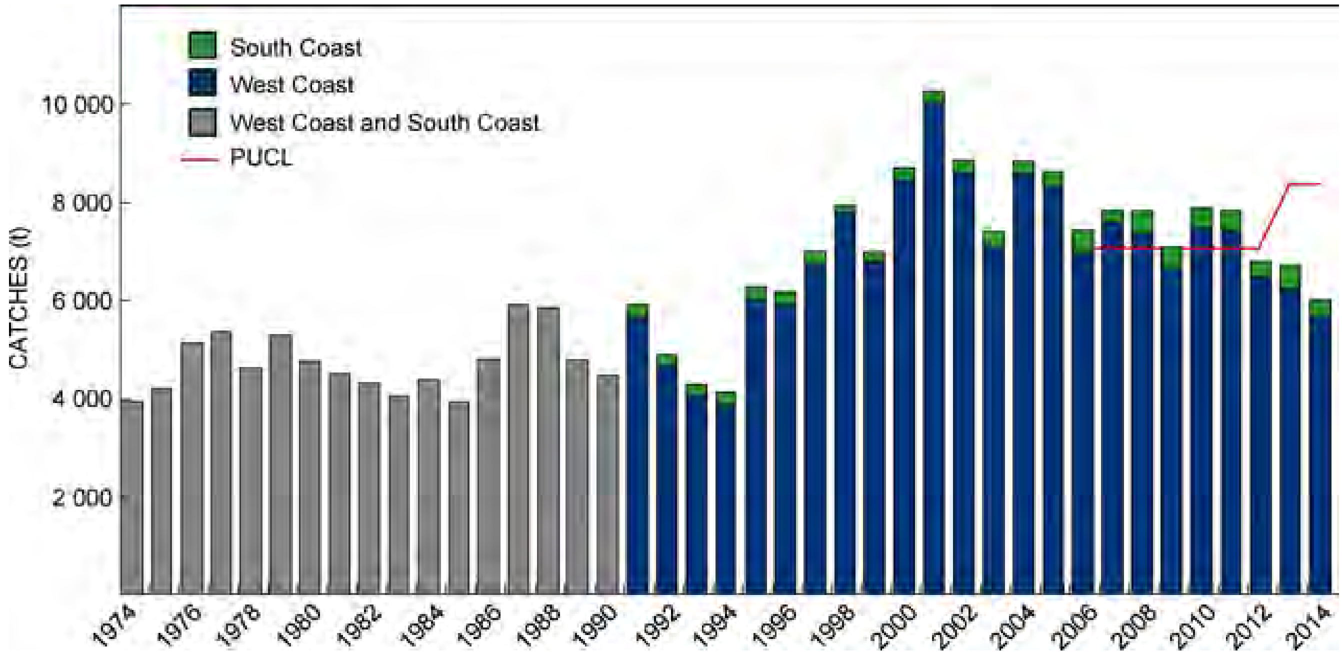


Figure 23: Annual catches of monkfish (tons) made by the hake trawl fishery for the period 1974–2014, and the Precautionary Upper Catch Limit (PUCL) that was introduced in 2006. Catches subsequent to 1990 can be separated by coast

bed (and often burrowing under the surface sediment) while awaiting potential prey to be attracted to the lure. Their diet comprises primarily other demersal fish species and crustaceans. Monkfish occur on both the west and south coasts of southern Africa, their distribution extending from off KwaZulu-Natal on the South African south-east coast to northern Namibia, and at depths ranging from about 50 m to 1 000 m (Figure 22). They are replaced by the African monk *Lophius vaillanti* off Angola, and by the blackmouth angler *Lophiomus setegerus* off KZN. As with most demersal fish species, individuals tend to move deeper and further offshore with increasing size/age.

The lifespan of the species is approximately 17 years, with fish reaching up to 1 m in length. The peak spawning period for females appears to be in September, based on trends in the gonadosomatic index (GSI; the weight of the gonads relative to whole body weight). The difference in testes weight between spawning and non-spawning males is not very large; consequently there is no clear seasonal trend in GSI for males. 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 in both cases).

The species is a high-value product, often marketed as "mock crayfish". Monkfish are caught almost exclusively as incidental bycatch during hake- and/or sole-directed fishing by the hake trawl fishery (both deep-sea and inshore sectors).

History and management

Annual catches of monkfish in the hake trawl fishery (made largely on the West Coast) fluctuated around 4 700 t over the period 1974–1994, and subsequently increased to a peak of over 10 000 t in 2001 (Figure 23). The increased catches raised concerns regarding the sustainability of this level of exploitation, and efforts were directed at assessing the status of the resource to establish a basis for sustainable management. An initial attempt to apply a modified version of a hybrid Age-Structured Surplus Production Model was unsuccessful as the model failed to converge due to the uninformative nature of the data. Subsequently a coast-disaggregated Replacement Yield (RY) approach was employed, the results of whichindicated that annual catches should not exceed 7 300 t. A Precautionary Upper Catch Limit (PUCL) was formally introduced into permit conditions in 2006, set at a level of 7 000 t per annum. The PUCL was generally exceeded during the early years of its implementation, largely due to difficulties associated with real-time monitoring and management. Effective co-management procedures have been developed and implemented over time, and catches subsequent to 2011 have been well below the PUCL (Figure 23).

The RY analysis is generally updated every two years. Although the 2011 assessment suggested that the PUCL could be increased to 8 300 t, it was maintained at 7 000 t for 2012 due to concerns regarding the over-catching during the preceding period. These concerns were addressed during 2012 through improved monitoring of catches and implementation of a co-management procedure with the hake trawl industry associations, and the PUCL was increased to 8 300 t for the 2013 fishing season, in line with the results of the 2011 assessment. Updated assessments conducted in 2013 and 2015 have provided no grounds to alter this PUCL, which has consequently been maintained at 8 300 t (Figure 23).

Research and monitoring

Abundance estimates for monkfish 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 monkfish) are included in the data collection. Additional to the abundance estimates, the surveys provide length-frequency data and

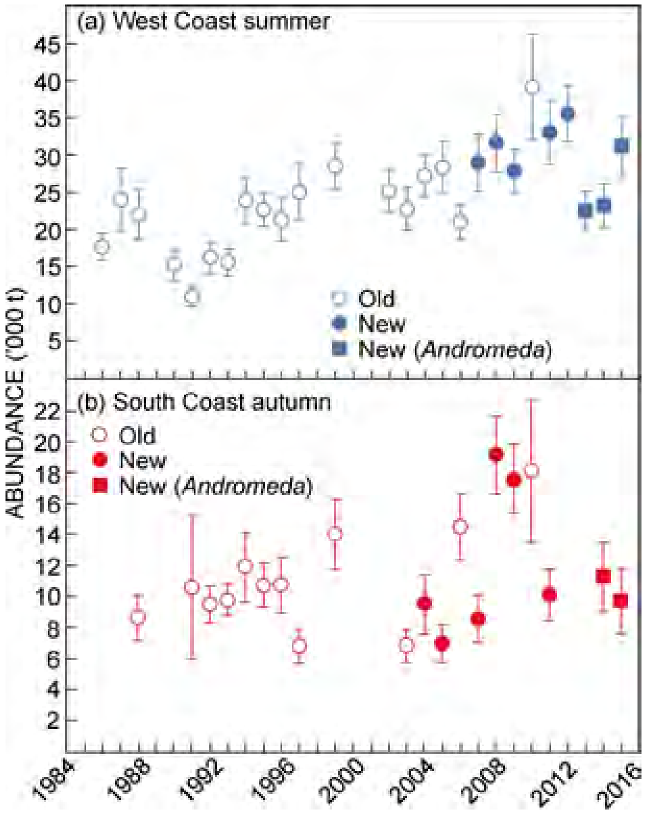


Figure 24: Estimates of monkfish abundance (± 1 SE) derived from the fishery-independent demersal research surveys conducted separately on the West (summer) and South (autumn) coasts each year. The various vessel-gear combinations are indicated as "Old" (RS *Africana* using old gear), "New" (RS *Africana* using the "new" gear configuration) and "New (MV *Andromeda*)" (the commercial vessel *Andromeda* using the new gear configuration)

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 uncertainty concerning the stock structure of monkfish. Studies using analyses of morphometrics and meristics showed some indications of stock structure between the West and South coasts, but this was not supported by genetic evidence derived from an analysis of allozyme markers. A research project investigating stock structure of monkfish using parasites as biotags has recently been initiated.

Current status

The most recent assessment of the monkfish resource was conducted in 2015, again using a coast-disaggregated RY approach to account for possible separate stocks. The assessment indicated that the resource is increasing on the West Coast and remains relatively stable on the South Coast (Figure 24). RY was estimated to be in the range of 8 130–8 345 t, depending on assumptions made regarding the relative catching efficiency of the Industry vessel that was used to conduct abundance surveys since 2012. These results suggest that the 8 300 t monkfish PUCL implemented in 2015 remains an appropriate catch limit for the resource.

Ecosytem interactions

South Africa has committed to implementing an Ecosystem Approach to Fisheries (EAF) management. 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.

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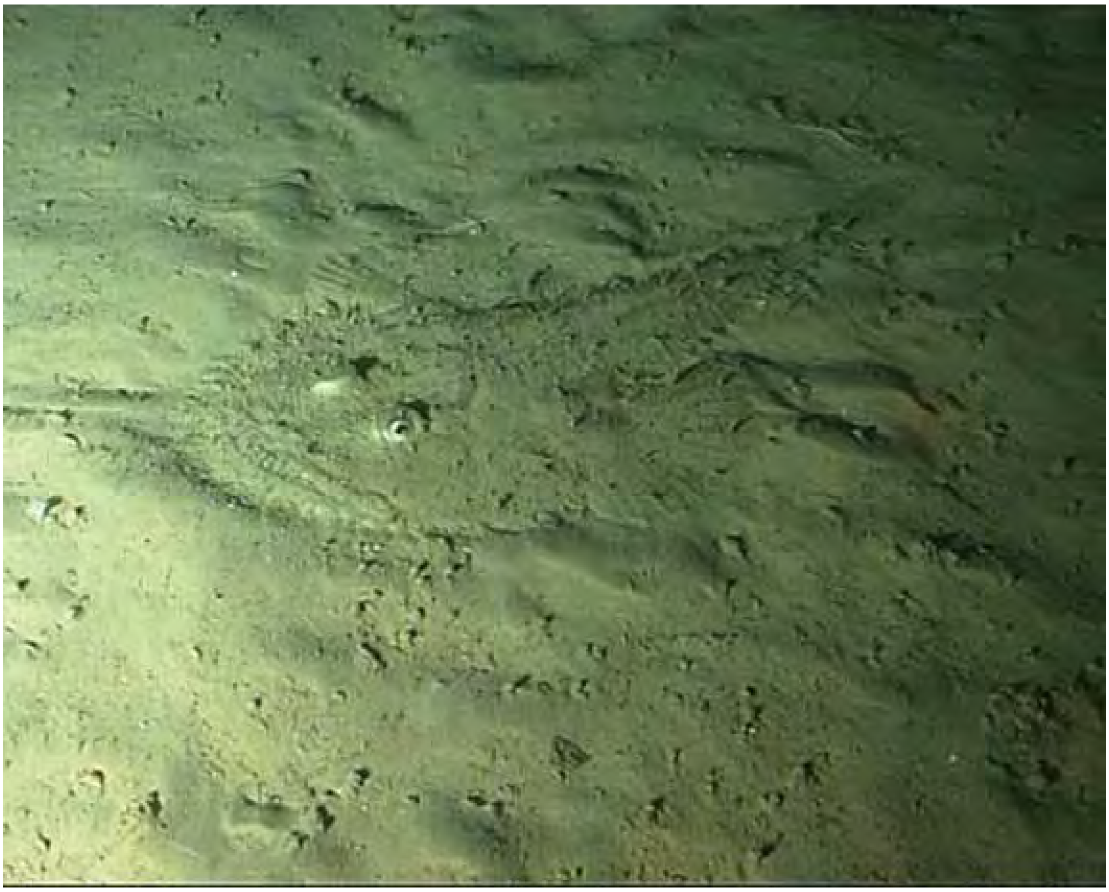
Useful statistics

Annual catches of monkfish (t) made by the hake trawl fishery for the period 1974–2014, and the PUCL that was introduced in 2006. Catches subsequent to 1990 can be separated by coast: WC = West Coast, SC = South Coast

Year	WC	SC	Total	PUCL	Year	WC	SC	Total	PUCL
1974			3 920		1995	6 008	238	6 246	
1975			4 190		1996	5 900	239	6 139	
1976			5 110		1997	6 723	235	6 958	
1977			5 350		1998	7 766	137	7 903	
1978			4 590		1999	6 805	145	6 950	
1979			5 260		2000	8 440	227	8 667	
1980			4 736		2001	9 997	221	10 218	
1981			4 478		2002	8 586	241	8 827	
1982			4 287		2003	7 047	328	7 375	
1983			4 009		2004	8 546	274	8 820	
1984			4 369		2005	8 294	312	8 606	
1985			3 893		2006	6 973	443	7 416	7 000
1986			4 785		2007	7 568	220	7 788	7 000
1987			5 901		2008	7 329	470	7 799	7 000
1988			5 812		2009	6 594	461	7 055	7 000
1989			4 754		2010	7 453	397	7 850	7 000
1990			4 433		2011	7 392	399	7 791	7 000
1991	5 593	290	5 883		2012	6 461	303	6 764	7 000
1992	4 646	212	4 858		2013	6 209	491	6 700	8 300
1993	4 051	198	4 249		2014	5 666	315	5 981	8 300
1994	3 853	236	4 089						



Netfish

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

Introduction

There are a number of active beach-seine and gillnet fisheries throughout South Africa. By far the biggest are the fisheries for harders (or mullet) *Liza richardsonii*, with 28 and 162 right-holders respectively from False Bay to Port Nolloth on the West Coast. 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 shark *Callorhynchus capensis* and species that appear on the 'bait list'. The exception is False Bay, where right-holders are allowed to target linefish species that they traditionally exploited. All evidence points towards the harder resource being over-exploited, and sector conflict arises due to real and perceived impacts on linefish resources from associated bycatch.

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, in particular white steenbras *Lithognathus lithognathus* and white stumpnose *Rhabdosargus globiceps*. The advent of gillnets in the 1800s saw effort directed at geelbek *Atractoscion aequidens*, with reports of gillnets being strung between Robben Island and the mainland to intercept shoals of these fish moving along the West Coast.

Harders were largely used for fertiliser, 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 hottentot seabream) fisheries. Many of the participants (including crew members) had retired from 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 excess effort in the fishery. Many only went to sea a few times each year, catching small quantities of fish. They only 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.

During this time, approximately 6 000 t were landed per annum by the beach-seine and gillnet fisheries. The gillnet fishery accounted for, on average, 3 250 t of harders, 650 t of St Joseph and 130 t of bycatch consisting of at least 27 species. Illegal gillnetting landed approximately 100 t of 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 predominantly linefish.

It is unlikely that the beach-seine and gillnet fisheries were generating 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 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 original permit-holders who were interviewed 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 numbers of legal beach-seine operations were reduced from around 200 to 28 and gillnet operations from just over 1 500 to 162.

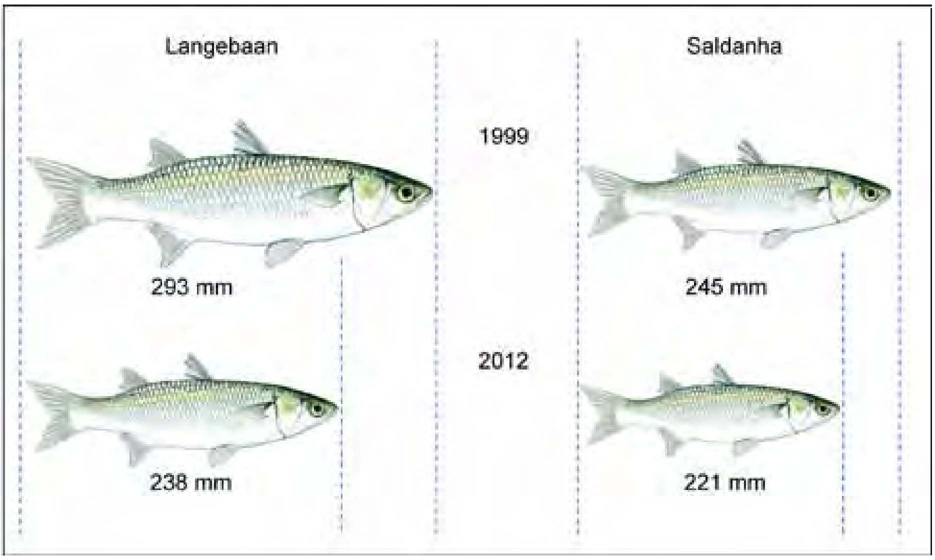


Figure 25: Change in mean size of *Liza richardsonii* in Langebaan Lagoon and Saldanha Bay, 1999–2012

Prior to this reduction in effort, size-frequency distributions of the harders caught suggested that the stock was over-exploited on a local and national scale, with a strong negative correlation between effort (number of nets) and the size of fish caught. The medium- and long-term rights allocation 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 of DAFF 2001 to facilitate rebuilding of the harder stock.

Also relevant was the linefish bycatch, most of which was composed of species regarded as over-exploited or collapsed. In turn, most of the catch of over-exploited or collapsed species were juveniles below 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. Recognising that estuarine gillnetting was severely compromising the nursery function of estuaries and having a negative effect on the fisheries for many other species, the management policy was to phase out all estuarine gillnets in the long-term. This has been implemented in all estuaries with the exception of the Olifants 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, one in Struisbaai and one in Simonstown. The latter has not been activated.

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 50% increase in gillnet fishing effort and a 10% and 20% decline in the average size of harders in Saldhana Bay and Langebaan Lagoon respectively (Figure 25). This has led to growth overfishing, with catches being made up of fish that are smaller than optimal and of lower market value. The Fishing Rights Allocation Process (FRAP 2015) and the small-scale implementation will see these fishers formally incorporated into the beach-seine and gillnet fisheries. Sustainability objectives require the necessary adjustments in effort to conform to the TAE and arrest the decline in growth rate.

Recent catch records indicate that the relationship between catch and effort is still the greatest influence in the fishery (see table in Section 'Useful Statistics'). Whereas the number of active right-holders halved from 2007 to 2014, individual CPUE (landed tonnage) doubled over the same period, suggesting fewer fishers sharing the same pool of fish.

Research and monitoring

Fishery-dependent data sources consist of ongoing length-frequency measuring, observer data, compulsory monthly catch returns by right-holders and an intermittent national linefish survey. The most important of the fishery-dependent data sources has been the national linefish survey as this provides comparable and combined catch, effort, compliance and socio-economic information for the beach-seine and gillnet fisheries, as well as the commercial, recreational and subsistence linefisheries. This survey, however, has not been able to be repeated since 1995. It is hoped to complete a survey of the beach-seine and gillnet fisheries during the course of 2015–2016.

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. Fish densities are compared across estuaries and surf-zones in relation to the different levels of fishing pressure and other variables such as freshwater flow into each of these systems. From these data, a predictive capability that can be incorporated into existing linefish stock assessment models is being 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 estuaries have been monitored once to four times annually from 2001 until the beginning of 2016.

Fishery-dependent size-frequency information allows comparison between areas with different levels of fishing effort and is validated by size-frequency distributions from fishery-independent sampling, most importantly that of the observer programmes. Past work has shown 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

Prior to the reduction in effort implemented after 2001, size-frequency distributions of the harders caught suggested that the stock was over-exploited on a local and national scale. There was a strong negative correlation between effort (number of nets) and the size of fish caught. This was not surprising considering that effort ranged from 0.5 nets per kilometre of coastline in Langebaan to 15 nets per kilometre in St Helena Bay. Also relevant was the linefish bycatch, most of which comprised species regarded as over-exploited or collapsed. In turn, most of this catch comprised juveniles 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.

There was some evidence for recovery of the harder stock in some areas. For example, in the Berg River Estuary, continued monitoring before and after the 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.

This success may, however, have been short-lived as data suggest that the illegal gillnet fishery in the Berg River Estuary has escalated since then. These data suggest that at least 400 t are harvested illegally from the Berg River Estuary alone each year. A total of 500 t reduction in reported catches by the legal fishery in the sea strengthens the veracity of this and highlights the likely impact on the legal fishery.

Similarly, in Langebaan a 50% increase in gillnet fishing effort over and above the TAE has seen growth overfishing and a 20% decline in theaverage size of harders caught.

Exacerbating the problem has been an anomalous series of 1-in-50 year floods in quick succession on the South Coast in recent years, which have considerably reduced juvenile recruitment over the last four years. This will have a negative impact on the adult stocks of many species in coming years, including harders and various linefish. Ultimately, the impact on the netfisheries will depend on the linkages between the South Coast and West Coast populations of these species.

Environmental drivers play an important role in harder growth, which varies between estuaries, islands and the nearshore, and between the cool West Coast and warm temperate South Coast. The sex ratios of fish in estuaries and the nearshore, where most of the fishery occur are 9 females: 1 male as opposed to 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 two years, whereupon female growth slows considerably and that of males becomes negligible. Females attain larger size-at-age in all regions and habitats. Females grow larger than males and continue to grow after maturity to maximise reproductive output.

Observed differences in growth are likely attributable to the interplay between harder life-history strategies and response to the environment and fishing. For example, South Coast female fish are larger than those from the West Coast and estuarine female fish are larger at age than those in the sea. It is hypothesised that this relationship may be a result of larger, fast-growing fish being caught by the West Coast net fisheries, thereby selecting for slow growth in populations there.

Females from islands on the West Coast appear to grow faster than those from the nearshore. 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

Most 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 catches comprise estuary-dependent species. This is illustrated by the declines in the harder stock and marine gillnet fishery catches on the West Coast, which have been directly attributed to recruitment over-fishing (the removal of too many fish so that they are unable to reproduce effectively and replenish their populations) in the Olifants and Berg estuaries.

Fishing aside, the health of estuarine habitats 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 freshwater 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% reduction in freshwater flow and 60% loss of floods to these estuaries. Climate change, hydropower demands and freshwater abstraction will see these losses being 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 pristine (or 'baseline' levels) and are likely to decline to less than 5% of this level under future flow projections. Partially estuary-dependent fish, most importantly harders which are the mainstay of the netfishery, have estuarine juvenile populations that are now at an estimated 60% of pristine.

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

High bird bycatch mortality, especially in unattended nets, led to legislation and permit conditions that no gillnet (either set or drift) may be left unattended. The most vulnerable species are crowned cormorant *Microcarbo coronatus* and African penguins *Spheniscus demersus* in the sea and African darters *Anhinga rufa*, reed cormorants *Microcarbo africanus* and great crested grebes *Podiceps cristatus* in the estuarine environment. More recently, an upsurge in illegal gillnetting has been accompanied by an increase in the retention of bird bycatch for food. This may need management intervention in the future.

Seal depredation of catches (i.e. the removal of captured fish from fishing gear by seals) is frequent in the beach-seine and gillnets fisheries. Catch loss is similar 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. There are limited seal mortalities, mostly of pups, in the beach-seine and St Joseph gillnet fisheries.

Bycatch and mortality of dolphins, especially of Heaviside's dolphin *Cephalorhynchus heavisidii*, has been an ongoing problem with the larger-mesh set nets used to target St Joseph shark and with the illegal galjoen gillnet fishery. Most of these mortalities occurred in the Cape Columbine region. Since 1999, there has been an effective 25 km zone from North Head Saldhana Bay to Cape Columbine from which the gillnet fishery is excluded in order to reduce catches of dolphins.

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

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Useful statistics

Total allowable effort (TAE, number of right-holders), proportion of right-holders active, CPUE (catch per net-day and catch per net-year) and total annual catch (including illegal component) for the beach-seine and gillnet fisheries. Right-holders include exemption holders.

	2007	2008	2009	2010	2011	2012	2013	2014
TAE (right-holders)	190	190	190	190	190	190	190	189
Right-holders active (%)	65	46	46	39	37	36	31	30
Catch per net-day (kg)	186	256	270	295	358	339	293	247
Catch per net-year (t)	12	20	20	25	28	27	25	23
Total annual catch (t)	1 862	2 323	2 313	2 639	2 846	2 694	2 407	2 167

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*, which is imported and used widely in marine aquaculture. 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 sub-tidal 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 sub-tidal 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, a handful of individuals (less than 8 people) held concessions to harvest oysters and employed large numbers of 'pickers' to assist with collections. In 2002,

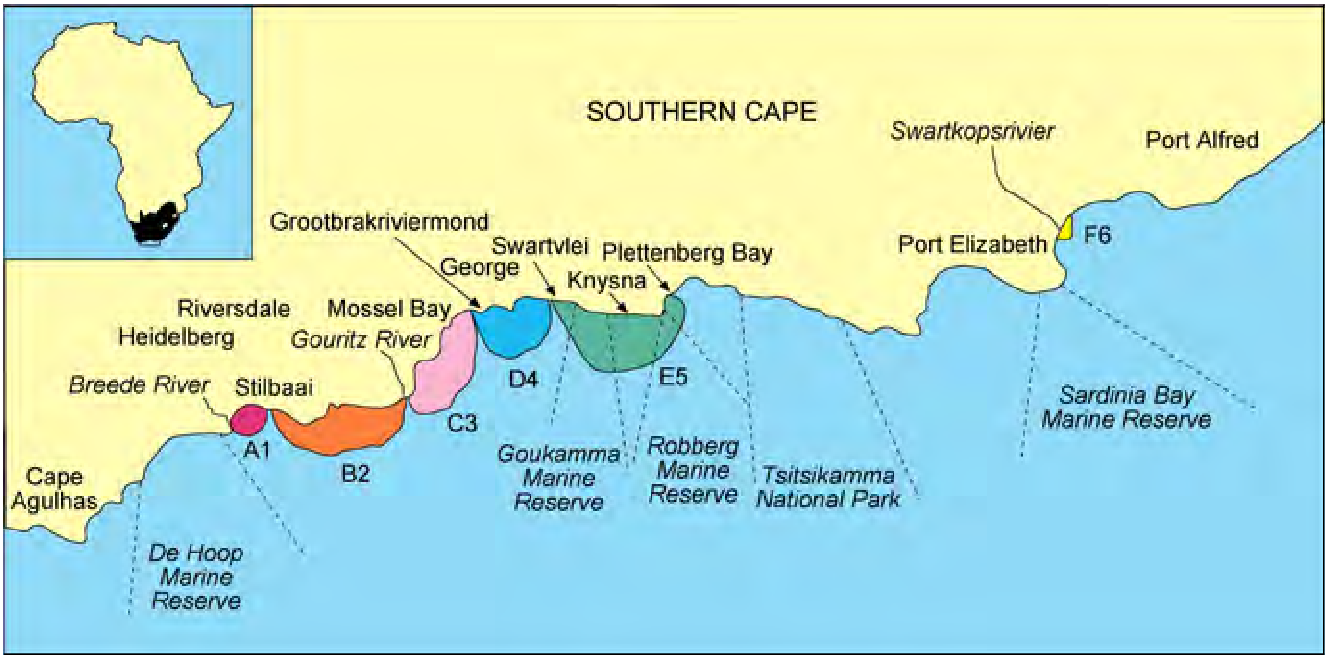

Figure 26: Oyster fishery in Port Elizabeth and the Southern Cape. The colour-coded areas indicate dedicated oyster collection zones

rights were redistributed and medium-term (four-year) rights were allocated to 34 right-holders, the majority of which held limited commercial rights and were allowed to work with up to three pickers each. A few right-holders held full commercial rights and were allocated 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 are required to harvest the oysters themselves and are no longer allocated additional effort (pickers) to assist with harvesting.

The oyster fishery was previously managed as two separate fisheries related to their areas of operation, namely the Southern Cape Coast and the KZN Coast. Since 2002 the oyster fishery has been managed as a national fishery. Under the new management system, four commercial oyster-harvesting areas were officially recognised, namely the Southern Cape, Port Elizabeth, KZN North and KZN South (Figures 26 and 27). Regional differences regarding regulations and harvesting patterns have been retained.

Research and monitoring

Research on the oyster resource has begun only recently. Since oysters are of relatively low value in comparison to other commercially exploited species, the fishery was not prioritised in terms of research effort and management attention in the past. The consequence is that the Total Allowable Effort (TAE) for the oyster fishery is currently determined according to historical effort levels and not on the basis of the assessed stock or status of the resource.

Initiatives are underway to improve the quality of catch and effort data, and towards undertaking resource assessments. Current research on oysters is therefore focused on developing appropriate methods for assessing the oyster resource, given that the patchy distribution and cryptic nature of oysters make accurate sampling of this resource in the intertidal zone exceedingly difficult. Once the method is refined and a reliable index of oyster abundance is obtained, improved scientific advice on sustainable harvesting levels will be able to be provided.

Due to the uncertain status of the resource, and evidence of over-exploitation in the Southern Cape, this region has been prioritised for research efforts aimed at establishing indices of abundance, estimating density and population size structure, and determining a more accurate TAE. Research and monitoring in KZN is carried out by the Oceanographic Research Institute (ORI) under contract to the Branch: Fisheries Management with the purpose of providing information on which to base recommendations for this region of the coast.

Current status

Currently, the overall TAE is 145 pickers. In the last few years, however, less than 50% of the TAE has been issued or utilised. The status quo is being maintained until further data become available.

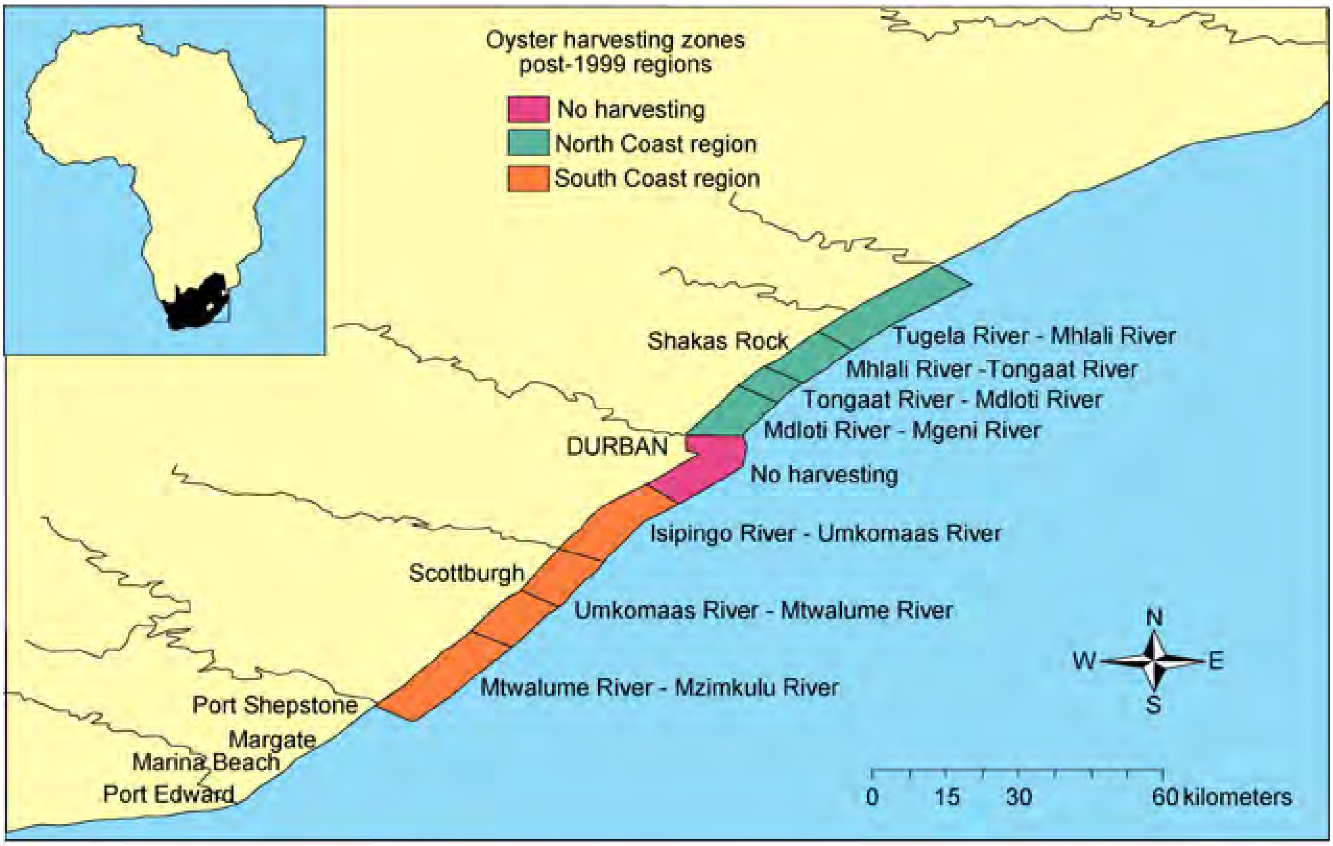

Figure 27: Oyster fishery in KwaZulu-Natal (re-zoning of South Coast included)

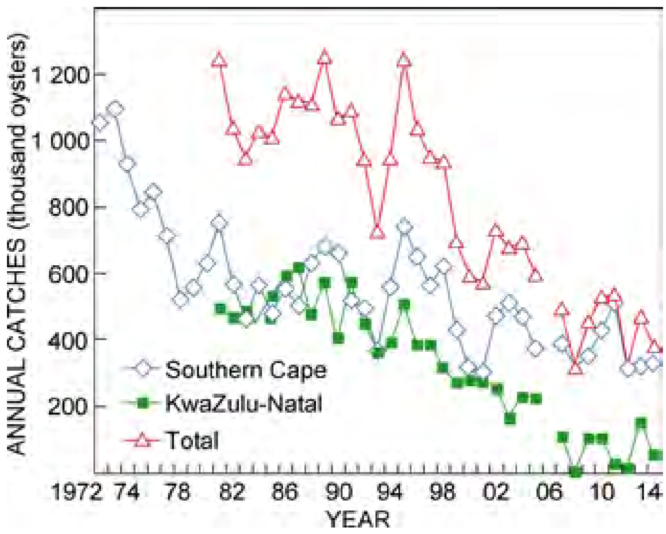

Figure 28: Total number of oysters harvested from the Southern Cape and KwaZulu-Natal coasts for the period 1972–2014

Total catches between 2002 and 2005 were between approximately 600 000 and 730 000 oysters, the majority of which being harvested in the Southern Cape (Figure 28). 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 individuals) was an exception, caused mainly by problems during permit processing. In recent years, total catch has stabilised at above 300 000 oysters. It is noteworthy, however, that these come mainly from the Southern Cape because catches in KZN have been at very low levels for the last seven years. This may have been a consequence of reduced effort (non-activation of permits), poor catch reporting (especially along the KZN South Coast) or a decline in resource availability. Further research is required for an updated assessment.

The oyster resource along the KZN coast is considered to be fully exploited. Resource assessments undertaken in 2006 during a research project outsourced to ORI showed that, although the oyster stocks had declined since 1980, they had been stable or had shown only a slight decline for approximately 20 years prior to the study. As mentioned above, however, harvesting figures have declined more recently.

In the Southern Cape there is concern that the intertidal zone is being denuded of oysters as a result of being over-harvested. Surveys undertaken between 2000 and 2004 that measured oyster density and size composition suggested that the intertidal component of the oyster stock along the Southern Cape coast appeared to be over-exploited. Moreover, there have been reports of divers illegally harvesting oysters from subtidal "mother beds".

Catch Per Unit Effort (CPUE) data for the Southern Cape oyster fishery are considered to be unsuitable for the purposes of stock assessment, and the status of this resource thus remains uncertain.

Ecosystem interactions

The 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.

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Useful statistics

Total allowable effort (number of pickers) and total catch (number of oysters) for the oyster fishery for the period 2002–2014

		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Southern Cape	TAE	105	105	105	105	105	105	105	105	105	105	105	105	105
and Port Elizabeth	Catch	471 360	511 946	468 485	373 322		387 831	315 807	350 853	426 649	508 422	311 186	320 312	327 120
KwaZulu-Natal	TAE	40	40	40	40	40	40	40	40	40	40	40	40	40
	Catch	257 238	163 357	227 067	222 864		105 552	2 796	103 684	102 168	24 928	13 695	149 863	52 620

Patagonian toothfish

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

Introduction

Patagonian toothfish *Dissostichus eleginoides* (Figure 29) belong to the family Nototheniidae, a family of fish that occurs in the Southern Ocean. Unlike other species in the family, Patagonian toothfish appear to lack antifreeze molecules in the blood and are consequently not found in waters colder than 2 °C. They are slow–growing, reaching sexual maturity at about 90–100 cm (9–10 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 40ºS and 55ºS. 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 killer whales *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.

Most of the Patagonian toothfish distribution falls 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.

Figure 29: A Patagonian toothfish *Dissostichus eleginoides*, with an individually numbered tag inserted just below the dorsal fin

History and management

An experimental fishery for Patagonian toothfish in the PEI-EEZ was initiated in 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 30). Another shift in the gear employed began with the introduction in 2008 of a modified longline gear, the trotline, which appreciably decreases the loss of catch to marine mammal depredation and has a higher retention of large fish. Use of this gear has subsequently increased to the extent that no Spanish longline gear has been used subsequent to the 2012/2013 fishing season (Figure 30). 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 2011/2012 season and continued through to the end of

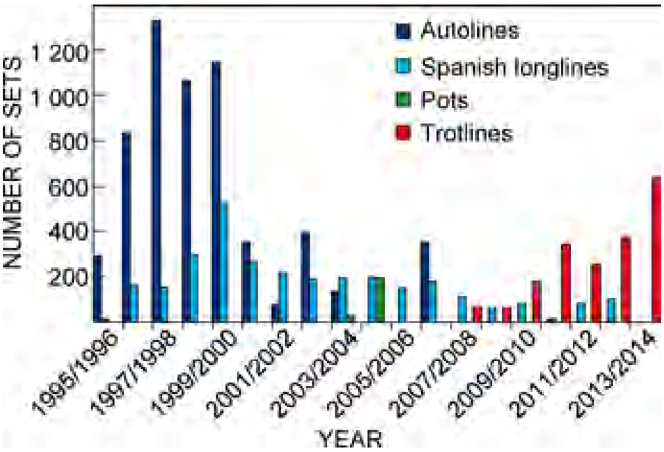

Figure 30: Number of sets (longlines) deployed per fishing season in the Prince Edward Islands EEZ. Data are shown for pot lines and for three different longline gear configurations deployed in the fishery over time.

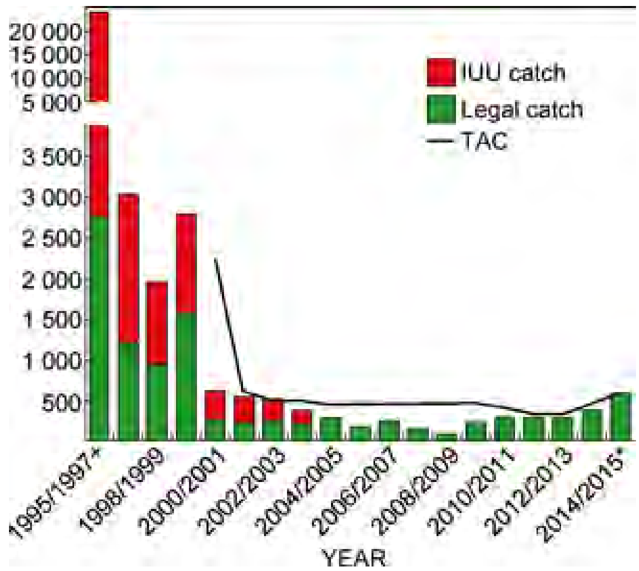

Figure 31: Legal and IUU catches of Patagonian toothfish taken from the Prince Edward Islands EEZ per fishing season since the inception of the fishery. Also shown are the Total Allowable Catch (TAC) limits since the 2000/2001 fishing season. Note the break in the Y-axis

† The legal catch is for 14 months (1 October 1995–30 November 1996), whereas the IUU catch is the estimated total for 1995 and 1996 combined

* The 2014/2015 season was not yet completed at the time of preparation, but the total catch for the season is likely to be close to the TAC as depicted here

the 2012/2013 fishing season. Currently, trotlines are the only gear deployed in this fishery.

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

Regulation of the fishery was initiated in the 2000/2001 fishing season by means of a TAC restriction of 2 250 t. The first assessment of the status of the resource was conducted in 2001 and used an Age Structured Production Model (ASPM) that was based on Catch-Per-Unit-Effort (CPUE) data derived from Spanish longline sets. The results of the assessment indicated severe depletion of the stock, which led to a decrease in the TAC to 600 t for the 2001/2002 season. At its October 2002 meeting, the CCAMLR Scientific Committee suggested that a TAC of not more than 400 t would be appropriate for the 2002/2003 season. In consultation with industry representatives, a compromise was reached between the 400 t suggested by CCAMLR's Scientific Committee and the 600 t TAC that was set in the 2001/2002 season. This compromise was firstly to demonstrate South Africa's commitment to CCAMLR, and secondly to provide sufficient catch to maintain a year-round legal fishing presence in the PEI-EEZ as a means of deterring further IUU fishing in the area. The TAC was thus set at 500 t for the 2002/2003 season and maintained at that level for the 2003/2004 fishing season.

The ASPM was extended to incorporate catch-at-length (CAL) data as a basis for TAC recommendations in 2003.Despite refinements to the model, the two primary resource monitoring indices (CPUE and CAL) yielded conflicting estimates of resource status. While the CPUE data indicated that the resource was severely depleted, the CAL data suggested that the situation was less serious. Attempts to reconcile these two indices were unsuccessful. These circumstances led to major difficulties in making scientific recommendations for appropriate catch limits for this resource, and a pragmatic approach was adopted that led to a reduction in the TAC to 450 t for the 2004/2005 season. The consortium of four right-holders withdrew their vessel in 2006 due to economic pressures, leaving only a single right-holder, with an allocation of 27% of the TAC, active in the fishery. Consequently the TAC was maintained at 450 t per annum until 2010 when the consortium of four right-holders re-entered the fishery. The annual catches over the 2006–2010 period were well below the TAC (Figure 31) as a result of only one right-holder being active in the fishery.

An updated analysis of the status of the resource incorporating additional catch data (2007–2010) was conducted in September 2011. The analysis was complicated by the gear change (Spanish longline to trotline) in the fishery in recent years, which had compromised the only index of abundance, namely the time-series of commercial CPUE. Depending on the data and approach used in the analysis, standardised CPUE dropped by between 16% and 34% in 2010 relative to preceding years. On the basis of these results, the TAC for the 2011/2012 fishing season was reduced by 20% from the 2010/2011 level to 320 t, and this level was maintained for the

2012/2013 season, pending further work on calibrating the Spanish longline and trotline CPUE indices.

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

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

In addition to updated catch data and the improved standardised CPUE index of abundance, the 2014 assessment model update involved several improvements over previous assessments. Tag-recapture data (Table 5) were incorporated for the first time, and a new basis for estimating the extent of depredation by cetaceans was used. The updated model yielded a changed perception of depletion, with estimates ranging from 55% to 60% of the average pre-exploitation spawner biomass. Although projections using the assessment model indicated that the resource would increase in abundance under catches of up to 700 t per annum, the poor fits to longline CPUE data, coupled with uncertainties regarding the stock recruit relationship, led to the decision to set the TAC for the 2014/2015 season at 575 t, with further increases dependent on a review of updated datasets.

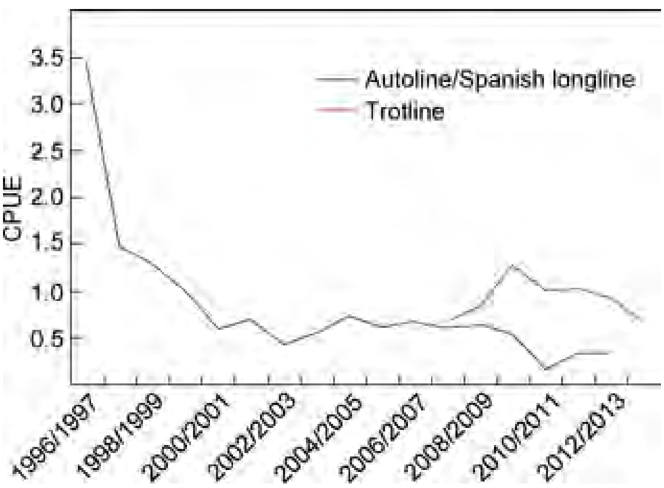

Figure 32: GLMM standardised CPUE trends for the autoline and Spanish longline combined and for the trotline (calibrated to be comparable to Spanish longline) gear types.

Table 5: Number of Patagonian toothfish tagged and released per year in the Prince Edward Islands-EEZ, and the number of tagged fish recaptured per year

Season	Released	Recaptured
2004/2005	175	1
2005/2006	179	1
2006/2007	120	4
2007/2008	140	0
2008/2009	74	7
2009/2010	131	2
2010/2011	206	11
2011/2012	162	8
2012/2013	253	10
2013/2014	380	27
2014/2015*	150	16
Total	1 970	87

* Includes those reported up to August 2015 only

Research and monitoring

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

Some toothfish were tagged during 2005 as a trial, and a tagging programme was initiated in 2006. Vessels are required to tag and release one fish per tonne of catch (in line with CCAMLR Conservation Measure 41-01). Fish should be selected at random for tagging (e.g. every 100th fish) so that a range of sizes is tagged. However, fishers 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 similarity between the size structures of the tagged fish and of the retained catch, 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. To date, 992 fish have been tagged and 33 have been recaptured (Table 5).

The majority of recaptures of tagged toothfish have been in relatively close proximity to 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 is 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 they showed a larger decline in CPUE over the last five years than that estimated by previous standardisations.

Efforts are being directed at continuing work on developing an Operational Management Procedure (OMP) to enhance effective management of the resource and fishery. Efforts are also being directed at attempting to improve estimates of depredation by marine mammals, which is currently a major source of uncertainty in the assessment process.

Current status

An updated assessment of the PEI Patagonian toothfish resource was conducted in 2015 using the same approach as in the 2014 assessment, with additional data extending to June 2015. The results did not differ markedly from those obtained in 2014, yielding similar perceptions of the level of depletion (53–60%), and similar projections of resource status under various future catch scenarios. However, concerns regarding the model fit to the recent longline data and uncertainties around the assumed levels of recent (and future) recruitment remained. In addition, the estimate of the trotline CPUE for 2014 was below the model prediction and is the lowest of the trotline time-series (Figure 32). Based on these observations, it was considered that any increase in the TAC for the 2016 fishing season should be deferred pending a review in 2016 of updated data (trotline CPUE in particular) collected during the 2015 fishing season, and that the TAC for 2015/2016 should be retained at 575 t.

Ecosystem interactions

South Africa has voluntarily undertaken to implement the CCAMLR conservation measures within the PEI-EEZ. These include 100% observer coverage, move-on rules to limit by-catch and specifications for mandatory bird scaring lines (tori lines). In addition the total catch of rattails (*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 rattails 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 (MPA) 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 MPA is primarily aimed at protection of biodiversity.

Further reading

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Useful statistics

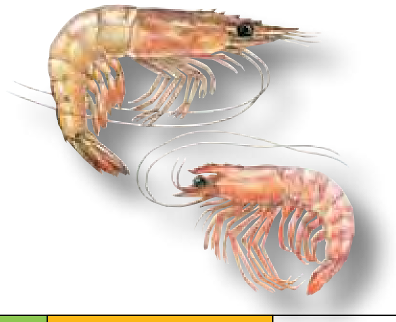
Catches of Patagonian toothfish estimated to have been taken from the Prince Edward Islands EEZ and the Total Allowable Catch (TAC) limit

Fishing Season	Legal Catch (t) Longline	Pot	Trotline	Total	Estimated Illegal catch (t)	Total (t)	TAC (t)
1995/1997[†]	2 754.90			2 754.90	21 350	24 104.90	
1997/1998	1 224.60			1 224.60	1 808	3 032.60	
1998/1999	945.10			945.10	1 014	1 959.10	
1999/2000	1 577.80			1 577.80	1 210	2 787.80	
2000/2001	267.80			267.80	352	619.80	2 250
2001/2002	237.30			237.30	306	543.30	600
2002/2003	251.10			251.10	256	507.10	500
2003/2004	182.50	34.30		216.80	156	372.80	500
2004/2005	142.60	141.90		284.50		284.50	450
2005/2006	169.10			169.10		169.10	450
2006/2007	245.00			245.00		245.00	450
2007/2008	88.80		56.40	145.20		145.20	450
2008/2009	41.80		30.70	72.50		72.50	450
2009/2010	49.20		174.60	223.80		223.70	450
2010/2011	1.00		290.40	291.40		291.40	400
2011/2012	70.70		205.50	276.20		276.20	320
2012/2013	50.00		215.30	265.30		265.30	320
2013/2014			367.50	367.50		367.50	450
2014/2015[*]			575.00	575.00		575.00	575

[†] Catch data for the two-year 1995–1997 season includes legal catches taken during the 14-month period October 1996–November 1997 and IUU catches taken during the full two-year period

[*] The total catch for 2015 is the expected catch for the year as the fishing season is still ongoing, and is assumed will be entirely caught with trotlines

Prawns



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

Introduction

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

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

History and management

Management of the fishery is via effort-control, which is effected by limiting the number of vessels allowed to operate in the two sectors of the fishery. The two major management challenges facing the fishery are mitigation of bycatch and setting Total Allowable Effort (TAE) levels that reflect the high inter-annual variability of the shallow-water resource. Closed shallow-water fishing seasons are used to reduce bycatches of juvenile linefish. It is important to note that many vessels fish in KZN only when prawns are abundant, but then re-locate to other areas (such as Mozambique) in periods when yields in KZN decline and the operation becomes uneconomical. Historically, the nominal fishing effort in the KZN prawn trawl fishery has remained virtually unchanged since 1993, although many of the vessels operate in KZN waters only occasionally. Recently, however, the effort has been low, with only three vessels operating in 2014. Recruitment failure on the Thukela Bank as a result of inadequate river run-off has severely impacted the shallow-water fishery in recent years. The opening of the mouth of the St Lucia estuary in 2012 due to good rains in the catchment area was expected to have a positive effect on shallow-water prawn landings in 2013. However, no effort was directed in the shallow-water areas (<100 m depth) in 2013 and 2014. The expected recovery of the shallow-water species can therefore only be assessed once trawling effort is directed at this zone.

Research and monitoring

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

A range of surplus production models was therefore applied to the catch and CPUE data for the KZN crustacean trawl fishery in 2009. This included a simple equilibrium model, fitting data separately to the Schaefer and Fox equations (on all four deep-water species combined and then individually). Unrealistically high levels of both Maximum Sustainable Yield (MSY)

Table 6: Total catches of the KZN prawn 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 by-catch	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	267.8
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	1.7	103.3	61.5	12.0	8.1	34.4	221.0
2014	7	0.3	149.6	56.2	11.5	4.9	25.2	247.7

and the fishing mortality that would produce this yield (FMSY) were obtained. Data were therefore fitted to both simple and complex non-equilibrium surplus production models (Schaefer, Fox and Pella-Tomlinson), which also resulted in unrealistic estimates of MSY and FMSY. The inability of the models to produce reasonable estimates of MSY and FMSY is probably a consequence of the time-series of data only commencing several years after the fishery began. Consideration will be given to utilising alternative methods of stock assessment for this fishery in future.

Current status

The fishery is regarded as optimally exploited, although there is a need for more and better data collection and systematic research on the biology of the various prawn species and bycatches. The fishing effort in the KZN prawn trawl fishery has remained virtually unchanged since 1993, although many of the vessels operate occasionally in KZN waters only (only three vessels were active in the KZN fishery in 2014).

Catches of shallow-water prawns strongly reflect annual recruitment from estuaries, and a predictive equation relating historical river flows to shallow-water prawn catch on the Thukela Bank was developed for the period 1988–2000 by the then Department of Water Affairs and Forestry. Very low catches in recent years (Figure 33) are attributed to drought conditions and the closure of the mouth of the St Lucia Estuary by a sandbar – recruitment of juvenile prawns from the estuary to the Thukela Bank has therefore been blocked, leading to recruitment failure on the Thukela Bank in the last 10 years. This has severely impacted on the shallow-water fishery and resulted in historically low catches of 1.7 and 0.3 t in 2013 and 2014 respectively, compared with, for example, a catch of 107 t in 2000 (Figure 33, Table 6). As a consequence, it has been recommended that the exploitation levels be retained at the current level, but that fishing on the Thukela Bank be restricted to between March and August.

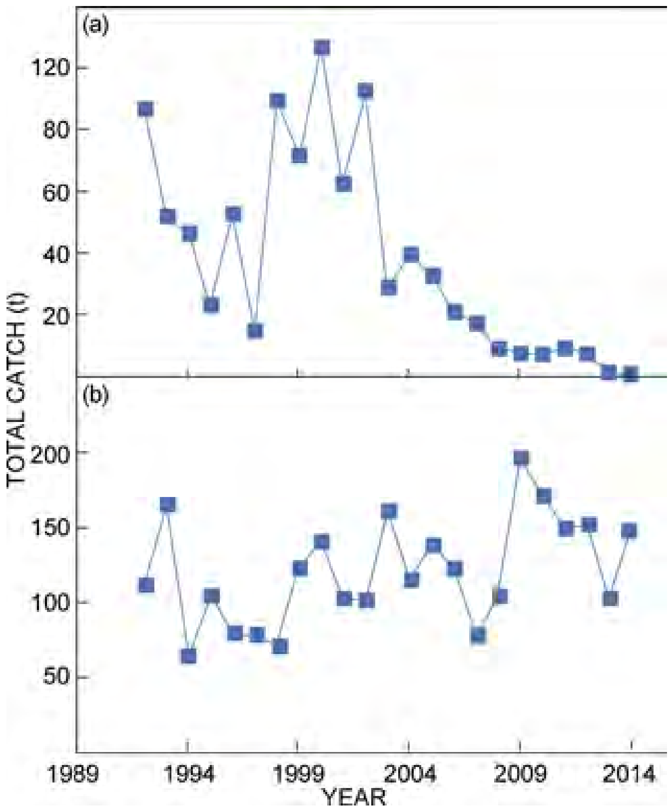


Figure 33: Total annual catches of (a) shallow-water prawns and (b) deep-water prawns in KwaZulu-Natal for the period 1992–2014

Trends in catches in the deep-water fishery relate both to abundance and targeting practices, where specific depths or substratum types are selected to achieve a desired species mix or highest economic value. Landings of deep-water prawns increased from a low level of 79.2 t in 2007 to a peak of nearly 200 t in 2009, and has been around 150 t in three of the past four years, confirming an overall increase in catch since 2007 (Figure 33). Langoustine catches have remained relatively stable recently at between 51 and 82 t, whereas catches of rock lobster declined dramatically from 23 t in 2011 to only 5 t in 2014. Catches of red crab also decreased sharply from 19.7 t in 2011 to 11.5 t in 2014, the lowest since the time-series began in 1992 (Table 6).

Ecosystem interactions

The prawn fisheries take high amounts of bycatch. The fishing season for the shallow-water fishing grounds (Thukela Bank) is therefore restricted to March–August to protect juvenile fish species that are important to the linefishery. Further research is currently being carried out with the aim to mitigate the impact of the fishery.

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Seaweeds

Stock status	Unknown	Abundant (non-kelps)	Optimal (Kelp)	Depleted	Heavily depleted
Fishing pressure	Unknown	Light (Kelp, non-kelp)	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 and Mtamvuna 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. 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 sector is small compared to many other fisheries, but is estimated to be worth at least R35 million annually and to provide at least 300 jobs. Much of the harvest is exported for the extraction of gums. The international seaweed industry is controlled by large international companies that can manipulate prices. Marketing of these raw materials is complicated and requires overseas contacts to sell seaweed or to obtain a good price. As a result, returns for South African companies that do not process locally may be marginal, and they often stockpile material while negotiating prices.

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

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

History and management

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

The coastline between the Orange and Mtamvuna rivers is divided into 23 seaweed rights areas (Figure 34). In each area, the rights to each group of seaweeds (e.g. kelp, *Gelidium*, or gracilarioids) can be held by only one company, to prevent competitive over-exploitation of these resources. Different companies may hold the rights to different resources in the same area.

Management of most seaweed resources is based on Total Allowable Effort (TAE), except for fresh kelp, for which a Maximum Sustainable Yield (MSY) is set in annual permit conditions. It should be noted that, since 2012, the commercial season for permits and reporting of seaweed harvests was changed from a calendar year to 1 April of year 1–31 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

Figure 34: Map of seaweed rights areas in South Africa

Table 7: Annual yields of commercial seaweeds in South Africa, 2001-2014, by calendar year. 'Kelp beach cast' (column 4) refers to material that is collected in a semi-dry state, whereas 'kelp fresh beach cast' (column 6) refers to clean wet kelp fronds that, together with 'kelp fronds harvest' are supplied as abalone feed. 'Kelp fresh beach cast' was only recorded separately since 2003. 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	*Gelidium* (kg dry weight)	*Gracilaria* (kg dry weight)	Kelp beach cast (kg dry weight)	Kelp fronds harvest (kg fresh weight)	Kelp fresh beach (cast kg fresh weight)	Kelpak (kg fresh weight)
2001	144 997	247 900	845 233	5 924 489	0	641 375
2002	137 766	65 461	745 773	5 334 474	0	701 270
2003	113 869	92 215	1 102 384	4 050 654	1 866 344	957 063
2004	119 143	157 161	1 874 654	3 119 579	1 235 153	1 168 703
2005	84 885	19 382	590 691	3 508 269	126 894	1 089 565
2006	104 456	50 370	440 632	3 602 410	242 798	918 365
2007	95 606	600	580 806	4 795 381	510 326	1 224 310
2008	120 247	0	550 496	5 060 148	369 131	809 862
2009	115 502	0	606 709	4 762 626	346 685	1 232 760
2010	103 903	0	696 811	5 336 503	205 707	1 264 739
2011	102 240	0	435 768	6 023 635	221 138	1 617 975
2012	117 149	0	1 063 233	6 092 258	1 396 227	1 788 881
2013	106 382	0	564 919	5 584 856	253 033	2 127 728
2014	75 900	0	775 625	4 555 704	244 262	1 610 023
Total	1 542 045	633 089	10 873 734	67 750 986	5 755 802	17 038 283

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 7).

Since the early 1980s, a local company has been producing a liquid plant-growth stimulant ("Kelpak") from *Ecklonia maxima* and marketing this nationally and internationally. A second local company now produces a similar extract that is used in South Africa.

The growth of abalone farming in South Africa since the early 1990s has led to increasing demands for fresh kelp as feed. In 2014 a total of 4 800 t of fresh kelp fronds was 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 Rights Areas 1, 20, 21, 22 and 23; Figure 34), where they have been harvested from intertidal areas since the mid- 1950s. Yields, which come almost entirely from Area 1, vary with demand but are usually about 120 t dry weight annually. Since 2010 there has been little or no harvesting from areas 20, 21, 22 and 23 (in the former Transkei) because of low prices for some of the species and access and security problems in these areas.

Gracilarioids

Gracilarioids produce agar of a slightly lower quality to that of *Gelidium*. Only the sheltered waters of Saldanha Bay (Seaweed Rights Area 17) and St Helena Bay (Areas 11 and 12 in part) contain commercially viable amounts of these seaweeds. Only beach-cast material may be collected commercially, because harvesting of the living beds is not sustainable. In Saldanha Bay, large yields (up to 2 000 t dry weight in 1967) were obtained until the construction of the ore jetty and breakwater in 1974, after which yields fell dramatically. Occasional small wash-ups are obtained in St Helena Bay. In the past decade, 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 *Mazzaella*. However, local resources of these species are small by international standards and harvesting has not been economically viable. Nevertheless, there is potential for local use of some species, for example in food products.

Research and monitoring

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

Estimates of kelp biomass are based on infrared aerial imagery, GIS mapping and diver-based sampling. Monthly harvest of fresh kelp is checked against the prescribed MSY as set in annual permit conditions. 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. 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. In 2014 a complete re-survey of kelp beds in part of Area 9 (Soetwater) was started, to improve estimates of biomass and MSY. Current research aims to improve our understanding of kelp biology in order to manage the resource better.

Table 8: Maximum sustainable yield of harvested kelp for all areas for 2014 season (1 March 2014–28 February 2015). *Note: in Areas 5 and 6 only non-lethal harvesting of fronds is allowed

Area number	Whole kelp (t fresh weight)	Kelp fronds (t fresh weight)
5	0*	2 625
6*	0*	4 592
7	1 421	710
8	2 048	1 024
9	2 060	1 030
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	16 098	15 287

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

Current status

Kelps

There are 14 areas in which kelp rights were held in 2014. No commercial activity was reported in five of these areas: in two of them right-holders could not access the resource. Two right-holders did not activate their rights during 2014.

Yields of dry beach-cast kelp totalled 775.6 t in 2014 (Table 7). A further 244.3 t wet weight of fresh beach-cast kelp was supplied to abalone farms, together with 4 555.7 t wet weight that was harvested directly as abalone feed. These yields have remained fairly steady over the past three years. Substantial harvests for abalone feed were obtained in Areas 5, 6, 7 and 11. Although there are more than 5 abalone farms in the Gansbaai – Hermanus area, they are supplied by four rights areas (Areas 5, 6, 7 and 8), with a substantial potential MSY between them.

In some areas, harvests (Table 7) were well below MSY (Table 8). The under-harvest is a result of lower demand for kelp in some areas and/or the use of alternative abalone feeds, and is not a reflection of the status of the resource in those areas. This substantial and potentially harvestable biomass ('spare' MSY) would allow for the expansion of abalone farms in such areas. In Area 9, the production of Kelpak (plant-growth stimulant) used 1 610 t of fresh kelp in 2014. The status of kelp resources therefore varies geographically: from well/almost completely exploited in some areas to almost completely under-exploited in others.

Monitoring, visual inspections and reports from right-holders show that the kelp resource is stable and healthy.

Gelidium

In 2014 substantial quantities of *Gelidium* were collected only from Area 1, where *G. pristoides* now comprises 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. Catch returns (Table 7) from Area 1 (75.9 t dry weight) were lower than in the recent past, mainly because of reduced demand. Inspections and measurements done in February and May 2015 indicate very healthy *G. pristoides* populations with density and biomass values well within normal limits

Gracilarioids

Biomass of this unreliable resource varied during 2014, but large wash-ups were observed early in winter. 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.

Other seaweed resources

Despite some commercial interest in *Ulva* and *Porphyra* in Areas 11 and 12, where research demonstrated small but viable resources, no further developments have taken place.

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

Ecosystem interactions

In the case of *G. 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.

Further reading

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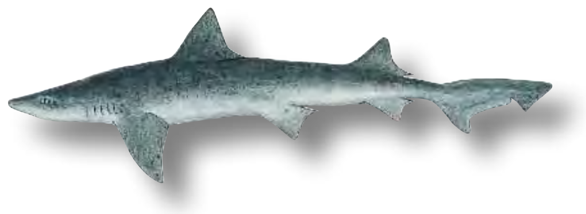
Sharks



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
	Shortfin mako Requiem Unidentified skates		Smoothhound Blue	*Soupfin	
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
			Blue sharks	Shortfin mako Requiem Unidentified skates Soupfin Smoothhound	

*Although recent stock assessments suggest that the stock is optimally exploited, stocks have not recovered to previous levels following the serious decline documented in 1949

Note: This table refers to a small number of species harvested commercially, whether targeted or taken as bycatch, in several fisheries. A large number of additional species are taken as bycatch in various fisheries

Introduction

South African chondrichthyans (including sharks, skates, rays and chimaeras) are harvested in eight of 16 commercial fisheries, are targeted increasingly by a growing number of recreational fishers, and are captured in the KwaZulu-Natal (KZN) bather protection programme. Commercial fisheries include those targeting chondrichthyans or harvesting them as bycatch. Fishery-dependent data for chondrichthyans were first collated in 1989, with an estimated landed catch of 2 595 t (dressed weight). Primary target species included soupfin shark *Galeorhinus galeus*, St. Joseph *Callorhinchus capensis*, and biscuit skate *Raja straeleni*, with landed catches of 506 t, 716 t and 1 197 t respectively.

Directed fisheries include the demersal shark longline fishery, pelagic longline fishery, boat-based and shore-based linefisheries (commercial and recreational), beach-seine net ('treknet') fishery, gillnet fishery and the KZN bather protection programme (a shark-fishing operation but not strictly a fishery in the conventional sense). Non-directed fisheries include the demersal trawl fisheries (inshore and deep-sea), hake longline fishery, prawn trawl fishery, and small-pelagic and midwater trawl fisheries. Infrequent chondrichthyan bycatch is taken by the tuna-pole, small invertebrate, rock lobster-trap (West Coast and South Coast) and squid fisheries, but the catch is seldom retained.

In all, 99 species of chondrichthyans were reported in the above fisheries between 2010 and 2012, comprising 49% of southern Africa's 204 known chondrichthyan species. Total reported catch was estimated to be at least 3 375 t, 3 241 t and 2 527 t dressed weight for 2010, 2011 and 2012, respectively. Chondrichthyans discarded (dead or alive) at sea are not recorded in the catch data. Furthermore, the ratio of total- to dressed weight varies between species; hence, reporting of dressed weight provides only a conservative estimate of total chondrichthyan catches.

History and management

A paper which thoroughly reviews chondrichthyan catch and by-catch in South African fisheries is included in the list of references. This report will only cover the following fisheries that target sharks or catch them in significant quantities; demersal shark longline fishery, pelagic shark catches in the tuna longline fishery, commercial linefishery, and demersal trawl fishery (inshore and deep-sea).

Initially, the shark longline fishery included both demersal and pelagic longline vessels. It was later separated into distinct demersal shark and pelagic shark longline fisheries, with the latter later absorbed into the 'large pelagic' longline fishery (see below). The demersal fishery targets demersal sharks using bottom-set gear in inshore environments (shallower than 100 m), while the pelagic fishery targets pelagic sharks using pelagic drifting gear offshore.

The demersal longline fishery targets primarily smoothhound *Mustelus* spp. and soupfin sharks *Galeothinus galeus* in coastal waters. Permits for the directed catching of sharks using demersal longlines were first issued in 1991. Prior to 1998, over 30 permits were issued. Due to poor fishery performance this was reduced subsequently, initially to 23 permits in 1998 and in 2004 to 11 permits. Since 2008, only six permits have been issued. Demersal shark longline vessels may not fish east of East London to protect the more diverse and less numerous shark fauna on the East Coast. Targeting of bull sharks *Carcharhinus leucas* and hammerhead sharks *Sphyrna* spp., as well as oceanic sharks such as blue sharks *Prionace glauca*, shortfin mako sharks *Isurus oxyrinchus*, oceanic whitetip sharks *Carcharhinus longimanus* and thresher sharks *Alopias* spp., is prohibited in this fishery.

Due to concerns about high catches of pelagic sharks such as blue sharks, mako sharks, and thresher sharks in the historic pelagic longline fishery, this sector was merged with the swordfish and tuna longline sectors in March 2011. Under current management, the bycatch limit for sharks in the large-pelagic fishery is set at 2 000 t dressed weight. Under the new management regime, shark-directed fisheries are required to switch their effort to swordfish. Should this bycatch limit be attained, the large-pelagic fishery would have to stop for the year.

The fishery catches oceanic species such as shortfin mako sharks, blue sharks, and, to a lesser extent, carcharhinid sharks. Permit conditions for the large-pelagic longline fishery include a prohibition on the use of wire traces by all vessels except those that were previously part of the pelagic shark longline fishery. No thresher, hammerhead, oceanic whitetip, dusky *Carcharhinus obscurus* or silky sharks *C. falciformis* may be retained on board the vessel. When fins are removed from trunks they may not exceed 8% and 13% of the trunk weight for mako sharks and blue sharks respectively, the difference being due to large variations in fin-to-trunk ratios.

The commercial linefishery has the longest history of targeting sharks in South Africa. Shark catches in this fishery have fluctuated dramatically in response to market forces. Since 1991, however, there has been a steady increase in catches, correlated with a decrease in the availability of valuable teleost species. Few catch limitations currently exist for the commercial linefishery, but recreational fishers have a daily bag limit of one shark, skate, ray or chimaera per species, with a maximum total catch of 10 cartilaginous fish.

The trawl fishery is responsible for a substantial bycatch of demersal sharks and other cartilaginous fish species. Cartilaginous fishes landed by inshore trawlers include biscuit skate, smoothhound sharks, soupfin sharks and St Joseph. Between 1979 and 1991, sharks comprised 0.3% of South Africa's total commercial landings by mass in this fishery. Annual shark catches for both sectors (i.e. inshore and deep-sea) in 1990 were estimated at 606 t. Owing to a high level of discarding and non-reporting, the actual number of cartilaginous fish caught in the trawl sector is difficult to quantify. The incentives for trawlers to target sharks and other cartilaginous species have increased with the advent of additional markets and hence an increasing market value of sharks.

Research and monitoring

Historically, there has been little coordinated research relating to the biology and stock assessment of commercially valuable sharks. Previous stock assessments conducted on such sharks from South African waters have been hampered by the lack of fishery-independent data, poor data quality and few life-history studies. Furthermore, the limited understanding of the movement and reproduction of these sharks complicates their assessment and limits the formulation of useful management advice.

Since 2008 there has been an increase in research by DAFF, with effort directed at collecting fishery-independent data and investigation of life-history parameters necessary to conduct robust assessments. Studies related to movement and reproductive biology have also been conducted in order to determine stock boundaries of commercially valuable shark species and to identify nursery areas.

Current research is directed mainly at collecting fishery-independent data for demersal and pelagic sharks from the RV *Ellen Khuzwayo*. A demersal shark survey was initiated in 2008; due to operational constraints the survey was restricted initially to the area around Robben Island. In 2010 this survey was extended to include the entire area between Mossel Bay on the South Coast and Dassen Island on the West Coast. This encompasses the fishing area for five of the six vessels operational in the demersal shark longline fishery. Although initial surveys included Robben Island only, those data will be useful for future assessments.

A shark component has been included in the fishery-independent survey of the large-pelagic fishery, also conducted on the RV *Ellen Khuzwayo*. Data on catch composition, length, sex and biological attributes are currently being collected. For logistical reasons, few fishery-independent surveys have been undertaken.

In order to develop appropriate management strategies for shark resources, it is vital to understand their reproductive biology. Life history information on growth, maximum age, fecundity, size and age at maturity, sexual segregation, pupping and mating migrations, and the use of nursery grounds, will aid sustainable utilisation of sharks.

Sharks are highly mobile and some species exhibit large-scale movement, including vertical and even transoceanic migrations. Movement of commercially important sharks affects the availability of sharks to fishing areas, the abundance of sharks in less-exploited areas and the effectiveness of Marine Protected Areas (MPAs) as a management tool for sharks. Thus movement studies are currently being undertaken on smoothhound sharks, soupfin sharks, broadnose sevengill cowsharks *Notorynchus cepedianus*, blue sharks and shortfin mako sharks. Results indicate that blue sharks move freely between the Atlantic and Indian Oceans, suggesting the existence of a single southern stock as opposed to separate southern Atlantic and southern Indian Ocean stocks. This research has also highlighted the existence of a nursery ground for blue sharks off southern Africa in the Benguela/warm Agulhas Current transition zone. This finding has significant implications for stock assessments conducted by Regional Fisheries Management

Organisations (RFMOs). It is possible that similar movements occur in other large pelagic species. South Africa is well placed geographically to study further the movement patterns of large pelagic species with a view to understanding stock separation between the Indian and Atlantic oceans.

Research into life-history parameters, movement and stock delineation, as well as the collection of fishery-independent data and eventual stock assessment, is a long-term and ongoing endeavour. Once sufficient data are collected, key species will be reassessed according to their priority listing. The National Plan of Action for Sharks (NPOA-Sharks) was released in 2013. This document provides a detailed plan for improving data streams from all fisheries where sharks are targeted and/or caught as bycatch in order to conduct future stock assessments.

The risks related to mercury consumption and bioaccumulation of the neurotoxin methylmercury has been well studied. As a potent toxin it is concentrated through the aquatic food chain. Methylmercury in human dietary items is of concern due to neurotoxic effects on embryonic and foetal development. Recent studies, including some by DAFF, showed for 12 of the 17 South African shark species studied that mean total mercury concentrations were above recommended guidelines, for all but smoothhound and whale sharks. Mako sharks, scalloped hammerheads *Sphyrna lewini*, white sharks *Carcharodon carcharias* and ragged-tooth sharks *Carcharias taurus* had average detectable amounts of total mercury of 10 mg kg^{-1}, therefore far exceeding limits set for safe human consumption, which are in the range 0.3–1 mg kg^{-1}.

The value of demersal shark fillets is heavily influenced by total mercury concentrations for international export. Smaller sharks (<10 kg on average, depending on species) are more valuable. DAFF is evaluating the effects of limiting fishing through a size slot limit by comparing market values and nutritional restrictions. Health considerations (i.e. market- imposed restrictions related to heavy metals) may be a good method to ensure that fishers obtain maximum value for their catches. The implementation of a slot limit of 70–130 cm for demersal sharks would therefore limit potential health risks in terms of human consumption, as well as provide protection for sharks under a precautionary management paradigm. The benefit of protecting older sharks comes from the increased fecundity of older demersal sharks and the higher natural mortality at younger sizes.

Other species on higher trophic levels with high tourism value and low economic value may also benefit from these restrictions. Less than 10 t of broadnose sevengill cowsharks are reportedly caught by the commercial linefishery and the demersal shark longline fishery. Due to low-quality fillets, their

economic value is low; fishers generally catch these sharks to defray fishing costs when catches of other higher value teleosts/sharks are poor. In the past five years, SCUBA diving for broadnose sevengill cowsharks has become a major tourist attraction within False Bay. Although the safety of divers is of some concern, the economic value of tourism related to these sharks far exceeds the economic fishery value of their products. Due to their life history, it is highly unlikely that they could sustain even moderate levels of fishing pressure. Furthermore, their diet, consisting of top predators (such as seals, dolphins and other sharks), could potentially lead to large accumulations of cadmium and mercury within their flesh. The consumption of these sharks should be discouraged until safety has been confirmed through peer-reviewed studies.

Current status

There is a paucity of data on life-history characteristics, movements and migrations, and key habitats for most South African sharks. This paucity of data is not restricted to South Africa – stock assessments for Atlantic blue and mako sharks conducted by the International Commission for the Conservation of Atlantic Tunas (ICCAT) have been difficult to conduct because of poor-quality data (see below) and high levels of under-reporting.

Fishery-dependent data are currently being collected for only eight species and a further seven families (i.e. at family level only). This represents a small proportion of the 99 species of sharks caught by South African fisheries. However, the information is representative of the most commonly caught species and therefore the bulk of the tonnage taken. Certain groups of sharks are difficult to identify and are currently being combined in the data, including *Carcharhinus* spp. (the requiem, or grey, sharks), dogfish *Squalus* spp., skates and rays.

National stock assessments have been attempted for the following demersal shark species: soupfin shark, smoothhound shark and spotted gully shark *Triakis megalopterus*. The results indicate that soupfin sharks are optimally exploited while smoothhound sharks are marginally over-exploited. Anecdotal evidence from the demersal shark longline industry suggests a shift in targeting from soupfin to smoothhound and requiem sharks due to a perceived decline in the South African population of soupfin sharks. Lliterature suggests that the soupfin fishery, once a dominant fishery in fishing villages in the Western Cape, suffered a serious decline in 1949 and subsequently has not recovered to previous levels. Although spotted gully sharks cannot be legally harvested (i.e. they are legislated as a recreational no-sale species), they are sometimes misidentified as smoothhound sharks and therefore landed in target and bycatch fisheries.

In the large-pelagic fishery, catches of thresher and hammerhead sharks have decreased as per permit conditions. Spatio-temporal analyses of nominal and standardised CPUE have revealed seasonality in catches of blue sharks, with CPUE peaking in summer and autumn off the West Coast. Standardised CPUE also revealed that blue shark abundance remained relatively stable from 1998 to 2008. This is contradictory to findings reported from observer data from the tuna-directed longline fishery, which suggest a significant reduction in CPUE, albeit over a shorter period, from 2001 to 2005. There remains considerable uncertainty regarding the stock status of shortfin mako sharks. Ecological Risk Assessments completed by the Indian Ocean Tuna Commission (IOTC) indicated that shortfin mako is the most vulnerable species in longline fisheries due to its low productivity. Trends in several standardised CPUE series from the IOTC show significant declines between 1994 and 2014. Standardised CPUE trends from South African data suggest a decline in abundance between 2002 and 2010.

Shark fisheries are widely accepted as requiring conservative management as sharks have life-history strategies that make them inherently vulnerable to over-exploitation. Stock assessments of pelagic species are the responsibility of RFMOs such as the IOTC and ICCAT. These organisations are currently unable to assess stocks adequately due to poor life-history data. However, there is global concern as to the status of pelagic sharks. The global IUCN Red List statuses of a number of sharks targeted or caught as bycatch by shark fisheries in South Africa have recently been changed to reflect an increased threat. These include the oceanic whitetip shark (Vulnerable), soupfin shark (Vulnerable), shortfin mako shark (Vulnerable), great hammerhead shark (Endangered – not commonly caught in South Africa but showing a decline in local waters), and spiny dogfish *Squalus acutipinnis* (Vulnerable).

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 catches themselves are often considered to represent ecosystem interactions of those fisheries.

One of the major limitations to assessing stock status of chondrichthyans (sharks, skates, rays and chimaeras) is generic reporting by most South African fisheries. They are often misidentified or identified to genus level only (e.g smoothhound sharks or dogsharks) or even superorder (e.g. skates and rays [Batoidea]). DAFF is currently developing an identification guide for chondrichthyans in South Africa that aims to improve data collection at a species level for all fisheries.

In September 2014, several species of chondrichthyans were listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). These include the oceanic whitetip shark, three species of hammerhead sharks (scalloped *Sphyrna lewini*, great *S. mokarran*, and smooth *S. zygaena*), porbeagle shark *Lamna nasus* and manta rays *Manta* spp. Trade in products from listed species require permits issued based on the following: (1) a non-detriment finding – data or expert scientific opinion on the biological status of the species indicating that international trade is not detrimental to species survival; and (2) a legal acquisition finding – evidence that specimens to be traded were not obtained in violation of any state, federal, or other jurisdictional law. Due to the processing of sharks at sea, fins are difficult to identify and this increases the difficulty of controlling the trade of listed species. There is a move internationally to prevent finning entirely and to compel fishers to land sharks with fins naturally attached. However, there is considerable debate as to the feasibility of implementing such measures.

Further reading

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Useful statistics

Average annual dressed weight of sharks (t) reported by the demersal shark longline, commercial linefish and inshore, offshore and midwater trawl fisheries for the period 2011–2014

Species	Demersal shark longline	Large pelagic longline	Linefish	Trawl	Total
Shortfin mako shark (*Isurus oxyrinchus*)	0.555	14.80	0.10	0.00	515.44
Blue shark (*Prionace glauca*)	0.104	69.77	0.56	0.00	470.43
Soupfin shark (*Galeorhinus galeus*)	25.72	0.13	68.28	75.96	170.08
Spotted gully shark (*Triakis megalopterus*)	0.00	0.00	1.22	0.00	1.22
Smoothhound shark (*Mustelus mustelus*)	49.69	0.00	19.75	60.20	129.64
Requiem sharks	7.23	14.86	36.67	0.00	58.76
Dogfish (*Squalus* spp.)	0.83	0.00	0.00	0.93	1.76
Broadnose sevengill cowshark (*Notorynchus cepedianus*)	0.53	0.00	2.85	0.00	3.39
Thresher sharks (*Alopias* spp.)	0.15	0.03	1.55	0.00	1.72
Hammerhead sharks (*Sphyrna* spp.)	1.04	0.00	1.38	0.00	2.42
Unidentified shark, skates and rays	3.32	0.00	38.47	675.66	717.45
St Joseph (*Callorinchus capensis*)	0.23	0.00	0.00	651.71	651.94

Small invertebrates and new fisheries

Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
	White mussel Octopus Red-bait Whelk	East Coast redeye			
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
	Red-bait Whelk	Octopus East Coast redeye	White mussel		

White mussels

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

The fishery for white mussels 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 35). 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 under-exploited.

Prior to 2007, each right-holder was limited to a monthly maximum catch of 2 000 mussels. However, due to unreliable data from the fishery from under-reporting and difficulties with catch monitoring, catch limits were not considered as an adequate regulatory tool to monitor this fishery. Therefore, as of October 2006, the monthly catch limit was lifted with the aim of removing constraints and thereby improving the quality of catch-and-effort data for use in future resource assessments. Since 2007 the commercial sector has been managed by means of a Total Allowable Effort allocation (TAE) 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 the decades preceding the 1990s, commercial catches declined continuously (Figure 36). Recent significant increases in commercial catches since 2006 can be attributed to the lifting of the commercial upper catch limit at that time.

The Interim Relief sector started in 2007. During the 2013/2014 season, 1 995 Interim Relief permits were issued for the Western and Northern Cape combined. This sector

Figure 35: Areas allocated for commercial harvesting of white mussel *D. serra* along the West Coast of South Africa

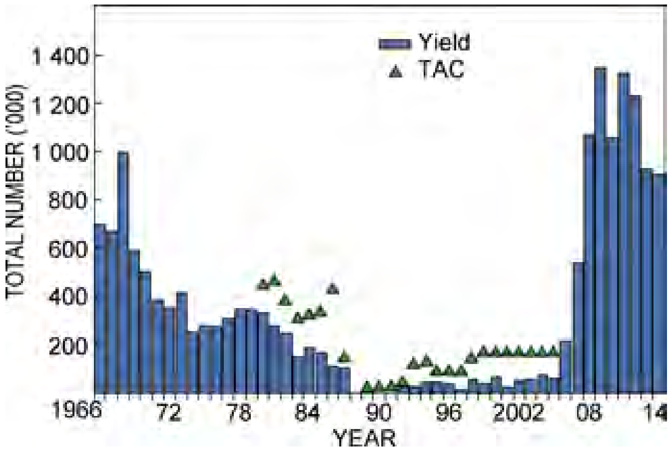

Figure 36: TAC and yield (total number) of white mussels harvested commercially per annum, 1966–2014

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.

Research on white mussels, in the form of fishery-independent surveys, has been conducted by the DAFF since 2003. 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 36). In addition, the development of a bait market in Namibia in recent years created a greater demand for this 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 by the recreational sector, but these catches are not monitored. There are also information gaps on the level of exploitation by Interim Relief harvesters and the levels of illegal take. On account of irregularities, the catch-and-effort data are considered unreliable. 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 3–5 more years to yield sufficient information for meaningful assessment. Uncertainty therefore remains regarding the current status of the white mussel resource. In conclusion, approximately 130 000 mostly adult-size mussels washed out during the red tide in March 2015, the effect of this on the resource performance will be monitored.

Octopus

Octopus are commercially fished in many parts of the world, including Australia, Japan, Mauritania and 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. It occurs along the entire South African coastline from intertidal rock pools down to depths of over 200 m, and inhabits various substrata including shell, gravel, sand and reef. Traditionally, octopus have been harvested primarily for subsistence purposes and bait. A pilot study to investigate the potential of a commercial fishery for octopus paved the way for a five-year experimental pot-fishery, which ran from October 2004 until September 2009. Difficulties caused by gear loss and damage from rough seas, vandalism and theft, access to suitable vessels and equipment, and the rigidity of the experimental framework, resulted in this experimental fishery not yielding sufficient information to assess the feasibility of establishing a commercial fishery. Lessons learned during these attempts were, however, used in developing and initiating a further 5-year exploratory fishery, which commended in 2012.

The exploratory fishery for octopus aims to improve performance by participants by introducing greater flexibility as regards 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 on a cradle and each line carrying 40 cradles, the total number of pots set per fishing day is up to 600 if using the Australian trigger traps.

Previous restrictions on pot type have also been removed, so that participants may use whichever pot design is most appropriate to their own operations. On retrieval of each line, octopus in each pot are recorded separately, and any bycatch is also identified and counted.

Catches have gradually increased from about 2 000 kg in the year 2013 to about 14 000 kg in the 2015 (Figure 37). The gradual increase in octopus catches reflects the efficiency of fishing gear, a better understanding of the fishing environment and improvement of fishing skills.

Access to adequate financial resources remains a challenge

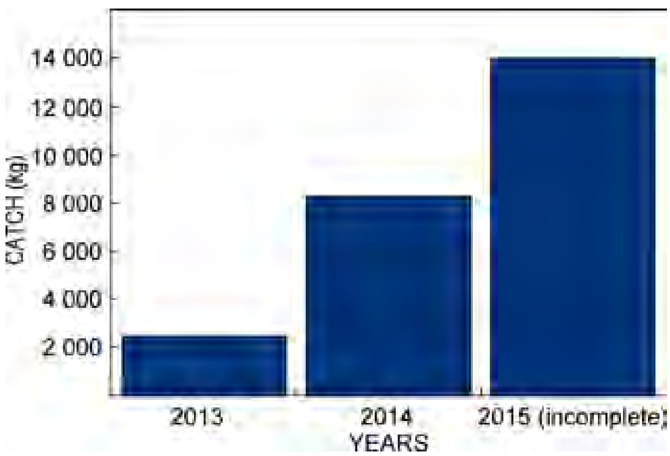

Figure 37: Annual octopus catches from 2013 to 2015. Note that the 2015 value is for 8 months (January–August)

in this fishery and is the main contributor to the 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 2 permit-holders fish on a regular basis. In effect, out of the 16 designated fishing areas, only one is being fished regularly.

Whelks and three-spotted swimming crabs

Whelks are large marine predatory snails, belonging to the Mollusc family Buccinidae. They are generally cold-water species occuring on various bottom types, but prefer muddy or sandy bottoms where they scavenge on dead animals. Three-spotted swimming crabs *Ovalipes trimaculatus* are similarly found in sandy habitats where they prey on bivalves and gastropods, including whelks. The two species are captured together in nets, traps or pots.

The distributions of the whelk *Bullia laevissima* and three-spotted swimming crab range from Namibia to the Wild Coast. At present there is no commercial fishery for whelks or three-spotted swimming crabs in South Africa. However, whelks are landed as bycatch in crab trawl fisheries in North Carolina in the United States of America. Whelks are harvested in many regions around the world using different traps and various bait types. Traps range from conical pots known as "Korean Pots" to homemade traps made from plastic tubs and buckets. Whelk traps are usually weighted with cement. Other whelk fisheries exist in Nova Scotia, Quebec, Great Britain and the Gulf of Maine. These fisheries process and market whelks into different products including fresh (live), whole cooked, frozen, pickled, smoked and as canned meat. There is a small market for whelk in the United States of America, with the main market in Europe and Asia, particularly Japan and Hong Kong. The Japanese prefer large whelk for use in the high-end sashimi market while smaller specimens are usually used in the lower-end sushi bars. The price for whelk meat is uncertain and often the cost of production is very close to or exceeds revenue generated.

An experimental hoop-net fishery for whelks and three-spotted swimming crabs was established in 1989 along the West Coast. Catch rates were as high as 160 kg h^{-1} for whelks and 17 kg h^{-1} for three-spotted swimming crabs. The experimental fishery ended in 1993 due to processing and marketing challenges, and a severe red tide that depleted populations of these resources.

Although of low value, whelks in particular are still considered to be an excellent candidate for a potential new fishery. In May 2008, an exploratory fishing permit was granted for targeting whelks and three-spotted swimming crabs (an unavoidable bycatch), and fishing commenced in 2009. Fishing grounds were between the west of Seal Island in False Bay and Cape Town Harbour, and a maximum of 100 baited hoop-nets were initially used, with longline traps also being used later. Various challenges were faced by this exploratory fishery, and the fishery did not yield sufficient results to draw any conclusions regarding the potential for the establishment of a new fishery. A further attempt was made in 2012 with a hoop-net and longline trap exploratory fishery within the western side of False Bay. A total of just over 2 t was harvested. Only half a tonne has so far been exported to markets in the East. Unfortunately, operational challenges again put an end to this exploratory fishery without sufficient data having been collected with which to determine the fishery potential for these species.

Red-bait

The sea-squirt red-bait *Pyura stolonifera* is distributed along the entire South African coastline in intertidal rock pools and on shallow subtidal reefs. The thick outer test protects the soft inner flesh, which is bright orange-red in colour. Although marketed for human consumption in the East, in South Africa red-bait is used solely as bait, and is much sought after as bait for a variety of linefish species. Red-bait occasionally washes up on beaches along the coast after rough winter seas, when it can be easily collected. It also grows prolifically on man-made structures such as jetties and other marine installations. There is currently no commercial fishery for red-bait in South Africa, but exploratory fisheries are underway to investigate the potential for a viable commercial fishery.

An exploratory fishery for red-bait began in Saldanha Bay in June 2009. Initially only washed-out red-bait was collected from the beach for this fishery. However, this proved too intermittent a supply for commercial viability. Live red-bait is now collected from man-made structures at Club Mykonos in Saldanha Bay during contracted cleaning of yacht jetties. Red-bait also grows and fouls man-made structures in the Port of Saldanha, however the Port is not part of this fishery as Saldanha Portnet did not give permission for red-bait to be periodically removed from these structures by exploratory permit-holders. Whole organisms are removed from the structures by divers using hand-held knives and gaffs. The total allocated amount is 7 t, with the harvesting area limited to the yacht jetties within Club Mykonos in Saldanha Bay. The bait is sold on the local market only, and used as bait for fishing. However, potential new markets in Namibia are also under investigation. At present, this fishery provides additional job creation opportunities for qualified divers. A further exploratory fishery is concerned with the collection of washed-up red-bait on the Cape South Coast. However, yields have been sporadic and quantities small, and this exploratory fishery will require a further period to evaluate the potential for economic viability. The red-bait gathered is sold as bait, which creates only a few employment opportunities and modest financial returns.

It is not considered necessary to monitor the red-bait resource as the harvesting thereof is only undertaken from populations growing on man-made structures, or of naturally washed-up red-bait, and there is thus no direct impact on naturally occurring stocks.

East Coast round herring (KwaZulu-Natal)

Two species of round herring occur in South African waters. The West Coast round herring *Etrumeus whiteheadi* is distributed from Walvis Bay to East London and is targeted by the purse-seine fishery for small pelagic species off the West Coast (see Small Pelagics section). There is very little data on the distribution, abundance and population size of the East Coast round herring, *Etrumeus wongratanai* (formerly known as *E. teres*) off South Africa. Data from hydro-acoustic surveys conducted in the late-1980s and in 2005, indicate a distribution that spans warm temperate waters from as far south as East London to warm tropical waters north of Durban. A hydro-acoustic survey of the East Coast from Port Elizabeth to Richard's Bay conducted in June/July 2005 on the RS *Africana* estimated a biomass of 13 000 t for this species within this region.

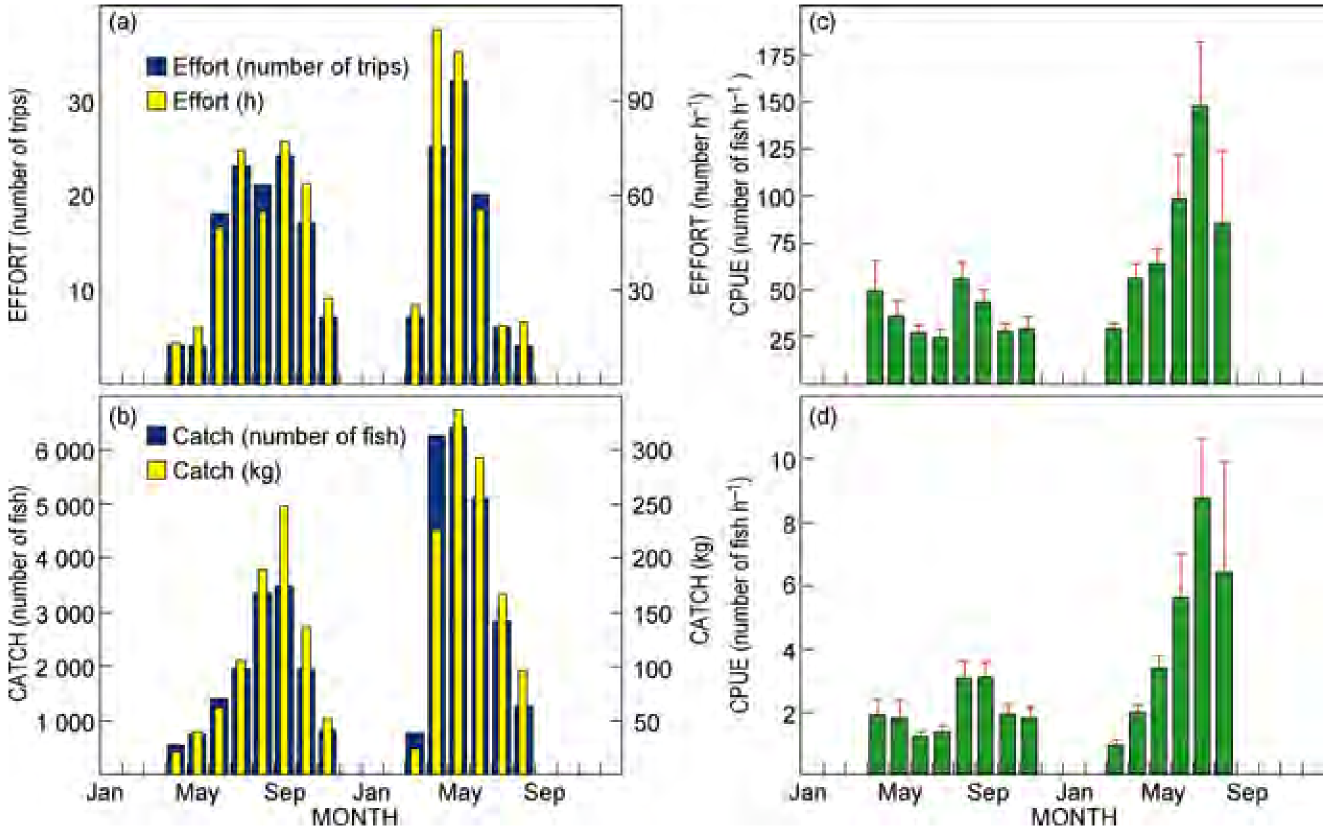

Figure 38: (a) Effort in terms of number of fishing trips and number of hours, (b) catch in terms of numbers of fish and kg, (c) average (+1 SE) and (d) CPUE in terms of fish h^{-1} and kg h^{-1}, and per month from January 2013 to August 2014 for exploratory fishing for East Coast redeye using jigging from kayaks or an inflatable

An application for an exploratory permit to fish for East Coast redeye using a purse-seine net deployed from a skiboat was received in the early-2000s, but delays in the granting of approval and difficulties in obtaining a net and vessel resulted in actual fishing operations only starting in 2006. Intermittent attempts at purse-seining have continued since then but this method has proved to be unsuccessful due to a variety of causes. These include inherent difficulties in deploying a purse-seine net from a small vessel in a region of strong currents, launch site limitations, the high incidence of other species (e.g. chub mackerel *Scomber japonicus*) schooling with East Coast redeye, which would result in a high bycatch (permit conditions limit bycatch and indicate that species other than East Coast redeye are not to be targeted), and the fact that purse-seining may not take place during the sardine run or when the KZN shark nets have been lifted (which occurs during the sardine run). In addition to exploratory fishing using a purse-seine, applications for exploratory fishing for East Coast redeye using jigging from an inflatable boat or a kayak were supported in 2012, and three such rights have since been granted, with permit-holders each limited to an upper catch limit of 50 t per annum. Jigging began in 2013 and this method has proved to be successful.

Permit conditions for this exploratory fishery include the reporting of catch-and-effort data. Whilst not a permit condition, permit-holders using jigging also kindly record the length and weight of around 100 fish per month from catch sub-samples and retain fish samples for further analysis by DAFF. Data on size and weight, sex, gonad maturity stage, gonad mass and fat stage of these fish are recorded, and some fish are retained for other biological studies.

Almost all of the exploratory fishing via jigging has been in the region of Scottburgh on the KZN South Coast. Effort, catch and CPUE data from January 2013 to August 2014 are shown at a monthly resolution in Figure 38. Trips ranged between 0.75 and 7 h in duration and almost all started in the early morning. A total of 118 trips (totalling 375.2 h at an average duration of 3.2 h) were reported in 2013, and 94 trips (totalling 334.7 h, at an average duration of 3.5 h) were reported to end-August 2014. No fishing was done in January–March 2013, and effort was initially low, but increased to around 20 trips (around 60 h) per month between June and October 2013 before declining again in November. No fishing was reported from December 2013 to February 2014. Fishing started again in March 2014 and the highest effort of the time-series was recorded for April and May 2014 (>25 trips and >100 h in each month), before effort declined again with fewer trips made in July and August. There was a significant positive correlation between the number of trips per month and the total time fished per month for data combined for both years (hours fished = [3.25 × number of trips] + 1.53; $n = 14$, $r^2 = 0.89$, $p < 0.001$).

Total catches of 14 175 (843.5 kg) and 22 597 (1 138.2 kg) of East Coast redeye were made in 2013 and 2014 respectively. Temporal catch patterns generally followed effort patterns, with >3 000 fish being taken in August and September 2013 and > 5 000 fish per month reported caught for April–June 2014. The highest monthly catch weights occurred in May 2014 (335 kg), June 2014 (292 kg) and September 2013 (247 kg). Average CPUE values did not show strong trends in 2013 and ranged between 24–55 fish h^{-1} and 1.2–3.0 kg h^{-1}. In contrast, average CPUE increased steadily during 2014, from 10 fish h^{-1} (0.9 kg h^{-1}) in March to 147 fish h^{-1} (8.8 kg h^{-1}) in July, before declining slightly in August.

Catch patterns indicate that the fishery appears to be predominantly a winter fishery, but the reason for the absence of fishing in summer (December–February) is not presently known and could indicate a lack of fish availability. A total catch of close to 37 000 fish (almost 2 t) was taken in 2013 and 2014 (to end-August). This quantity is very small compared to the single biomass estimate for this species and indicates that present, legal jig-fishing levels are unlikely to be prejudicial to the resource. The low catches also suggest that the present PUCL of 50 t per right-holder per annum is too high, and this could be substantially reduced (perhaps to 5 t per annum) without compromising the viability of individual rights. The small quantities taken also indicate that access to this exploratory fishery can be broadened should more applications be received. The economic viability of this fishery has yet to be properly assessed but the input costs are likely low, particularly for operators fishing from kayaks that do not use any fuel. The product is in high demand, does not require further processing and apparently sells for a high unit (individual fish) price in its landed state, and the sustained fishing by exploratory right-holders suggests that the fishery is economically viable.

Additional resources that are also currently the subject of new fisheries exploration:

- KZN deep-water lobster
- Horse mackerel purse-seine
- Squids (see section on squid)
- Abalone (see section on abalone)
- Hagfish

Resources that have been investigated as potential new fisheries, but have been found unable to support viable fisheries:

- Periwinkles
- Limpets (West Coast)
- Alikreukels
- Sea urchins
- Sea cucumbers

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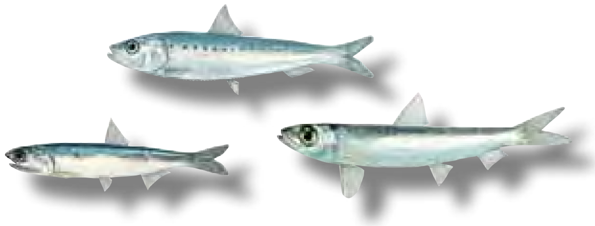
Small pelagic fish (sardine, anchovy and round herring)



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

Introduction

Off the coast of South Africa, small pelagic forage fish, consisting predominantly of anchovy *Engraulis encrasicolus*, sardine *Sardinops sagax* and redeye round herring *Etrumeus whiteheadi* generally account for more than 90% of the total pelagic purse-seine catch. Forage fish are usually found in the 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 results in large natural fluctuations in abundance over space and time. Long-term changes in the relative abundance of anchovy and sardine, over decadal and centennial time-scales, have been observed both locally and worldwide. These species alternations are generally associated with variability in the recruitment of both species, owing to changing environmental factors that affect, among others, transport of eggs and larvae and feeding conditions.

Pelagic fish resources are important to the country for several reasons. Firstly, the purse-seine fishery in which they are caught is South Africa's largest fishery (in terms of landed mass) and second only to the hake fishery in terms of value. Secondly, pelagic fish are an important and high-quality source of protein. Anchovy and round herring are mostly reduced to fish meal and oil in industrial-scale factories and used as a protein supplement in agri- or aqua-feeds. Sardine are 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 foodweb where they are the link that transfers energy produced by plankton to large-bodied predatory fish, seabirds, and marine mammals. Because many animals and humans 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.

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 and horse mackerel *Trachurus capensis* 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. As sardine and horse mackerel stocks started collapsing in the mid-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 sardine catches reached 374 000 t during the early-2000s following rapid population growth, particularly on the Cape South Coast. Anchovy catches also recovered quickly during the early-2000s, resulting in total pelagic landings in excess of 500 000 t between 2001 and 2005. Several successive years of low sardine recruitment since then have resulted in annual sardine catches in the order of 90 000 t over the past eight years. Anchovy catches currently dominate the fishery again, with average catches of around 200 000 t over the past five years. Round herring catches have been reported since the mid-1960s but have never exceeded 100 000 t or dominated the pelagic landings, despite several attempts by the pelagic industry to increase catches of this species.

Historically, the fisheries for sardine and anchovy were managed separately in South Africa. Since 1991, the South African anchovy fishery has been regulated using an Operations Management Procedure (OMP) approach, which is an adaptive management system that is able to respond rapidly, without increasing risk, to major changes in resource abundance. The first joint anchovy-sardine OMP was implemented in 1994, with subsequent revisions. The OMP formulae are selected with the objectives of maximising average directed sardine and anchovy catches in the medium term, subject to constraints on the extent to which TACs can vary from year to year in order to enhance industrial stability. These formulae are also conditioned on low probabilities that the abundances of these resources drop below agreed threshold levels below which successful future recruitment might be compromised.

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. TACs for both species and a Total Allowable Bycatch (TAB) for sardine bycatch are set at the beginning of the fishing season, based on results from the adult biomass survey of the previous November. However, because the anchovy fishery is largely a recruit fishery, the TAC of anchovy and the juvenile sardine bycatch allowance is revised mid-year following completion of the recruitment survey in May/June. The relative stability of South African pelagic fish yields since the introduction of the OMP approach has been attributed largely to this effective, conservative and adaptive management method.

A new OMP (OMP-14) finalised in December 2014 was used to recommend TACs and TABs for the small pelagic fishery for 2015 and 2016. A feature of OMP-14 is the inclusion of a “buffer rule” for the directed sardine TAC, which is applied in cases where the sardine biomass estimated during the previous November survey was between 300 000 t (below which Exceptional Circumstances would be declared) and 600 000 t. This results in a conservative initial directed sardine TAC being recommended at the beginning of the year, below the minimum 90 000 t that would apply at higher biomass levels. The initial directed sardine TAC is increased mid-season, depending on the survey estimate of sardine recruitment.

Research and monitoring

Ongoing research on a number of 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, among others, population structure, biology and ecology, catch patterns, distribution and behaviour of key species.

The biomass and distribution of anchovy and sardine, but also of other schooling pelagic and mesopelagic fish species such as round herring, juvenile horse mackerel and lanternand lightfish (*Lampanyctodes hectoris* and *Maurolicus walvisensis* respectively) are assessed biannually using hydroacoustic surveys. These surveys, which have been conducted without interruption for the past 32 years, comprise a summer adult biomass survey and a winter recruit survey. Data for the estimation of a number of other key biological measurements needed as input into the OMP and information pertaining to the environment are also collected during these surveys. Given the fluctuating nature of the abundance of pelagic fish species, these surveys continue to provide estimates that are far more reliable than those that would have been obtained through mathematical estimation from commercial catch data only, and have enabled optimal use of these resources at times of high biomass while offering protection to them at low biomass levels.

Following mechanical breakdown of the RS *Africana* midway during the November 2012 survey, and the importance of these surveys in ensuring sustainable utilisation of these pelagic resources and their safeguarding at low biomass, a decision was taken to complete the survey on board an industry fishing vessel, *Compass Challenger*. Subsequently, the May 2013–2015 and November 2013–2015 surveys were also successfully conducted on the same vessel. This has ensured that this valuable time-series has not been compromised and that the pelagic fishing industry has not been disadvantaged by the need for very conservative management measures and hence reduced catch allocations that would have been adopted should no survey have taken place.

Of increasing concern to the pelagic fishing industry and scientists alike is the large undercatch of the anchovy TAC during recent years. Since 2000, only 54% on average of the TAC allocated for this species has been caught, and in 2013 the percentage of the anchovy TAC landed dropped to an all-time low of 17% with only 80 000 t of the 450 000 t TAC caught, despite above-average recruitment having been measured. The tendency of forage fish to form large shoals as a defence against natural predators should render them easily detectable and catchable by modern fishing technologies. It appears however, as if pelagic right-holders are finding it increasingly difficult to successfully catch their annual allocations. Several factors have no doubt contributed to this undercatch, including: reduced processing capacity in the light of increasingly stringent environmental regulations governing factory emissions and effluent discharge; severe winter weather and sea conditions; and disruptions caused by high bycatches of juvenile horse mackerel and sardine at times, along with the industry’s resultant attempts to minimise these by temporarily stopping fishing in such areas (Figure 39). In 2013 and subsequent years, several other factors were suggested as reasons for the very low catch of anchovy, including: the close proximity of anchovy to the coast in areas too shallow to fish; a decreased size and density of anchovy schools; and their deeper occurrence close to the seabed where they are not accessible to purse-seine gear. An analysis of fishing effort conducted in 2015 suggests that factors relating to the profitability of the sardine fishery relative to that of the anchovy fishery is also contributing to underutilisation of anchovy, but further work on this and other suggested factors potentially affecting the catchability of anchovy is continuing.

Data on catch statistics including landed mass, species composition, and catch position and date are obtained from

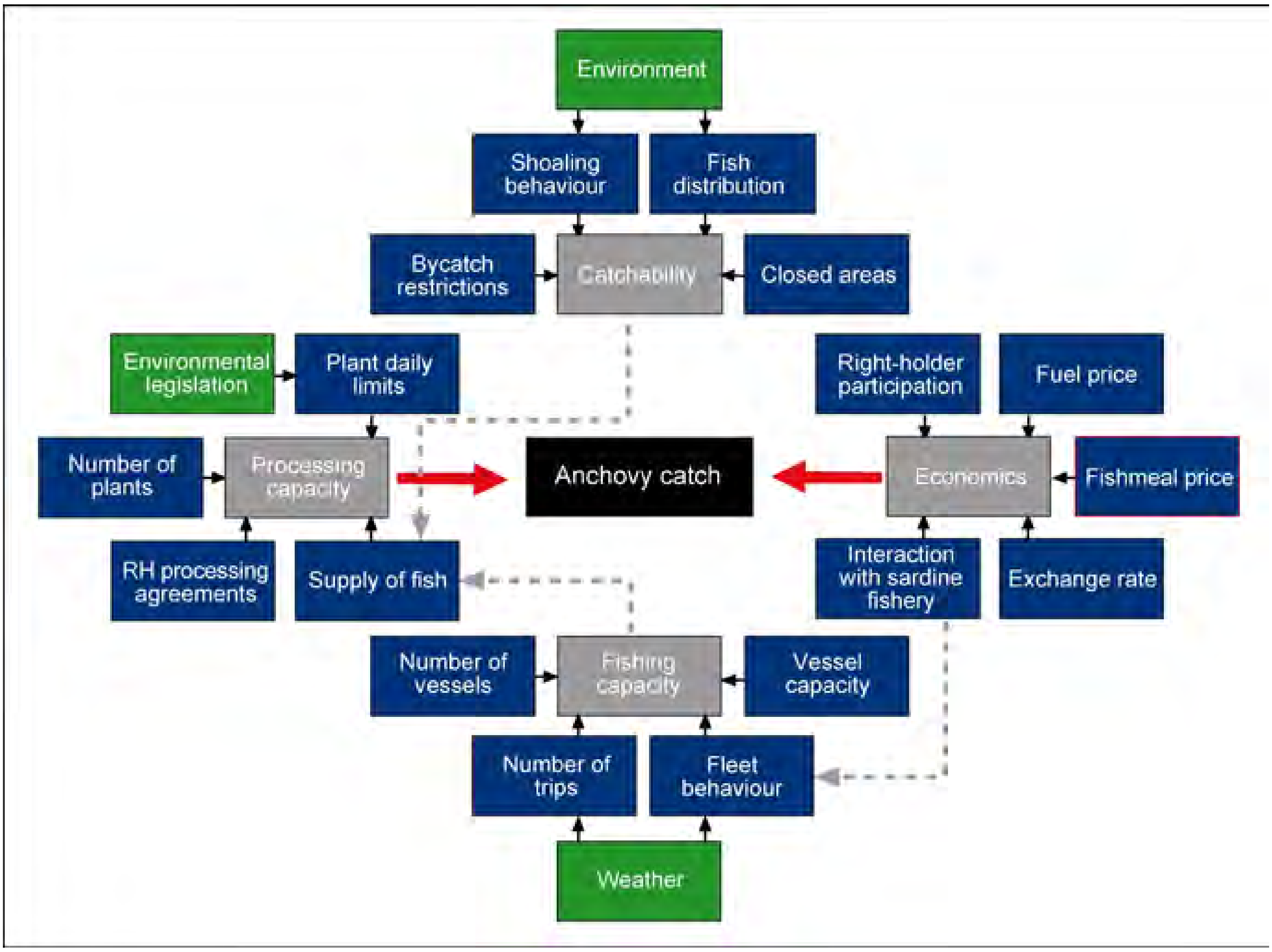


Figure 39: A schematic representation of direct and indirect factors that impact the small-pelagic fishing industry and influences its ability to fully utilise the annual anchovy TAC

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.

Round herring (West Coast redeye) is presently considered to be underutilised, and analyses of the fishery and the collection of biological data for the development of an assessment model for this species have recently been conducted. The bulk (>90%) of round herring caught are adults taken in directed-fishing operations, but some juvenile round herring are also taken as bycatch in anchovy-directed fishing and a very small amount of adults are taken as bycatch in sardine-directed fishing.

A major recent focus of research has been a multi-disciplinary investigation into the population structure of sardine, including the use of parasites as biological markers, the comparison of meristic (number of vertebrae and gill-rakers) and morphometric (body shape, otolith shape, gill-raker length and spacing) as well as life-history characteristics between sardine caught on the Cape West and South coasts. This work stems from mounting evidence that the previously reported eastward shift of sardine was in fact brought about by differential growth in the sizes of western and southern sardine stocks. Recently, an international scientific review panel reconfirmed that a two-stock scenario is more plausible than that of a single sardine stock. The implications of the sardine resource consisting of two stocks rather than a single stock is being investigated in the development of a new OMP (OMP-16), which may include the introduction of spatial management measures to safeguard the sardine resource, possibly in the form of separate sardine- directed TACs for the areas to the west and east of Cape Agulhas.

That sardine has remained at a low biomass since 2006 remains a concern. Also of concern are apparent negative impacts on sardine of environmental anomalies on the South Coast in recent years, in particular extensive harmful algal blooms (HABs) there. A HAB dominated by the dinoflagellate *Gonyaulax polygramma* occurred in inshore waters between Cape Columbine and Plettenberg Bay during November 2011, and was thought to arise from unseasonal westerly winds that promoted nearshore aggregations of this dinoflagellate and supressed normal diatom community development. Analysis of environmental and biological data collected during the 2011 Pelagic Biomass Survey (PBS) conducted at the time of that HAB showed that sardine within the bloom area off the south coast were in poorer condition (i.e. having a lower than expected weight-at-length) than those elsewhere. Sardine in inshore waters off Mossel Bay, where *G. polygramma* concentrations were highest, were in particularly poor condition with a body weight of 65% of average, and the overall condition factor of

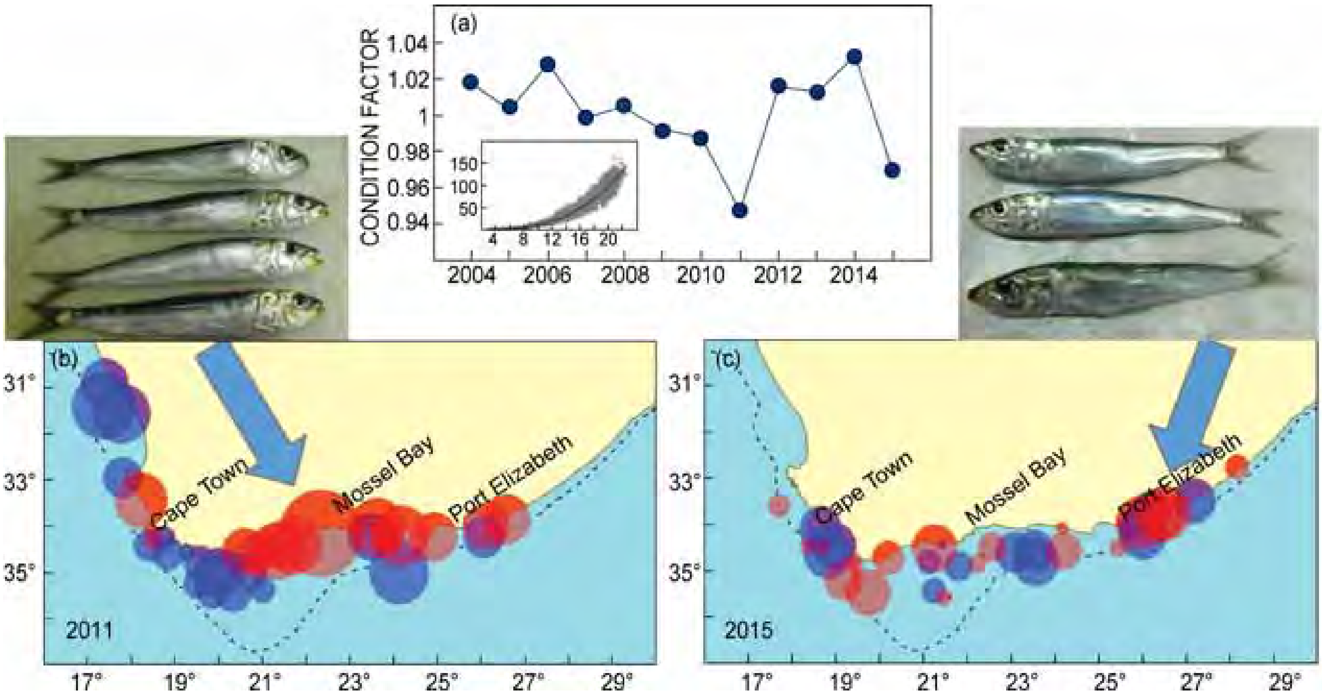


Figure 40: (a) Time-series of annual average (±SE) condition factor for sardine sampled during Pelagic Biomass Surveys (PBS) 2004-2015 (condition factor for individual fish was calculated as the ratio between observed and expected weight, with expected weight derived from a common length-weight regression [shown as an insert; WBM = 0.0069*$CL^{3.1964}$; r^2 = 0.9792; n = 13 341; p < 0.001 and calculated using all length and weight data collected during the Pelagic Biomass Surveys (PBS) since 2004]); and spatial distribution of mean sardine condition factor sampled during the (b) 2011 and (c) 2015 PBS, where red circles indicate below average condition factor (i.e. CF <1) and blue circles indicate above average condition factor (i.e. CF >1), and their size is proportional to their deviance from average (i.e. CF = 1) condition factor (note that expected weights for (b) and (c) were calculated using year-specific length-weight regressions). Photographs of poor condition sardine from inshore waters off Mossel Bay and Algoa Bay collected during the 2011 and 2015 PBS are shown with their respective survey plots (photographs: Y Geja)

sardine during the 2011 PBS was the lowest observed since collection of these data began in 2004 (Figure 40a, b). The apparent negative impact of the bloom on sardine is hypothesized to have been due to the fact that this species possesses a fine-meshed branchial basket that can retain these dinoflagellates, which are 30–50µm in size, and that their retention on sardine gill rakers "irritated" the fish in some way (physical and/or chemical irritation) such that they ceased feeding and lost condition. Spatial patterns in condition factor of anchovy or West Coast round herring did not match the bloom distribution and these species did not appear to be negatively affected by the bloom, but both have coarse-mesh branchial baskets that cannot retain such small particles.

The distribution of directed sardine catches has shifted over the past 15 years, with the relative contribution of South Coast catches rapidly increasing from 5% in 2000 to 64% in 2005, then declining thereafter and stabilising at around 35% from 2009 onwards (Figure 41). Catches of sardine in the Mossel Bay area in 2012 following the 2011 HAB were 14 403 t, the lowest since 2001 (Figure 41), possibly as a result of the bloom impacting either the abundance or availability of sardine there. Another spatially and temporally extensive HAB off the South Coast was observed from January to March 2014 between False Bay and East London. Dominated by *Lingulodinium polyhedrum*, a dinoflagellate similar to *G. polygramma*, that HAB resulted in several instances of marine organism mortalities in Algoa Bay. Whilst sardine were not observed in those mortalities, sardine catches in the Port Elizabeth area in 2014 only totalled to 700 t, substantially reduced compared to the previous 15 years (Figure 41), during which catches have been >5 000 t in all but one other (2013) year. Reduced catches in 2014 indicate a decline in sardine availability, with the fish likely moving away from the region (and/or possibly dying offshore where this would not be observed) in response to the HAB. Following the poor 2014 fishing season off Port Elizabeth, and because of some right-holders there canning rather than freezing their sardine catch, which cannot be done at Port Elizabeth, virtually no effort was expended in this area in 2015 and purse-seiners moved to and fished from Mossel Bay in 2015. Only 3 t of sardine was landed at Port Elizabeth in 2015.

The average sardine condition factor observed during the 2014 PBS was the highest of the time-series, indicating that by the end of 2014 sardine had recovered from deleterious effects that may have been caused by the *L. polyedrum* bloom earlier that year. However, average sardine condition factor during the 2015 PBS, was again low and similar to that observed in 2011 (Figure 40a). During the 2015, PBS poor condition sardine were observed in inshore and shelf waters between Danger Point and Mossel Bay, and in Algoa Bay where fish in the poorest condition were observed (Figure 40c) although good fishing conditions were also observed there. In contrast, anchovy and West Coast round herring poorest conditions were found between Cape Columbine and Cape Agulhas, with individuals of these species being mostly in average to good condition east of Mossel Bay. A HAB, again dominated by *L. polyedrum*, was reported off the South Coast in early-December 2015, apparently originating in Algoa Bay and spreading westwards to Mossel Bay. Although detailed analyses of environment and

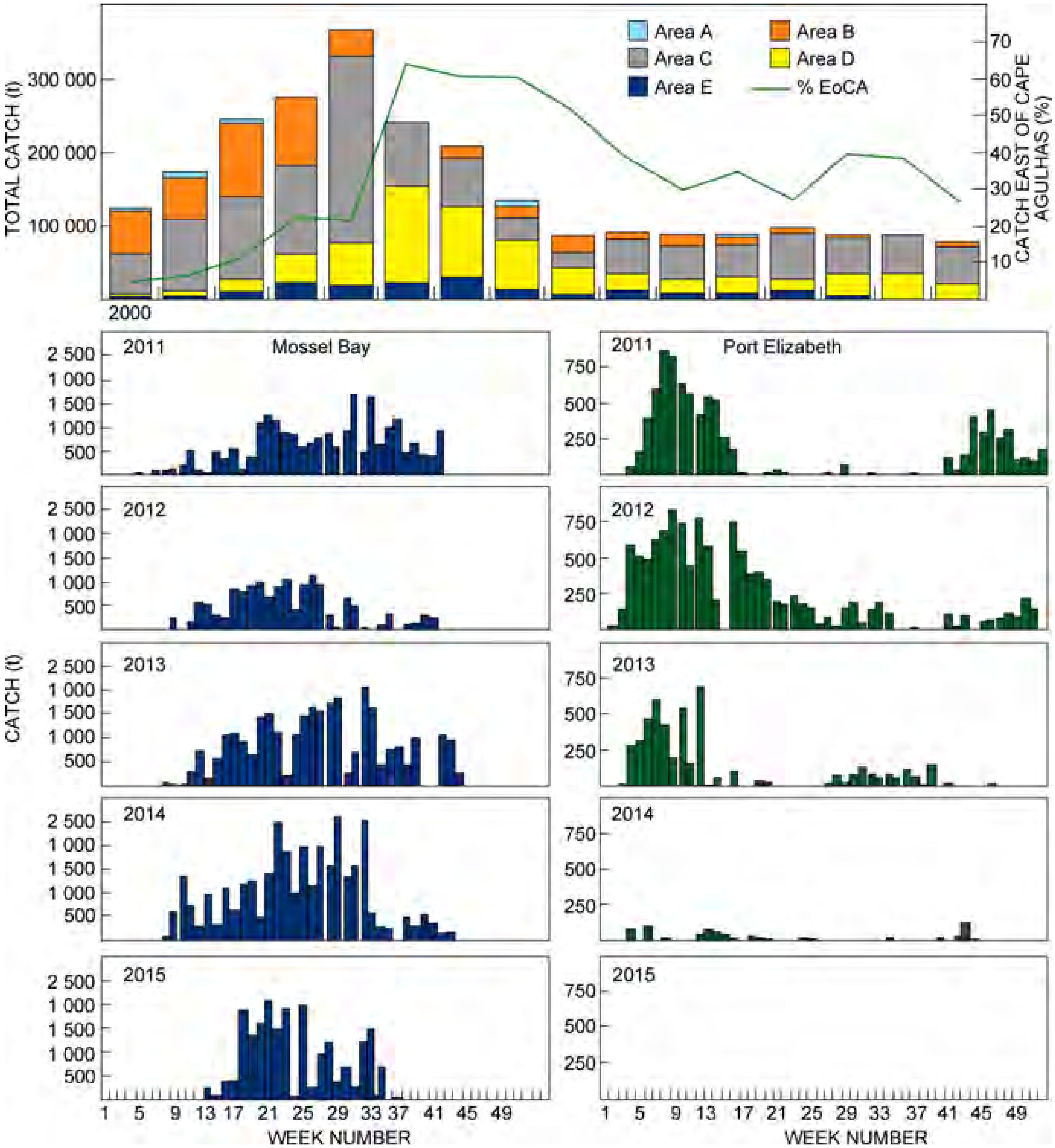


Figure 41: Annual directed sardine catch per Pool Area (stacked histograms; A is north of Cape Columbine; B is Cape Columbine to Cape Point; C is Cape Point to Cape Agulhas; D is Cape Agulhas to Cape St Francis; and E is east of Cape St Francis), and the % of the total directed sardine catch taken to the east of Cape Agulhas (EoCA) for the period 2000–2015 (upper plot); and weekly directed sardine catches taken in the Mossel Bay (Pool Area D; left panels) and Port Elizabeth (Pool Area E; right panels) areas, 2011–2015. Note that the y-axes are differently scaled in the weekly plots for Mossel Bay (max. = 3 000 t) and Port Elizabeth (max. = 1 000 t)

fish data collected during the 2015 PBS have yet to be done, the temporal and spatial overlap between the dinoflagellate bloom and low condition of sardine but not the other two small pelagic species supports the hypothesis that these HABs negatively impact sardine only.

Poor condition has negative implications for spawning success and subsequent recruitment, because energetic reserves are important in determining annual reproductive output in clupeoids. Hence the poor condition of sardine off the South Coast in 2011 and 2015, whether caused by HABs or not, is likely to have curtailed their reproduction, and fish in poor condition typically have underdeveloped gonads. The HABs off the

South Coast in recent years are unprecedented because these have previously occurred predominantly off South Africa's west coast; only 3% of dinoflagellate-dominated HABs observed over the period 1989-1997 occurred off the South Coast. The spatial and temporal extent of these South Coast HABs is also extraordinary and their occurrence may be anthropogenically forced, given that HABs have been predicted to increase because of eutrophication of coastal ecosystems and increased water stratification arising from climate change. Should HABs continue to occur on the South Coast and if the hypothesis that they exert a negative impact on sardine is correct, then this would have serious implications for the fishery and the ecosystem in that region, given the important role of sardine in the foodweb.

Current status

Annual TACs and landings

The total combined catch of anchovy, sardine and round herring landed by the pelagic fishery in 2014 was 372 000 t, up by more than 80% from 2013 and due mainly to a substantial increase in the catch of anchovy, from below 80 000 t in 2013 to 240 000 t in 2014. The combined catch for 2015 was almost 350 000 t, slightly higher than the long-term average annual catch of 335 000 t (Figure 42). Despite the high anchovy TACs allocated for most years since 2000, the utilisation of anchovy remains low with an average catch of anchovy since 2000 amounting to only 220 000 t (Figure 43a).

The sardine-directed catch in 2014 was 89 000 t, decreasing to 80 000 t in 2015 (Figure 43b). In 2015, the sardine-directed TAC was for the first time since 1997 reduced to below 90 000 t, the minimum allowed under the previous OMP and which had also applied between 2008 and 2014. This decreased TAC reflects the depleted state of the sardine resource, which has failed to recover from several years of poor recruitment.

Sardine bycatch, which includes juvenile sardine caught with anchovy, adult sardine, and round herring, as well as adult sardine caught with round herring, amounted to 8 000 t in 2014 and 15 000 t in 2015 (Figure 43c). The levels of sardine by-catch were substantially less than that allowed for, mainly reflecting the low level of sardine recruitment caught in 2014 and 2015. This undercatch of the sardine TAB is encouraged because the OMP, whilst making provision for occasional high bycatch levels, assumes that the TAB will be undercaught on average. Furthermore, industry has also put in place measures to avoid areas with high bycatches of sardine, so as to improve the chances of a recovery in the size of the adult sardine population.

The catch of round herring has been below the 2000–2015 average annual catch since 2013. In 2015 the catch of round herring was only 14 000 t, the lowest since 1980 (Figure 43d).

Following two *ad hoc* increases to the horse mackerel Precautionary Upper Catch Limit (PUCL) in 2011, necessitated by high bycatches of horse mackerel in the anchovy fishery, the process for setting that PUCL was reviewed. Instead of a constant annual PUCL of 5 000 t, a three-year rule, whereby the PUCL over any consecutive three-year period would total to 18 000 t, was introduced in 2013. This has allowed for increased flexibility and increased bycatches of horse mackerel in years when horse mackerel recruitment is high and incidental by-catch with anchovy is unavoidable. This PUCL was working well, but has since been decreased to a maximum of 12 000 t over a consecutive three-year period because of recent declines in directed horse mackerel CPUE and concerns about the status of the adult population size. In 2014, only 2 700 t of the 15 000 t PUCL was landed and in 2015 the bycatch of horse mackerel fell below 2 000 t (Figure 43e).

An annual PUCL for mesopelagic fish of 50 000 t was in-

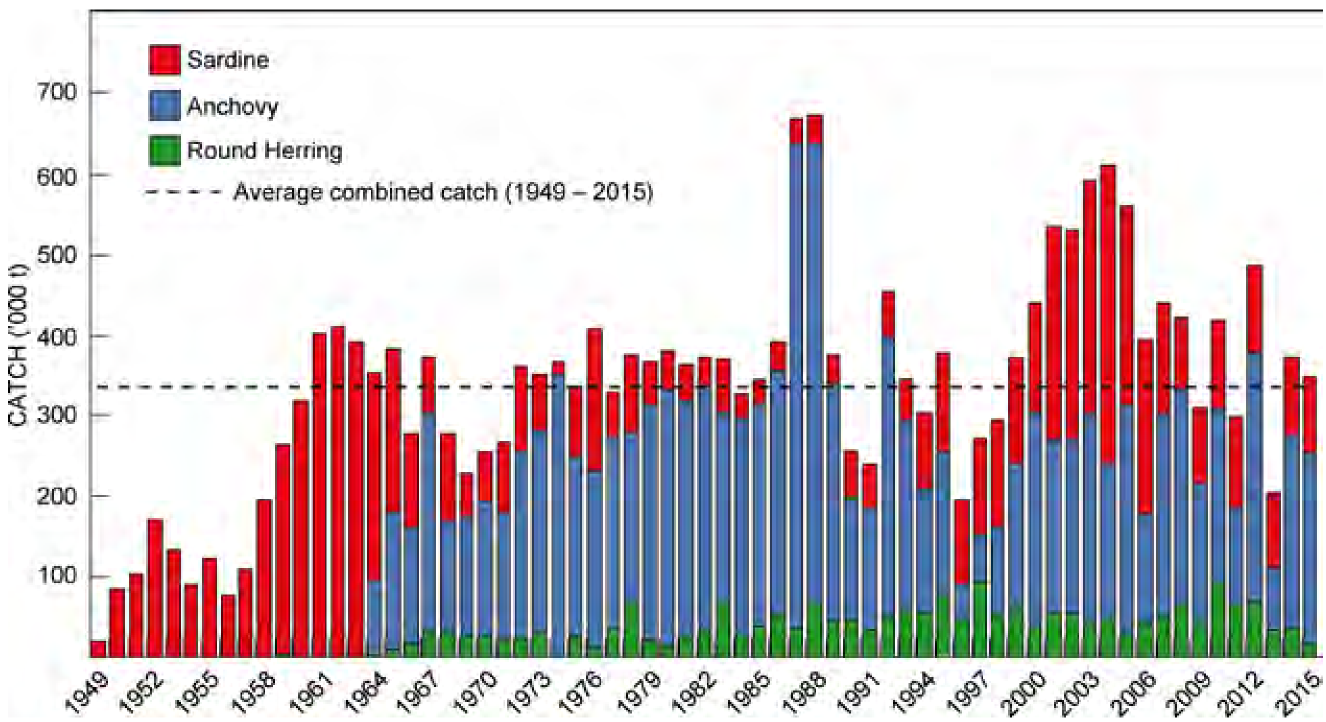


Figure 42: The annual combined catch of anchovy, sardine and round herring. Also shown is the average combined catch since the start of the fishery (1949–2015)

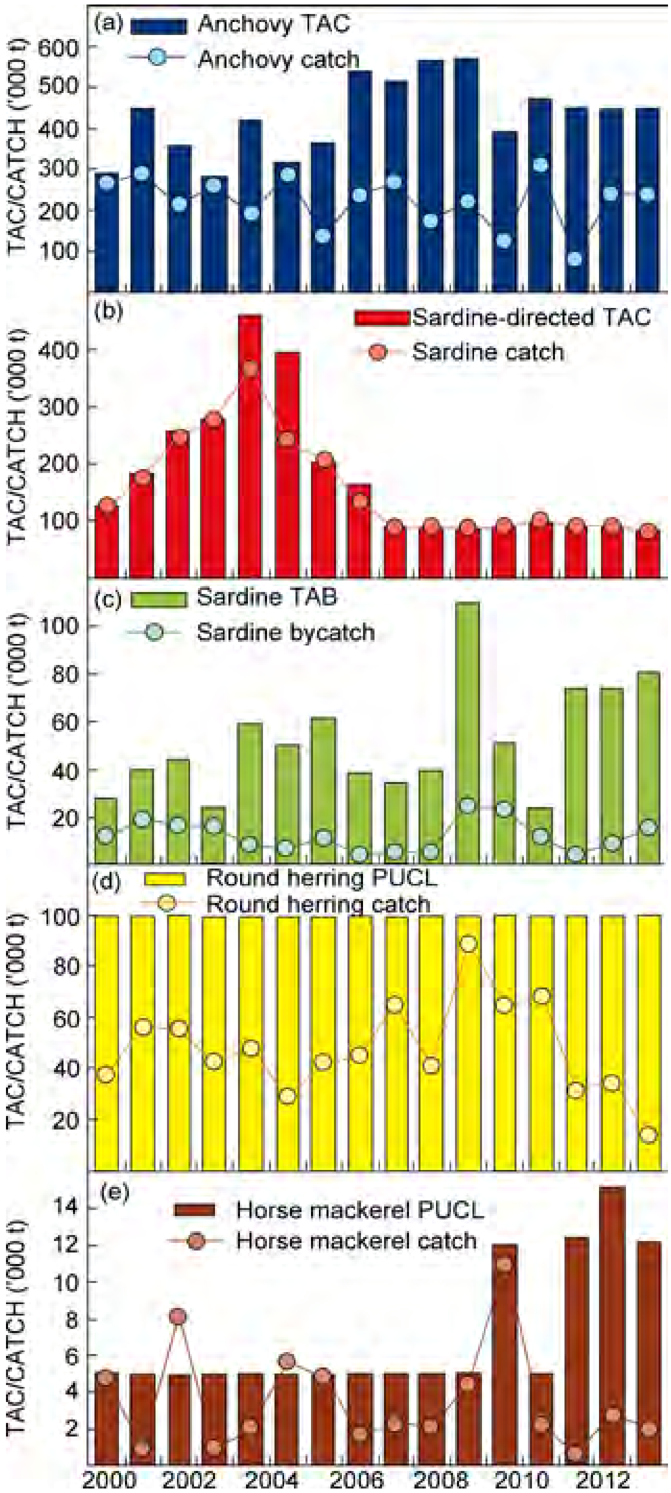


Figure 43: Total Allowable Catches (TACs), Total Allowable By-catch (TAB) and Precautionary Upper Catch Limits (PUCLs), and subsequent landings for each by the South African pelagic fishery for (a) anchovy, (b) directed sardine, (c) sardine by-catch, (d) round herring and (e) horse mackerel, 2000–2015

troduced in 2012, following increased catches of lanternfish and lightfish by the experimental pelagic trawl fishery in 2011, when just over 7 000 t of these species were landed. Since then, however, catches have been minimal and the trawl experiment has not yet been resumed, primarily because of the lack of South African-flagged vessels to undertake this work. The small pelagic scientific working group has also requested that further pelagic trawl efforts be directed at catching round herring and adult anchovy.

Recruitment strength and adult biomass

Anchovy recruitment estimated in 2014 was 224 billion fish, appreciably lower than the 353 billion estimated in 2013 and below the long-term average of 230 billion fish (Figure 44a). This below average recruitment resulted in a slightly reduced adult anchovy biomass by November 2014 of just under 3 million t. Despite an above average recruitment estimate of 263 billion fish in 2015, the adult anchovy biomass decreased further to 1.9 million t. This estimate is below the long-term average and the lowest since 2011.

Sardine recruitment in 2014 was very low, amounting to just 1.99 billion fish. This was the lowest recruitment estimated for sardine since 1991 (Figure 44b). The 2015 recruit estimate of 9.2 billion sardine was considerably higher than the 2014 estimate, but still well below the long-term average of 13.1 billion. Given this further sustained below average recruitment, the adult sardine biomass has continued to decrease and has resulted in a depleted population estimated at only 363 000 t in November 2015.

The round herring recruit estimate of 29 billion fish measured in 2014 was the second highest on record (Figure 44c). This was followed with another above average recruitment estimate in 2015 of 14.2 billion fish. Consequently, the size of the round herring population remains high with more than 1.3 million t estimated in both November 2014 and 2015.

Shifts in the distribution both of anchovy and sardine adults that have previously been reported on (see Status of the South African Marine Fishery Resources Report of 2012 and 2014) continue to be monitored. The abrupt eastward shift of anchovy that occurred in 1996 still persists and seems to have intensified in recent years, with only 33% of the adult anchovy biomass observed in the area to the west of Cape Agulhas in November 2015 (Figure 45a). Given the recent decline in the size of the anchovy population, the biomass of anchovy in this western area has declined to only 655 000 t, a level far below that observed from 2012–2014. The percentage of the sardine biomass found in the area to the west of Cape Agulhas remains highly variable. Around 77% (>600 000 t) of the sardine biomass was found in the area to the west of Cape Agulhas in 2013 (Figure 45b), but this percentage decreased to 44% in 2014 and was only 27% by 2015. The biomass found to the west of Cape Agulhas in 2015 was consequently <100 000 t, the lowest measured in this area since 2008, which highlights the need for fishing effort to be spread further east in 2016. This decrease in the biomass of sardine to the west of Cape Agulhas may also compromise future recruitment, given reduced transport of eggs and larvae to the West Coast nursery area from South and East coast spawning.

Ecosystem interactions

The primary approach that has been used to limit catches of forage fish is rights-based management with a specified annual Total Allowable Catch (TAC). Incorporation of ecosystem considerations and the development of ecosystem-based management is being undertaken through the revised Operational Management Procedure (OMP-14) and further development

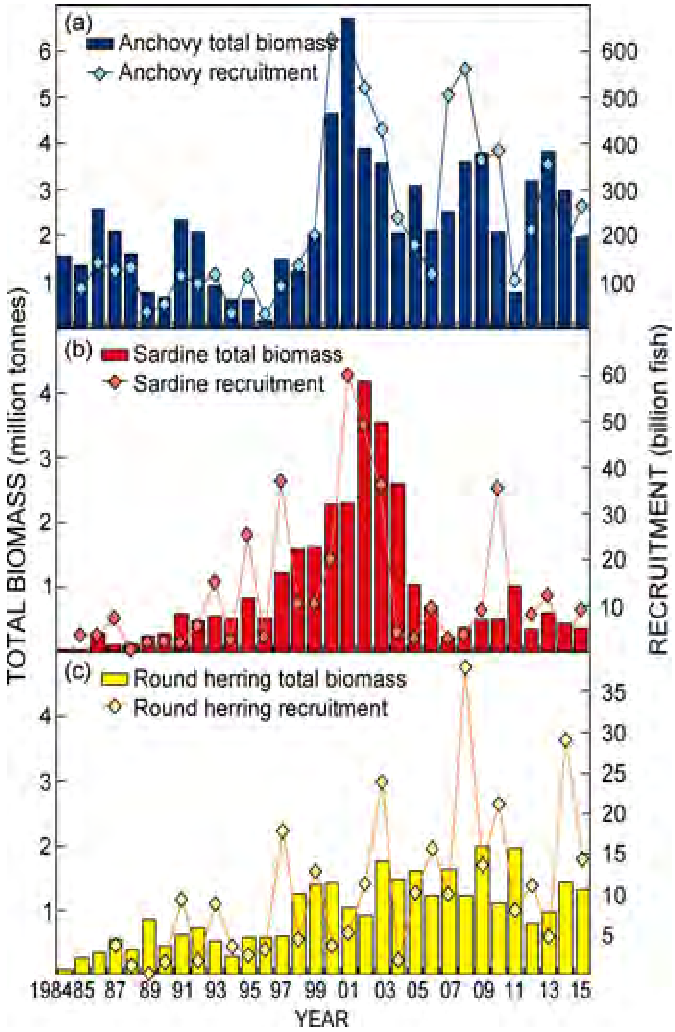


Figure 44: Time-series of acoustically estimated recruitment strength and total biomass of (a) anchovy, (b) sardine and (c) round herring, 1984–2015

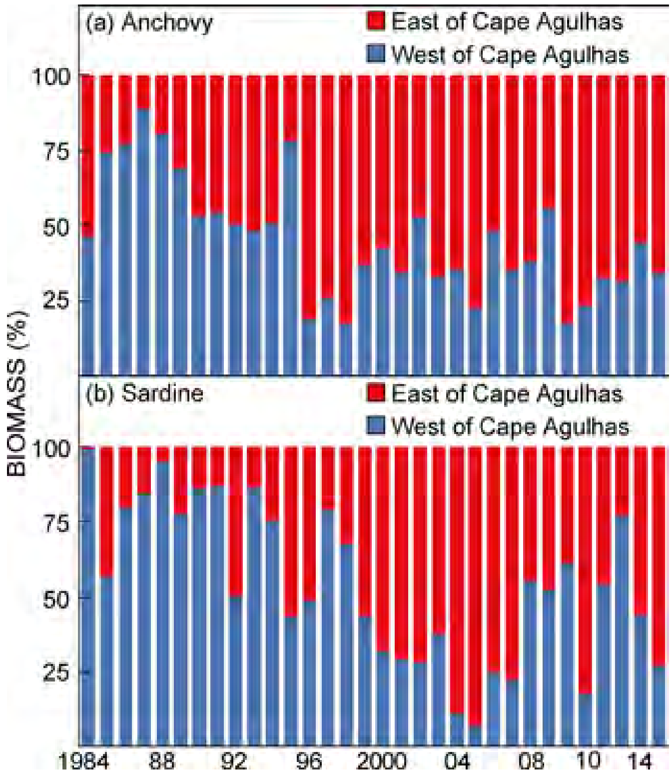


Figure 45: Percentage of (a) adult anchovy and (b) sardine biomass found to the west and east of Cape Agulhas, 2000–2015

thereof (OMP-16).

OMP-14 was simulation-tested to ensure an acceptable level of risk regarding the probability that sardine and anchovy abundances would drop below specified thresholds over a variety of harvest strategies. In adopting OMP-14, additional performance statistics related to several ecosystem objectives under different harvest strategies were also evaluated and an interim spatial component aimed at balancing catches and available sardine biomass on a regional scale was agreed.

OMP-14 was 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 anchovy and sardine and because of their conservation status, which has been of recent concern due to appreciable reductions in numbers at the major breeding colonies on Robben and Dassen Islands over the last few years. As part of the implementation of an ecosystems approach to fisheries (EAF) in South Africa's fishery for small pelagic fish, a model of penguin dynamics has been developed for use in conjunction with the small pelagic fish OMP so that the impact on penguins of predicted future pelagic fish trajectories under alternative harvest strategies could be evaluated. These studies have so far indicated that even with large reductions in pelagic catches under an alternative OMP, there would be little benefit for penguins.

Further evaluation of these results under a sardine two-stock operating model will be attempted during the development of the next OMP (OMP-16). Central to the new OMP will also be the consideration of harvest strategies that include spatial management of sardine, given the likely existence of two or more local stocks of this resource. Such spatial management potentially also has the associated benefit of preventing local forage fish depletion and heightened competition between dependant predators and the fishing industry.

Additionally, penguins may be potentially sensitive to changes in pelagic fish abundance and distribution as a consequence of their land-based breeding sites and their limited foraging range (<20 km) during breeding. Additional measures to possibly restrict fishing in close proximity to penguin breeding colonies are also being investigated. Since 2009, a feasibility study, aimed at collecting data and determining when sufficient data were available to conduct a power analysis in relation to an experiment to determine the effect of fishing on penguins, has been underway. This study has now been completed. The international review panel recommended in December 2014 that pending further analyses, the current programme of closures to pelagic fishing around certain islands that contain penguin breeding colonies be continued. Further progress in developing the methods to evaluate the results of this closure programme was made in 2015 and finalised by the 2015 international review panel. It is anticipated that a decision on the future of this experiment will be taken in December 2016.

Further reading

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Useful statistics

Pelagic fish catches and TACs, TABs and PUCL, 1990–2015 ('000 t)

Year	Anchovy	Total sardine	Directed sardine	Bycatch sardine	Horse mackerel	Chub mackerel	Round herring	Mesopelagic fish	Total
1990	152	57	42	15	8	0	46	1	263
1991	151	53	40	13	1	10	34	1	249
1992	349	55	34	21	2	0	48	1	455
1993	236	51	30	21	12	0	57	1	357
1994	156	95	50	44	8	2	54	1	316
1995	178	121	77	44	2	3	77	1	382
1996	41	108	79	29	19	1	47	0	216
1997	60	119	92	27	13	4	92	0	289
1998	108	133	109	24	27	0	53	7	327
1999	180	132	118	14	2	0	59	0	373
2000	267	135	124	12	5	0	37	0	445
2001	288	192	173	19	1	0	55	0	535
2002	213	261	245	16	8	0	55	0	537
2003	259	290	274	16	1	0	43	0	593
2004	190	374	366	8	2	0	47	0	614
2005	283	247	240	6	6	0	28	0	564
2006	134	217	206	11	5	0	42	0	398
2007	253	140	135	5	2	0	48	0	443
2008	266	91	86	5	2	1	64	0	424
2009	174	94	89	5	2	1	40	0	312
2010	217	112	88	25	4	1	88	0	423
2011	120	112	89	23	11	0	65	7	315
2012	307	109	98	12	2	0	68	0	487
2013	79	92	88	4	1	0	31	0	203
2014	240	98	89	9	3	1	34	0	376
2015	238	95	80	15	2	1	14	0	350

Year	Anchovy TAC	Sardine TAC	Sardine TAB directed	Redeye PUCL PUCL	Horse mackerel PUCL	Mesopelagic TAB and PUCL	Total TAC,
1990	150	42	0	0	0	0	192
1991	150	37	0	0	0	0	187
1992	350	32	0	0	0	0	382
1993	360	27	0	0	0	0	387
1994	150	50	45	0	0	0	245
1995	210	75	42	0	0	0	327
1996	70	76	29	0	0	0	175
1997	60	88	50	0	0	0	198
1998	175	106	35	0	0	0	316
1999	231	136	26	0	0	0	393
2000	291	126	38	0	5	0	460
2001	451	182	50	0	5	0	688
2002	360	258	54	0	5	0	677
2003	282	250	44	100	5	0	681
2004	423	457	69	100	5	0	1 054
2005	297	397	60	100	5	0	859
2006	362	204	71	100	5	0	743
2007	537	162	49	100	5	0	853
2008	518	91	38	100	5	0	752
2009	569	90	43	100	5	0	808
2010	573	90	115	100	5	0	883
2011	390	90	54	100	12	0	646
2012	473	101	27	100	5	50	756
2013	450	90	66	100	12	50	769
2014	450	90	66	100	15	50	771
2015	450	83	73	100	12	50	769

South Coast rock lobster

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

Introduction

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

Products (frozen tails, whole or live lobster) are exported to the USA, Europe and the Far East. Sales are affected by seasonal overseas market trends and competition from other lobster-producing countries. High prices on international markets and the decline of the Rand to US Dollar exchange rate make the sector lucrative. Prices for commodities fluctuate and the sales prices in the USA are currently the equivalent of R440–R600 per kg tail mass.

Longline trap-fishing is labour intensive and, as such, each boat requires approximately 30 officers and crew. The total sea-going complement of the fleet is about 300 individuals, nearly all previously disadvantaged individuals. In addition to sea-going personnel, the sector employs approximately 100 land-based factory (processing) and administrative personnel, mostly previously disadvantaged people. The total export value in 2012 was approximately R190 million.

History and management

The South Coast rock lobster was first described in 1900 and was recorded occasionally in trawler catches for sole at a depth of about 70 m. The commercial fishery commenced in 1974, after the discovery of concentrations of rock lobsters on rocky ground at a depth of around 110 m off 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 had to withdraw from the fishery in 1976, when South Coast rock lobster was recognised as a species occurring wholly within South African waters. From 1977 onwards, the sector operated solely as a local commercial fishery.

The fishery has a management history dating back to 1974. The fishery was regulated initially by limiting the number of traps permitted per vessel. Catches and catch rates declined significantly between 1977 and 1979 (Figure 46). The introduction of management measures such as reduction of effort and catches during the early 1980s resulted in resource recovery (Figures 46 and 47). An annual 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 1993/1994 season (Figure 46), and a more rigorous procedure for stock assessment was developed in 1994.

The fishing season for South Coast rock lobster is year-

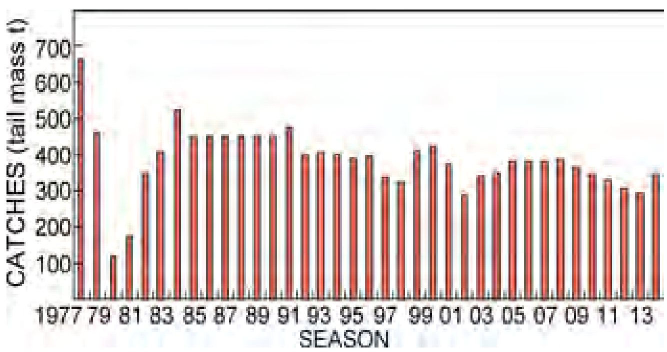

Figure 46: Annual catches of South Coast rock lobster, 1974–2013

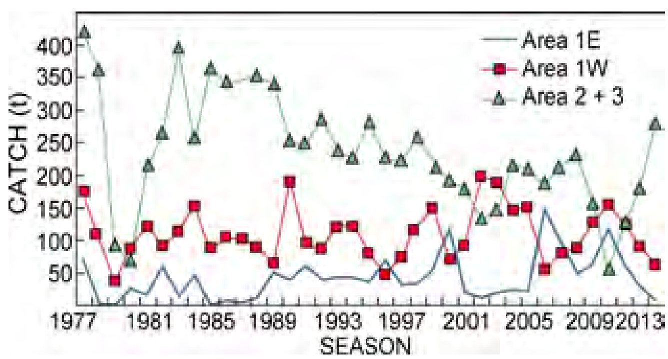

Figure 47: CPUE of South Coast rock lobster by Area

Table 9: South Coast rock lobster historical records of TAC, TAE and standardised CPUE by area

Season	TAC (t tail mass)	TAE (Allocated seadays)	Catch (t tail mass)	Standardised CPUE (kg trap^{-1})		
				Area 1E	Area 1W	Area 2 and 3
1977/1978			667	2.592	1.908	2.256
1978/1979			461	1.453	1.488	2.018
1979/1980			122	1.131	1.588	1.786
1980/1981			176	2.960	2.296	2.036
1981/1982			348	2.524	1.806	1.928
1982/1983			407	2.005	1.576	1.610
1983/1984			524	1.705	1.788	1.845
1984/1985	450		450	2.336	1.632	1.706
1985/1986	450		450	0.456	1.468	1.610
1986/1987	450		450	1.257	1.641	1.935
1987/1988	452		452	1.011	2.210	1.731
1988/1989	452		452	1.774	2.094	2.040
1989/1990	452		452	3.361	1.911	2.051
1990/1991	477		477	1.923	1.862	1.585
1991/1992	477		400	1.456	1.362	1.404
1992/1993	477		408	1.982	1.156	1.516
1993/1994	477		402	1.458	1.048	1.367
1994/1995	452		389	1.012	1.106	1.160
1995/1996	427		395	1.357	0.914	1.149
1996/1997	415		340	0.992	0.912	0.943
1997/1998	402		322	0.909	0.895	0.839
1998/1999	402		413	1.528	1.266	0.686
1999/2000	377		425	1.251	1.013	0.674
2000/2001	365	2 339	375	1.702	1.074	0.734
2001/2002	340	1 922	288	1.482	1.327	0.865
2002/2003	340	2 146	340	1.738	1.460	0.779
2003/2004	350	2 038	350	1.743	1.371	0.987
2004/2005	382	2 089	382	1.920	1.300	1.352
2005/2006	382	2 089	382	1.379	1.216	1.030
2006/2007	382	2 089	381	1.335	0.790	0.815
2007/2008	382	2 089	387	1.096	1.100	1.100
2008/2009	363	2 675	365	1.414	1.215	1.146
2009/2010	345	2 882	345	1.181	1.172	0.845
2010/2011	328	2 550	328	1.370	1.238	0.922
2011/2012	323	2 443	307	0.980	1.089	0.933
2012/2013	342	2 536	295	0.834	0.882	0.962
2013/2014	359	2 805	344	1 402	1.256	1.364

round, extending from 1 October to 30 September of the following year. The management strategy is a combination of TAC and Total Allowable Effort (TAE). The TAC limits the total catch and is based on an annual resource assessment, whereas the TAE is measured in fishing days allocated to each vessel. A vessel may fish until its fishing days expire or its quota is filled, whichever occurs first. The number of days spent at sea by each vessel is monitored. Catches may only be off-loaded in the presence of fishery control officers, and are weighed at designated off-loading points. At the conclusion of each trip, skippers must provide the Directorate with accurate daily catch statistics.

The scientific recommendations for catch limits are based on an Operational Management Procedure (OMP) which was introduced in 2008 and modified ("retuned") in 2010. A full review of the OMP was completed in 2014 (designated 'OMP-2014'). 'OMP-2014' was used to provide the scientific recommendation for the 2015/2016 season and will be used to make TAC recommendations until 2017/2018, at which time it will be reviewed. The major change between the previous and current assessments is in the geographical split in the available resource information.

The objective of the OMP is to increase the spawning biomass of the resource by 20% over the 20 year period from 2006 until 2025, while restricting the inter-annual TAC fluctuations to a maximum of 5%.

Research and monitoring

The stock assessment model used for South Coast rock lobster (an Age-Structured Production Model) is based, *inter alia*, on size and age composition of the catch, somatic growth rates, and population size estimates. A tagging programme supplies the critical growth and population size estimates, as well as estimates of migration. Lobsters are tagged by trained observers during commercial fishing operations. 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.

Scientific observers are deployed aboard commercial South Coast rock lobster fishing vessels. These observers primarily collect data relating to catch composition, take biological measurements (length, sex and reproductive state), estimate catch and effort, report on gear used, observe fishing practices such

as discarding, dumping and bycatch, and also record the areas where fishing takes place. The data are utilised in the annual stock assessment used to determine the TAC.

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

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

Collaborative research between the Directorate and the South Coast Rock Lobster Fishing Industry Association aims to examine the spatial and temporal distribution of females with eggs (berried females) throughout the known distribution range of South Coast rock lobsters and to investigate the feasibility of introducing a fisheries-independent survey to track status indicators for this resource.

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

Current status

In 1977–1979/1980, fishing effort and catches increased above sustainable levels (Figures 46 and 47), thereafter the catches declined rapidly to 122 t tail mass (Figure 46). The decline in catches was partly as a result of the withdrawal of the foreign vessels from South African waters in 1976 and overfishing. By the end of the 1970s, several of the remaining local fishing vessels were forced out of the fishery by low catch rates. Gradual recoveries of catches between 1980 and 1984 and of catch rates between 1980 and 1982 were accompanied by a resurgence of interest in the fishery by fishers who had previously withdrawn. In response to the possibility of overfishing, a TAC was introduced into the fishery, and quotas were allocated to companies that were active in the fishery. This measure effectively limited the number of participants in the fish.

The TAC restricted the total catches to 450 t tail mass (970 t whole mass) per year (Table 9); fluctuations in the TAC up to 1994 included the addition of 2 t (tail mass) for research purposes in the 1988/1989 fishing season, and the addition of 25 t in 1990/1991. The latter increase was justified by the inclusion of a previously unfished area off the Ciskei coast after 1990. The TAC remained stable at 477 t up to the 1993/1994 fishing season.

Resource assessments introduced in 1993/1994 indicated that an annual catch of 477 t could not be sustained. Consequently, a programme of annual TAC reductions was initiated in 1994/1995, reducing the TAC in steps of 25 t per year. The 2001 assessment of the resource indicated that the reductions had, however, failed to impact significantly on the trend of declining abundance.

The 2001 CPUE-index indicated that the abundance of this resource declined by 65% over the 12 years between 1988 and 2000.

The exploitable biomass is currently around 30% of pre-fished levels and spawner biomass is around of 29%.

Ecosystem interactions

There are no major ecosystems issues that require urgent attention in this fishery at present. However, the spatial and temporal distribution of berried females should be investigated to allay concerns regarding the vulnerability of these females under current fishing practices.

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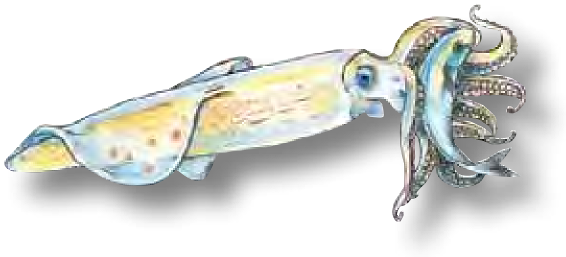
Squid



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

Introduction

Squid *Loligo reynaudii*, locally known as ‘chokka’, is an ubiquitous loligonid squid that occurs around the coast from Namibia to the Wild Coast off the Eastern Cape. They are fast-growing, reaching reproductive size in approximately one year or less and their total lifespan is less than two years. Maximum observed mantle lengths are 48 cm for males and 28 cm for females. Spawning occurs throughout the year with a peak in summer, and its distribution is governed largely by environmental conditions. Spawning occurs on the seabed, mostly in inshore areas of less than 50 m depth, and occasionally in deeper waters. Their chief prey items are fish and crustaceans, but they also sometimes feed on other cephalopods, and cannibalism is fairly frequent. The abundance of squid fluctuates widely, mainly due to biological factors such as spawning distribution and survival rates of hatchlings and juveniles, and environmental factors such as temperature, currents, turbidity and macro-scale events such as *El Niños*.

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

History and management

In the 1960s and 1970s, the squid resource was heavily exploited by foreign fleets, predominantly from the Far East. Foreign fishing activity was gradually phased out in the late 1970s and early 1980s following South Africa’s declaration of an Exclusive Economic Zone (EEZ). Since then, squid and other cephalopods have continued to be caught by South African trawlers. Over the past decade, the squid bycatch in the demersal trawl fishery has fluctuated between 200 and 800 t annually (Figure 48).

A commercial jig fishery for squid was formally established

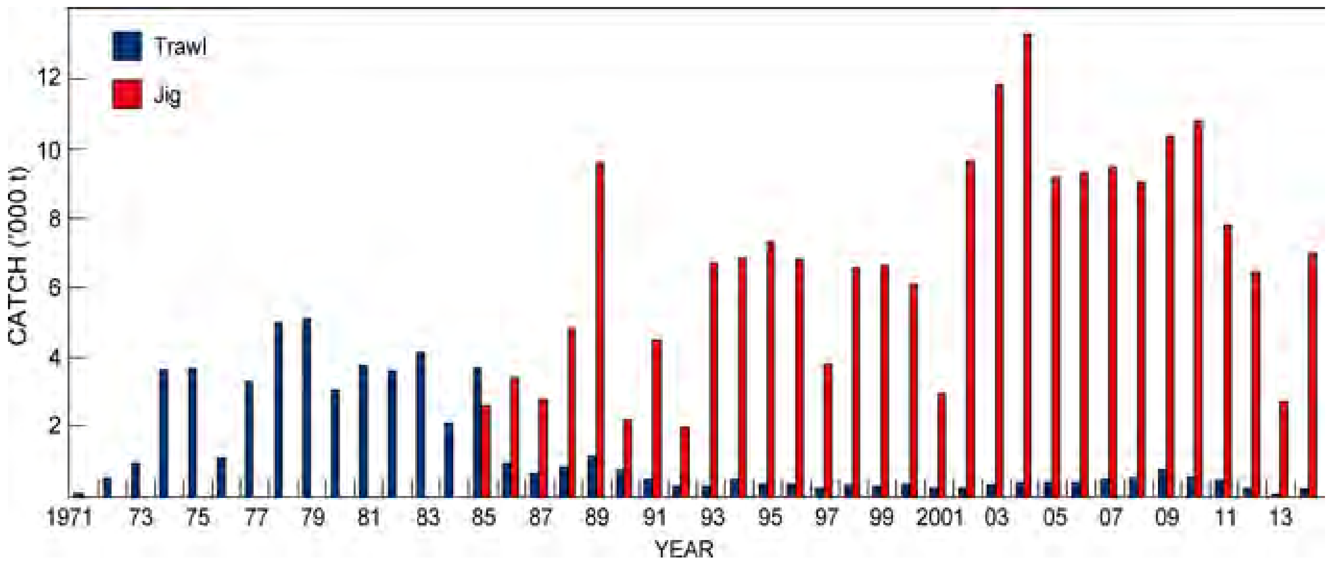


Figure 48: Annual catches of trawl- and jig-caught squid off South Africa, 1971–2014. Trawl data are from the demersal database. Jig data are from the South African Bureau of Standards (SABS) provided by the Industry for the period 1985-2007, and the National Regulator for Compulsory Standards (NRCS) for the period 2008–2014

in 1984. Hand-held jigs are used to catch squid, making this a particularly labour-intensive fishery. Between 1986 and 1988 a licensing system was introduced with a view to limiting the number of boats participating in the fishery. Catches in the 1990s ranged between 2 000 and 7 000 t, and in the 2000s between 3 000 and 13 000 t. In 2004 the jig fishery registered its highest catch of over 13 000 t (Figure 48).Catch data indicates an increase in squid catches over the period 2001–2004, followed by catches stabilising at approximately 9 000 t between 2005 and 2008, and then increasing again to just over 10 000 t in 2009 and 2010 (Figure 48). Annual catches in both the jig and trawl fisheries declined after 2010, reaching a level in 2013 that was almost the lowest since the inception of the jig fishery. It is encouraging that this declining trend has subsequently reversed.

The fishery is effort-controlled and allocated fishing effort is capped at a maximum of 2 422 crew, with the number of vessels commensurate with the number of persons permitted to fish. The recommended TAE is 250 000 person-days and a three month closed season has been implemented since 2013 to accommodate the allocated crew complement of 2 422. In addition, a 5-week closed season (October–November each year) has been implemented since 1988, with the intention of protecting spawning squid and improving recruitment the following year.

The current management objective for the squid fishery is to cap effort at a level that 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 South Coast in autumn each year (and also in spring in some years). Interpretation of the trends in the time series of abundance estimates (Figure 49) is complicated by the changes in the gear and vessels employed during the surveys (see the section on Cape hakes for details). The data obtained from surveys conducted with different gear and vessels are not directly comparable, and any apparent trends in the time-series should be viewed with caution pending the development of reliable calibration factors for the various vessel-gear combinations. Although data from both the autumn and spring surveys are used in assessments of the resource, the spring surveys provide the most useful indication of spawning stock abundance, given that these surveys are conducted just prior to peak spawning season. It is therefore a cause for concern that various budgetary and operational constraints have resulted in no spring surveys having been conducted since 2008.

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

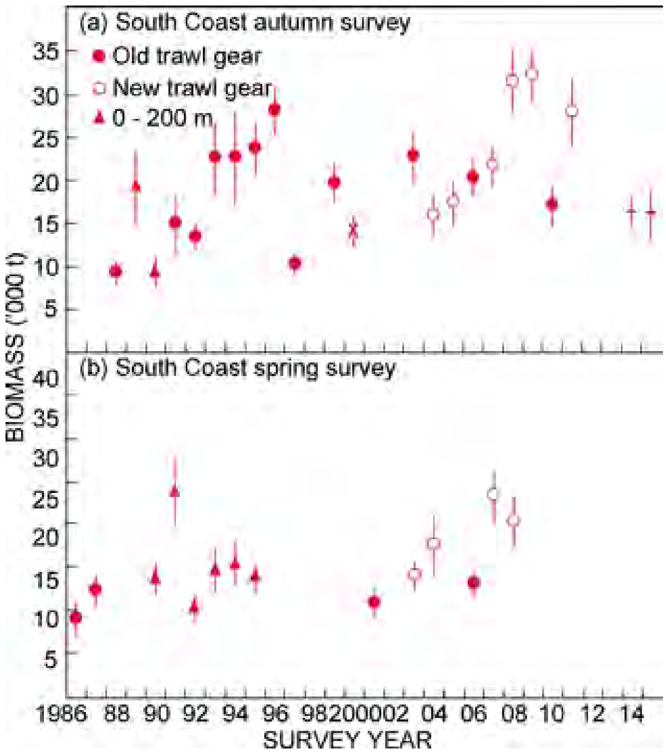


Figure 49: Survey abundance indices for chokka squid with 95% confidence intervals from the spring and autumn demersal hake-directed trawl research surveys. Note that the trawl gear was changed in May 2003 and the time-series using the old trawl gear (closed circles) is not directly comparable with the time-series using the new gear (open circles). Triangles represent old gear survey estimates restricted to depths less than 200 m. The dash (-) in the autumn survey panel represents biomass estimates obtained from surveys by the MV *Andromeda* and the (x) represents a biomass estimate obtained from a survey by the RV *Fridjhof Nansen*

system has indicated that the previous data were not as reliable as had originally been assumed. Efforts to improve the quality of the data and indices used as inputs for assessment of the resource are ongoing.

Chokka squid is one of the best researched squid species in the world and aspects of its early life history and adult ecology are relatively well known. However, capacity constraints within the Department have considerably slowed research efforts. Current research is focused on the distribution of paralarvae, genetics of adults (stock identity), environmental influences on stocks, acoustic mapping of inshore spawning grounds, acoustic survey of squid egg beds and investigating the potential damage of anchors on squid egg beds. It is envisaged that results from these studies will assist in enhancing the management of this resource.

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

Current status

A biomass-based stock assessment model is applied to assess the status of the squid resource. The squid assessment model

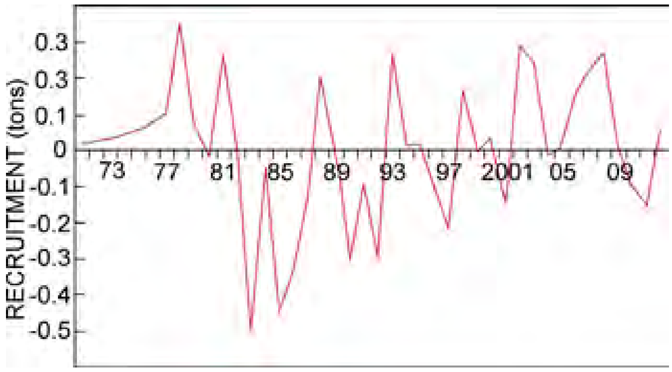


Figure 50: Recruitment residuals, 1971–2012

Figure 51: Estimated begin-year biomass,1971–to 2013

was revised during 2013, based upon recommendations made by a panel of experts at the annual International Stock Assessment Workshop held in November 2012. Updated results from the revised model, based upon the Baranov catch equations, indicate that the squid resource is less productive than previously thought. Above average recruitment had been observed over the period 2002–2009, but had declined in 2010 and 2011 to below average levels, before showing some improvement in 2012 (Figure 50). The assessment indicated a period of declining abundance subsequent to 2009 (Figure 51), and estimated the stock to be at about 29% of pre-exploitation levels in 2013. Future projections of biomass under various management scenarios were conducted using a Bayesian approach, the results of which indicated that, in order to continue utilising the resource without undue risk, an effort level corresponding to 250 000 person-days was appropriate. This reduction in the effort applied by the fishery has been achieved through the implementation of an additional 3-month closed season for the fishery. To some extent, this may be an availability issue, possibly related to unexplained anomalous environmental events, given that other species on the Cape South Coast have been similarly affected. It may, however, also be partially as a result of the target effort level in the jig fishery being exceeded in recent years.

Ecosystem interactions

The South African chokka squid fishery employs hand-held jigs, mainly targeting aggregations of spawning adult squid. This method selectively targets the desired species and there is little to no bycatch in this fishery and jigs have little impact on the environment. Some damage to the seabed may occur during deployment of anchor and chain, which may affect the squid population, and a study is currently underway assessing the impact of anchors to squid eggs and egg beds. Chokka squid is currently listed as green (most sustainably choice from the healthiest and most well-managed fish populations) under WWF's SASSI (South African Sustainable Seafood Initiative) assessment.

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Useful statistics

Total squid catches from jig and as by-catch from trawl, as well as squid TAE over the period, 2003–2012

Year	Squid jig catches	Squid landings as bycatch from hake trawl	Squid TAE
2003	11 820	338	2 423 unrestricted crew* 41 restricted crew*
2004	13 261	391	2 423 unrestricted crew* 41 restricted crew*
2005	9 147	374	2 423 unrestricted crew* 22 restricted crew*
2006	9 291	358	2 423 crew or 138 vessels, whichever occurred first
2007	9 438	496	2 422 crew or 136 vessels, whichever occurred first
2008	9 021	523 ń	2 422 crew or 136 vessels, 2 422 crew or 136 vessels, whichever occurred first
2012	6 458	227	2 422 crew or 136 vessels, whichever occurred first
2013	2 705	61	2 422 crew or 136 vessels whichever occurred first
2014	6 983	213	2 422 crew; vessels commensurate with number of crew

***N.B.** 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 Ciskei. Restricted permits were eventually phased out of the fishery from 2006

Tunas and swordfish

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

Introduction

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 and large pelagic longline fisheries. Additionally, the boat-based commercial linefishery catches tunas opportunistically and the boat-based recreational anglers undertake game fishing for tuna and billfish.

Tuna species, including temperate albacore *Thunnus alalunga* and southern bluefin *T. maccoyii*, tropical yellowfin *T. albacares* and bigeye *T. obesus*, and billfishes such as swordfish *Xiphias gladius* are highly migratory species. They are distributed throughout the Atlantic and Indian oceans, except for southern bluefin tuna, which are confined to the Southern Hemisphere. Southern bluefin tuna is the largest of the tuna species and can reach a length of up to 2 m and a weight of 200 kg Bigeye tuna, yellowfin tuna and swordfish are the main targeted species in the longline sector. Albacore tuna, blue sharks *Prionace glauca* and shortfin mako sharks *Isurus oxyrinchus* are the main bycatch species in the longline sector. Juvenile and sub-adult albacore and, when available in the inshore regions, yellowfin tuna, are the main targets in the tuna pole-line fishery. Billfish species aren't commonly caught in either sector. Bluefin tuna is generally not targeted by longline vessels due to the small (40 t) quota for this species.

Tuna and billfish species will migrate to tropical and subtropical waters to spawn when environmental conditions are favourable. Juvenile bigeye, yellowfin and skipjack *Katsuwonus pelamis* tunas are often found together, with fewer occurrences of mixed schools that include the temperate albacore. Pop-up satellite tagging studies have revealed that for many of the large pelagic species there is a daily vertical movement pattern whereby fish inhabits the surface waters at night and dives deep during the day, to aid thermoregulation and feeding. Tuna and billfish are opportunistic feeders with high metabolic rates, feeding on a variety of fish, molluscs, and crustaceans.

A single stock for the entire Atlantic Ocean is assumed for yellowfin tuna and bigeye tuna. For albacore and swordfish, two different stocks are recognised in the Atlantic, a North and South stock, separated at 5˚N. The Indian Ocean is considered to have one stock of yellowfin, bigeye and albacore tunas. Until the Indian \ocean tuna Commission (IOTC) stock structure project has been completed, swordfish will be managed as one Indian Ocean stock There is a management boundary that separates the Indian and Atlantic Oceans at 20˚E, though there is concern over its bio-geographical validity for tuna and the extent to which tuna, billfishes and pelagic shark populations straddle this boundary.

History and management

Tuna pole-line

Traditionally, albacore is the main target of the South African tuna pole-line (baitboat) fleet, which operates in waters up to 1 000 km off the south and west coasts of South Africa and off Namibia, from October to May. The fishery started in the late 1970s and originally targeted yellowfin tuna, but switched to albacore when yellowfin moved off the Cape waters in 1980, a pattern that repeated itself from 2005 to 2007 and in 2011 and 2014, when the yellowfin became abundant again around the Cape. Although tuna occur in mixed shoals, catches of bigeye tuna and skipjack are caught in low numbers. 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 tuna pole-line fishery.

The tuna pole-line fishery was originally managed as part of the linefishery, but it became a separate sector after an environmental emergency was declared in 2000 due to the collapse of most of the targeted sparid (sea bream) and sciaenid (kob) stocks. The other two sectors that were created were traditional linefish and hake handline. In 2005, DAFF allocated 191 commercial tuna pole-fishing rights, thereby authorising 198 vessels (greater than 10 m long) and more than 2 600 crew to target tuna using the pole method. On average, there were 130 vessels active over the period 2005–2013. The 2013 long-term rights allocation process resulted in 127 rights and 134 vessels authorised to fish in this industry. The outcome of the long-term rights appeals process will be concluded shortly and may lead to an increase in the rights allocated to this fishery.

In the South Atlantic, the Chinese-Taipei longline fleet accounted for 46–90% of the total annual southern Atlantic albacore landed between 1970 and 2004. The South African baitboat fleet follows that of Chinese-Taipei, landing approximately 4 000 t annually. Catches vary depending on the availability of albacore and yellowfin tuna in inshore waters and on foreign currency exchange rates. Other important southern Atlantic albacore fisheries are in Brazil (longline), Namibia (bait-boat) and Japan (longline).

Large pelagic longline fishery

Although domestic commercial longlining for tuna has been documented from the early 1960s, with catches reaching approximately 2 000 t, the fishery declined rapidly in the mid-1960s as a result of a poor market for the low-quality bluefin and albacore tuna landed by the South African fishery. Foreign vessels fished in South Africa's waters from the 1980s through to the 2000s under bilateral agreements. Interest in targeting tuna by South Africans using longline gear was rekindled in 1995, when a joint venture with a Japanese vessel confirmed that tuna and swordfish could be profitably exploited in South African waters. In response to the expressed interest in longlining for tunas, 30 experimental longline permits were issued for South African waters towards the end of 1997, primarily for catching tuna. Catches peaked at over 2 500 t during the experimental phase of the fishery, with the main target species being swordfish and yellowfin and bigeye tuna. Other important species caught in smaller quantities included albacore and southern bluefin tuna, and blue and mako sharks.

The experimental longline fishery was formalised into a commercial fishery in 2005 when long-term rights were allocated. The primary objectives of this allocation were to develop a record of tuna catches to indicate South Africa's performance and abilities in the fishery and to grow the local fishery. In this allocation process, 18 rights were issued for the swordfish-directed fishery and 26 for the tuna-directed fishery (one right per vessel) to promote the targeting of tuna and to reduce the pressure on the swordfish resources along the coastline. Joint venture agreements with Japan have been underway since 1995 whereby these foreign-flagged vessels are permitted to fish under a South African Rights Holder agreement. The vessels adhere to South African permit conditions and are required to carry an observer onboard every trip. The catch from these vessels accrues to South Africa.

Because large pelagic resources are highly migratory and fished by many nations, these resources are managed by Regional Fisheries Management Organisations (RFMOs). South Africa has been a member of the International Commission for the Conservation of Atlantic Tunas (ICCAT) since 1967. The country is currently a Co-operating Non-contracting Party of the IOTC and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). Membership of both these bodies has, however, been approved by Cabinet and Parliament in September 2015, and South Africa's accession to these two RFMOs is therefore imminent.

ICCAT and CCSBT have quota controls or a TAC for individual species. South Africa received an annual South Atlantic swordfish catch limit of 1 001 t and an annual South Atlantic albacore catch limit of 4 400 t from ICCAT for the period 2014–2016. The country was also allocated a southern bluefin quota of 40 t from the CCSBT for 2014 and 2015. Subject to South Africa's accession to the CCSBT, South Africa will receive an increased annual southern bluefin quota from 40 t to 150 t for 2016 and 2017. No other quotas have been allocated to South Africa thus far.

In 2014 the decision was taken to no longer distinguish between the two different fishing strategies, tuna-directed and swordfish-directed, since the targeting dynamics of the local fleet have changed from exclusive swordfish directed to include tunas and sharks. The fishery is now referred to as the

Large Pelagic Longline Fishery and includes vessels that target tunas, swordfish and sharks. The 10-year long-term rights granted in 2005 expired in February 2015, and 15-year rights will be allocated in the 2015/2016 period by the Department (DAFF). The fleet is currently fishing under exemption permits until the process has been concluded.

Pelagic sharks

In 2005 the shark longline sector was split into a demersal shark longline component, which predominantly targets soupfin *Galeorhinus galeus* and smooth hound sharks *Mustelus mustelus*, and a pelagic longline component (seven vessels), which predominantly targets shortfin mako and blue sharks. This fishery was split as a precursor to phase out the targeting of pelagic sharks due to the following reasons: (1) blue sharks are Near-threatened and shortfin mako sharks are Vulnerable according to the International Union for Conservation of Nature IUCN; (2) substantial pelagic shark bycatch is expected in the tuna/swordfish fisheries; (3) sharks are slow-growing, mature late, and have low fecundity, which makes them particularly susceptible to overfishing; (4) concerns over ecosystem effects of reducing numbers of apex predators; and (5) concerns over the stock status of these species. The pelagic shark fishery operated under exemptions from 2005 until March 2011 when South Africa incorporated the remaining vessels into the tuna/swordfish longline fishery. After operating under exemption from 2005, the pelagic shark longline fishery was merged into the Large Pelagic Longline fishery in March 2011. A Precautionary Upper Catch Limit (PUCL) of 2 000 t dressed weight of all sharks has been set. Once this limit is reached, fishing in the large pelagic fishery would close. In response to sustainability concerns expressed by the RFMOs, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the IUCN, South Africa has prohibited the retention of thresher (genus *Alopias*), hammerhead (belonging to genus Sphyrna), oceanic whitetip *Carcharhinus longimanus*, porbeagle *Lamna nasus*, silky sharks (*C. falciformis*) and the dusky shark (*C. obscurus*) which resembles silky sharks. The National Plan of Action (NPOA) for sharks was finalised and launched at ICCAT's 23rd Regular Meeting of the Commission held in Cape Town in 2013. Shark-related issues discussed in the NPOA have been categorised into clusters with proposed actions by the responsible unit within a time frame (NPOA-Sharks, 2013). A task-team of relevant stakeholders is required to achieve the tasks set out in the NPOA.

Research and monitoring

The scientific observer programme for domestic longline vessels came to an end in March 2011. Currently, 100% coverage is achieved on foreign-flag vessels but there has been minimal coverage on domestic vessels in 2014 and 2015. The observers record all operations on the vessel and obtain length frequencies, biological samples, and fisheries information on target and bycatch species. An observer coverage of 5–20% of catch days (the lower coverage is the minimum requirement by IOTC) for domestic longline vessels is envisaged once the programme is re-established. Port-side monitoring of tuna pole-line vessels will also re-commence upon the re-establishment of the scientific observer programme.

There is uncertainty over the extent of movement of large pelagic species across the 20°E management boundary that

separates the Indian and Atlantic oceans. The extent of the mixing between the populations has strong implications for stock assessments. A multidisciplinary approach is required to resolve this question, combining tagging, genetic and stable isotope research.

Albacore has been studied mainly in the North Atlantic and the North Pacific, and little is known about this species in the southern regions and tropics. In the Pacific and Atlantic oceans there is a clear separation of southern and northern stocks associated with the oceanic gyres. The Indian Ocean population is thought to comprise of a single stock, distributed from 5°N to 45°S, but the link between Indian Ocean and South Atlantic stocks needs to be established. South African scientists collaborated on the Genetic Structure and Migration of Albacore Tuna (GERMON) project led by Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) and Institut de Recherche pour le Développement (IRD) to better understand the stock structure of albacore between the Indian and Atlantic oceans. Genetic, morphological and biological sampling was concluded in July 2014 and the data are currently being analysed for publication. The conclusion of a study on the foraging ecology and habits of albacore tuna in the south east Atlantic Ocean, including comparisons made with yellowfin tuna, will provide additional insights into albacore life history.

Swordfish is commercially important to the domestic longline fleet, and research on this species has been motivated by a sharp decline in catch rates since the start of the experimental fishery. The scientific observer programme was used exten-

sively from 1998 to collect swordfish length frequencies and biological material for age and growth studies, sexing, maturity staging and dietary studies. A population genetics study is currently underway utilising microsatellite markers on samples of swordfish to analyse the stock structure around South Africa.

Similarly to the albacore and swordfish, a study on the stock structure of yellowfin tuna caught around South Africa's coastline is underway with the use of genome-wide population genetics techniques.

A study on the genetic diversity and population structure among Atlantic nursery grounds (i.e. western Iberia, Azores and South Africa) of the blue shark is nearing conclusion. The study aims to help clarify the Atlantic stock structure of blue sharks by using 13 microsatellite markers and a 993 bp fragment of the mitochondrial control region, and by sampling young-of-the-year and small juveniles (<2 years) at each of three reported Atlantic blue shark nurseries.

A number of satellite tags (i.e. pop-up satellite archival tags (PSAT) and Smart Position or Temperature Transmitting (SPOT) tags) as well as conventional tags have been placed on tunas (11 satellite), swordfish (11 satellite) and sharks (9 satellite, 495 conventional) during the five dedicated pelagic longline research cruises on the RS *Ellen Khuzwayo* since 2008. Movement and distribution of blue sharks (based on PSAT tag data) suggests a single blue shark stock within the southern Atlantic Ocean.

South Africa's involvement in Component 4 (Assessment and sustainable utilisation of large pelagic resources) of the South West Indian Ocean Fisheries Programme (SWIOFP) was primarily focused on investigating the distribution and movement of swordfish, bigeye and yellowfin tuna within the SWIO region. SWIOFP provided 15 PSATs for deployment on swordfish, yellowfin and bigeye tunas as well as hook monitors and time depth recorders for the deployment of an instrumented longline. The Department's national research cruise in 2011 was highly productive, resulting in 11 swordfish PSAT-tagged, the first successful swordfish tagging in the SWIO region. Tags were programmed for either 90 or 180 days. Of the 11 tags, four remained on the swordfish for more than two months. Three of the swordfish were tagged in the SWIO region and remained there, whilst the fourth crossed the 20˚E management boundary between ICCAT and IOTC twice.

Two bigeye tuna and one southern bluefin tuna were successfully PSAT-tagged during the August 2015 research cruise. Data from these tags will reveal horizontal movement patterns off the South African coastline.

The heavy metal contamination of commercially important yellowfin tuna, blue shark and shortfin mako shark has been investigated by a PhD student in the Meat Science, Processing and Product Development research team (Department of Animal Sciences) at Stellenbosch University, and a similar study on swordfish is currently underway by the IRD in the Indian Ocean.

The Department, with the assistance of NGOs (e.g. Birdlife SA), assesses the impact of longline fisheries on seabirds, turtles and sharks and investigates various mitigation and management measures. A National Plan of Action for seabirds (NPOA-seabirds) was published in 2008, which aimed to reduce seabird mortalities below 0.05 seabirds per 1 000 hooks. There is good collaboration with the fishing industry, researchers and managers to improve mitigation measures and to implement stringent management measures through permit conditions. Close monitoring through the observer programme has resulted in decreased seabird mortalities and the country edges closer each year to achieving the NPOA-seabirds goal of less than 0.05 seabird mortalities per 1 000 hooks. The Albatross Task Force (ATK, BirdLife South Africa) has been working with Fishtek (http://fishtekmarine.com/hookpod.php) to trial the Hook Pod on the pelagic longline vessels to reduce the incidental catch of seabirds during setting operations. The device is designed to easily attach to pelagic (midwater) longline gear and prevents incidental seabird capture by protecting the barb of the hook during the setting operations. Once the fishing gear sinks to a predetermined depth, the pod opens (using a pressure-release system), releasing the hook to begin fishing. The pod is then simply retrieved during hauling operations closed and is ready to be reused on the following set (BirdLife South Africa website 2015). The Smart Tuna Hook by OceanSmart was tested in 2014 on 27 longline sets during two fishing trips.

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, while stock assessments for southern bluefin tuna are conducted by the CCSBT. South Africa contributes abundance indices (standardised catch-per-unit-effort CPUE) and catch data towards the stock assessments of albacore and swordfish since 1996.

Yellowfin tuna

A stock assessment for yellowfin tuna conducted by ICCAT in 2011 (using catch-and-effort data through 2010) indicated that the yellowfin stock in the Atlantic Ocean was overfished and catches were about 10% higher during 2008–2010 than in 2007. ICCAT has recommended that no additional effort be exerted on the Atlantic yellowfin stock, as this will slow or reverse rebuilding of the stock. The 2015 stock assessment results for Indian Ocean yellowfin tuna produced equally pessimistic results. The spawning stock biomass in 2014 was estimated to be 66% (58–74%) of the level which can support Maximum Sustainable Yield (MSY) and the fishing mortality estimates for 2014 was 34% (2–67%) higher than the corresponding fishing mortality rate that would produce MSY. The stock status determination changed in 2015 as a direct result of the large and unsustainable catches of yellowfin tuna taken over the last three years, and the relatively low recruitment levels estimated in recent years.

Albacore

A full southern Atlantic albacore stock assessment was conducted by ICCAT in 2013, using a broad range of methods and data up to 2011. The results of the stock assessment suggest there is a 57% probability that the stock is both overfished and experiencing overfishing. The large confidence intervals reveal uncertainties in the status of the stock. Consequently, the TAC was maintained at 24 000 t in the South Atlantic region with contracting parties receiving hard-limit quotas. South Africa received an annual catch limit of 4 400 t for 2014–2016. Although there were considerable uncertainties in the results of the stock assessment models used in 2014, the albacore stock in the Indian Ocean has been deemed not overfished and not subject to overfishing.

Swordfish

Notwithstanding the conflicting results between the models used in the swordfish stock assessment, the stock is not considered in an overfished state and not experiencing overfishing. Until improved scientific information is available in the form of more consistent indices, tagging studies to estimate fishing mortality or abundance, or other improved information, uncertainty will remain. South Africa's TAC was maintained at 1 001 t for 2014–2016. In the Indian Ocean, the decrease in longline catch and effort from 2005 to 2011 lowered the pressure on the Indian Ocean stock as a whole, and despite the recent increase in total recorded catches (29 902 t in 2014), current fishing mortality is not expected to reduce the population to an overfished state over the next decade.

Bigeye tuna

In the Atlantic Ocean, the bigeye tuna stock has been exploited by three major gears (longline, baitboat and purse-seine fisheries) and by many countries throughout its range. Catches reached a historic high of about 135 000 t in 1994 and have declined gradually since then. In 2001 the catch fell below 100 000 t and the preliminary catch for 2014 is estimated at 72 585 t. During 2010–2014 the longline fleets contributed 48%, the purse-seine fleets 37% and baitboat fleets 15% of the total weight of bigeye landed. The Atlantic bigeye tuna stock was estimated to be overfished and overfishing was occurring in 2014. Projections indicate that catches at current TAC level of 85 000 t will have around 30% of probability to recover the population to a level that is consistent with the convention objectives by 2028. Therefore, the Scientific Committee has recommended that the Commission reduce the TAC to a level that would allow the recovery of the stock with high probability and in as short period as possible. The longline catches in the Indian Ocean have fallen sharply between 2007 and 2011, largely due to the decline in the number of Taiwanese longline vessels active in the north-west Indian Ocean in response to the threat of piracy. Since 2012 catches appear to show some signs of recovery as a consequence of improvements in security in the area off Somalia and fleets (mostly Taiwanese longline vessels) resuming activities in their main fishing grounds. However, current catches (100 231 t) still remain far below levels recorded in 2003 and 2004. The last stock assessment in the Indian Ocean was conducted in 2013 and the data indicated that the stock is not overfished and is not subject to overfishing.

Southern bluefin tuna

The stock is currently estimated to be at 9% of the initial Spawner Stock Biomass (SSB) and below the level to produce MSY. However, as there has been some improvement since the 2011 stock assessment (including positive trends in the CPUE and aerial surveys indices), the global TAC was increased to 12 449 t for 2014 and it is currently 14 647 t for the years 2015–2017. Catch rates at the current TAC are expected to achieve rebuilding of the stock.

Ecosystem considerations

Extensive research and corresponding management advice have gone into mitigating the bycatch of seabirds, turtles and marine mammals in the pelagic longline fishery. The most common caught seabird species, all of which are either Near threatened, Vulnerable or Endangered, are the White-chinned petrel *Procellaria aequinoctialis* and albatrosses. Leatherback *Dermochelys coriacea* and loggerhead turtles *Caretta caretta* are the most commonly-caught turtle species, though a large percentage of turtles were not identified to species level.

The World Wildlife Fund (WWF) South Africa Responsible Fisheries Programme, now the WWF Sustainable Fisheries, has worked since 2007 to facilitate the implementation of an Ecosystem Approach to Fisheries (EAF) management in Southern Africa. An Ecological Risk Assessment (ERA) was conducted in 2007 to identify the issues (e.g. ecological well-being, human-wellbeing and ability to achieve) in the pelagic longline, shark longline and tuna pole-line fisheries. A performance report identified the gaps among research, management, compliance and industry and has been used to guide work plans and implementation of EAF considerations in permit conditions.

The Responsible Fisheries Alliance (RFA) is a forum for environmental NGOs and responsible fishing companies to work together to ensure that healthy marine ecosystems underpin a robust seafood industry in southern Africa (RFA, 2011). The RFA has been a valuable initiative driven by the fishing industry to develop skills of fishers and fisheries managers to implement an EAF approach to operations and management, and to promote and implement independent high-quality research on the implementation of an EAF.

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Useful statistics

Total catch (t) and number of active domestic and foreign-flagged vessels for the period 2005–2014. Figures for sharks denote dressed weight

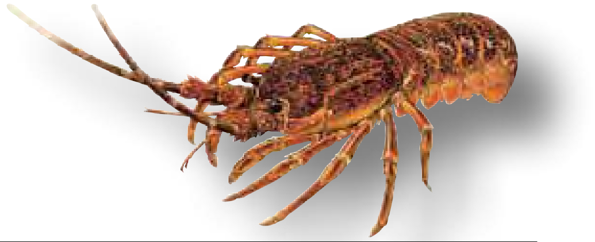
Year	Bigeye tuna	Yellowfin tuna	Albacore	Southern bluefin tuna	Swordfish	Shortfin mako shark	Blue shark	Number of active vessels	
								Domestic(*)	Foreign-flagged
2005	1 077.2	1 603.0	188.6	27.1	408.1	700.1	224.6	13 (4)	12
2006	137.6	337.3	122.9	9.5	323.1	457.1	120.7	19 (4)	0
2007	676.7	1 086.0	220.2	48.2	445.2	594.3	258.5	22 (5)	12
2008	640.3	630.3	340.0	43.4	397.5	471.0	282.9	15 (4)	13
2009	765.0	1 096.0	309.1	30.0	377.5	511.3	285.9	19 (4)	9
2010	940.1	1 262.4	164.6	34.2	527.8	590.5	311.6	19 (5)	9
2011	906.8	1 181.7	338.7	48.6	584.4	645.2	541.6	16 (6)	15
2012	822.0	606.7	244.6	78.8	445.3	313.8	332.6	16 (6)	11
2013	881.8	1 090.7	291.1	50.9	471.0	481.5	349.0	15 (5)	9
2014	543.8	485.8	113.8	31.2	223.1	609.6	573.4	16 (6)	4

*Pelagic shark vessels, included in total

Total catch (t) and number of active vessels in the tuna pole-line sector for the period 2005–2014

Year	Albacore	Yellowfin tuna	Snoek	Yellowtail	Skipjack tuna	Bigeye tuna	Number of active vessels
2005	3 149.4	975.0	193.4	13.8	0.9	1.7	111
2006	2 526.6	978.9	118.0	1.4	0.0	1.0	116
2007	3 681.0	945.2	79.5	19.2	0.2	20.5	128
2008	2 189.9	347.8	313.7	13.0	3.6	22.9	109
2009	4 795.3	223.8	186.2	33.4	4.0	37.9	118
2010	4 272.8	177.2	476.8	41.2	1.6	12.6	108
2011	3 346.8	629.5	163.8	26.9	5.4	35.5	111
2012	3 619.6	165.6	180.1	27.5	8.0	13.2	119
2013	3 488.8	374.5	620.5	18.2	2.6	125.8	106
2014	3 526.4	1 308.2	266.9	11.1	4.6	43.3	94

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 the most important rock lobster fishery in South Africa due to its high market value (more than R 260 million per annum) and its importance in providing employment for over 4 200 people from communities along the West Coast. It is a cold-water, temperate spiny lobster species that occur 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 deep. This slow-growing species inhabits rocky areas and exhibits a seasonal inshore-offshore migration governed by its biology and environmental factors. Currently, 20% of the resource is harvested by hoop nets from 'bakkies' in the nearshore region up to one nautical mile offshore and 80% by offshore trap vessels operating up to water depths of greater than 100 m. The resource in the nearshore region is also harvested by recreational fishers and small-scale or subsistence fishers operating exclusively in the nearshore region during the summer months.

The invasion of West Coast rock lobsters in to the traditional abalone fishing zones east of Cape Hangklip marked the onset of the eastward shift in their distribution. Commercially viable quantities of lobster in this area resulted in the opening of three new lobster fishing areas (Areas 12–14). However, the fishery on the West Coast, which historically landed the bulk (60%) of the lobster catch, now lands only 40% of the total catch annually. This decline in catch 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 OMP was developed that 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 (Figure 52). Lobsters were predominantly caught with hoop nets prior to the 1960s and from 1965 more efficient traps and motorised deck boats were also used. Catches declined by almost half to 10 000 t during the 1960s and continued to decline sharply to around 2 000 t in recent years. The decline in catches is believed to be due to a combination of changes in fishing methods and efficiency, changes in management measures, over-exploitation, 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, CL), 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 over-fishing. A minimum legal size limit of 76 mm CL was implemented in 1959, after which the 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 CL was implemented. In 1979 the tail-mass production quota was replaced by a whole lobster quota, which led to the introduction of the 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 53, 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 migration of lobster to the area east of Cape Hangklip. Currently, the stock is managed on a per zone (super-area) basis. The resource in Zones A, E and F are exclusively harvested by fishers operating with hoop nets in the nearshore region.

Other management controls applied included protection of females with eggs (berried females) and soft-shelled lobsters, a closed winter season, and a daily bag limit for recreational

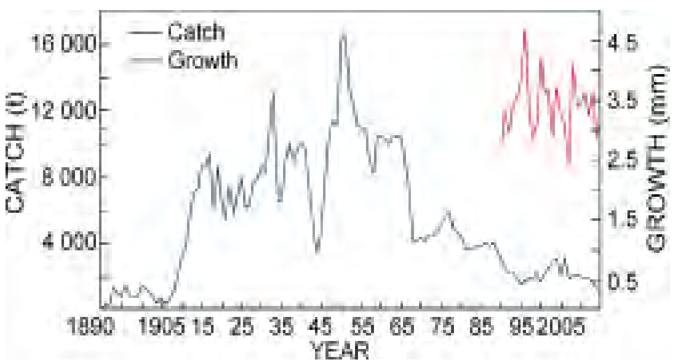


Figure 52: Historical catches of West Coast rock lobster, with the associated trend in growth indicated for the period post-1980.

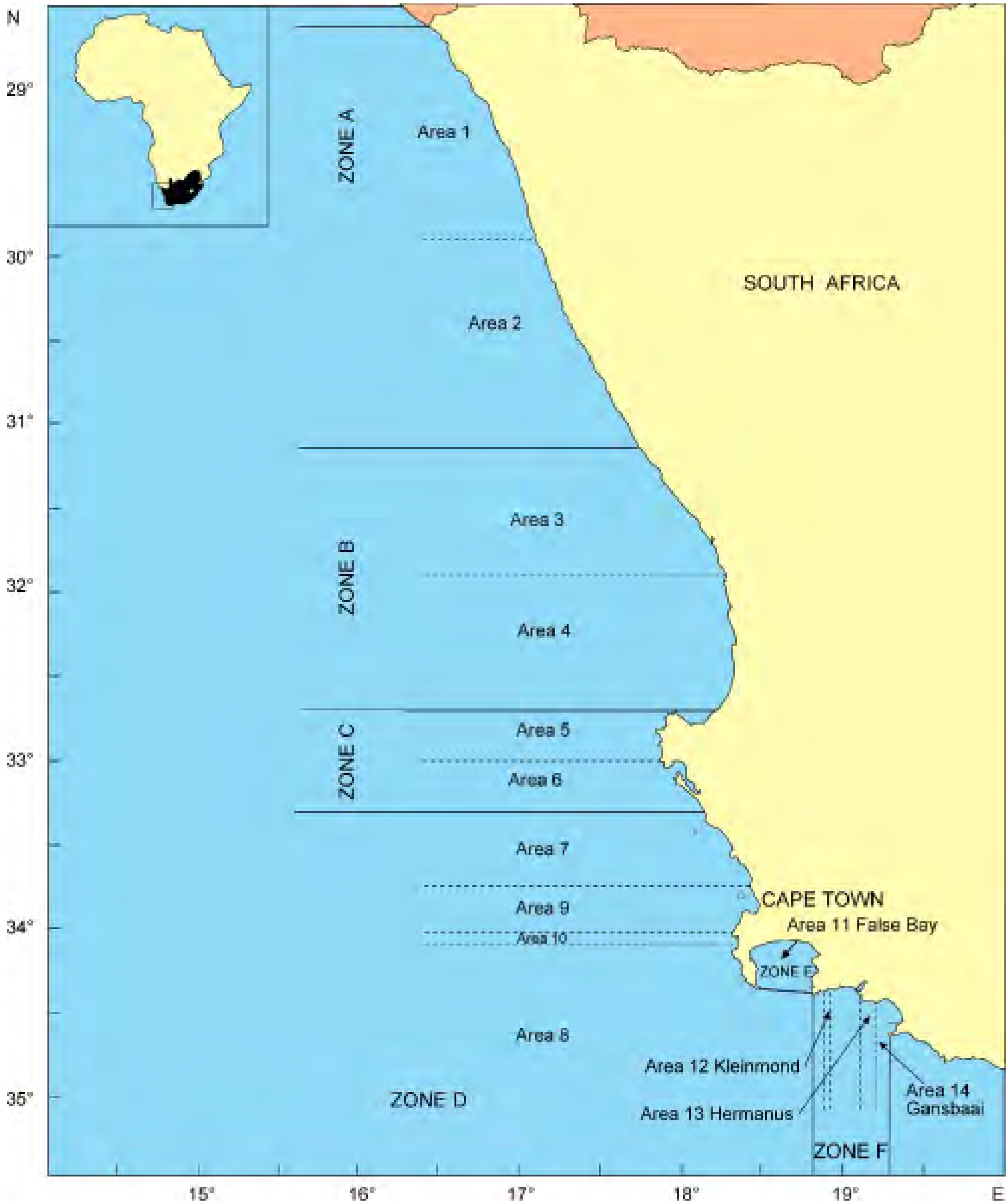


Figure 53: West Coast rock lobster fishing Zones and Areas. The five Super-Areas are A1–2 corresponding to Zone A, A3–4 to Zone B, A5–6 to Zone C, A7 being the northernmost Area within Zone D, and A8+ comprising Area 8 of Zone D in conjunction with Zone F

Table 10: Input data for the 2011 OMP TAC calculations for Super-Areas 1–8+

Year	Trap CPUE (t)	Hoop CPUE (t)	FIMS CPUE (t)	Somatic growth of 70mm male lobster (mm y^{-1})
		Super Areas 1+2		
2005	–	1.404	–	2.753
2006	–	1.308	–	2.815
2007	–	1.419	–	3.880
2008	–	1.148	–	3.584
2009	–	1.578	–	7.023
2010	–	1.042	–	4.534
2011	–	0.851	–	4.197
2012	–	0.819	–	5.995
2013	–	0.934	–	3.384
2014	–	0.998	–	3.910
		Super Areas 3+4		
2005	–	0.486	61.63	3.600
2006	–	0.388	39.79	3.421
2007	–	0.785	39.79	2.591
2008	–	1.286	25.00	4.356
2009	–	1.365	21.32	3.656
2010	–	1.263	29.45	3.587
2011	–	1.630	19.72	3.852
2012	–	0.856	21.55	3.432
2013	–	0.974	20.23	4.027
2014	–	2.077	23.24	3.152
		Super Areas 5+6		
2005	–	0.790	46.00	4.156
2006	–	0.868	44.98	3.978
2007	–	1.069	39.43	3.148
2008	–	1.357	46.01	4.912
2009	–	1.116	44.75	4.213
2010	–	1.382	48.46	4.144
2011	–	1.495	35.36	4.409
2012	–	1.413	37.97	3.989
2013	–	1.325	42.73	4.584
2014	–	1.329	43.52	3.708
		Super Area 7		
2005	0.673	–	31.60	3.249
2006	0.826	–	36.62	3.046
2007	0.501	–	36.96	3.305
2008	0.404	–	20.29	4.605
2009	0.636	–	14.41	2.983
2010	1.020	–	18.47	4.150
2011	0.355	–	30.12	4.220
2012	0.332	–	32.69	3.240
2013	0.448	–	26.25	3.243
2014	0.582	–	25.40	3.146
		Super Area 8+		
2005	0.982	1.103	23.78	2.633
2006	0.857	0.990	27.45	2.454
2007	0.770	0.864	29.17	1.624
2008	0.866	0.913	23.72	3.389
2009	0.871	1.054	23.44	2.690
2010	1.006	1.149	12.68	2.620
2011	1.028	1.050	19.30	2.885
2012	0.806	0.940	23.39	2.465
2013	0.596	0.778	22.95	3.060
2014	0.494	0.532	27.86	2.185

Table 11: The resource indices for each Super-Area calculated using the data in Tables 1a-e and the critical values below which the Exceptional Circumstances (EC) rule would be invoked.

Super-Area	The gear-combined index of abundance	The critical values below which EC would be declared
1+2	0.9	0.7
3+4	1.56	0.85
5+6	0.99	0.7
7	0.71	0.8
8+	0.9	0.7

fishers. Catches stabilised around 3 500–4 000 t until 1989 when the resource started to decline further. This decline in the resource continued during the 1990s and early 2000s and 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 CL to reduce mortalities resulting from discards of undersized lobsters. By 1996 catches 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 to rebuild the resource to more healthy levels (defined as pre-1990). The initial target for the Operational Management Procedure (OMP) developed in 1997 was to increase resource abundance to 20% above the 1996 level by 2006. By 2003, the resource had improved to 16% above the 1996 level. However, by 2006 resource abundance had decreased again dramatically to 18% below the 1996 level. This decline was due to recruitment failure and increased fishing pressure (increase in the number of nearshore right-holders) in the Long-Term Rights Allocation Process in 2003/2004. The commercial TAC was decreased by 10% for the following three consecutive seasons (2006/2007, 2007/2008 and 2008/2009) in an attempt to rebuild the stock to the new target of 20% above 2006 levels by 2016.

In 2013/2014 an interim approach (as a result of Exceptional Circumstances (ECs) being declared in Super-Area 7 (Figure 53) following a large decline in abundance there, and time constraints in completing a full OMP review) was developed to provide a TAC recommendation, which was consistent with the intent of the rebuilding plan inherent in 'OMP-2011'. While it was envisaged that this interim approach would be for one year only, various constraints precluded the finalisation of a new OMP in time for the 2014/2015 TAC recommendation. A revised interim approach was therefore used to provide the TAC recommendation for the 2014/2015 season. A new OMP (OMP-2015) was developed in 2015 to provide the scientific recommendations for TACs for the West Coast rock lobster resource for the 2015/2016 and following three seasons. The management aim for this resource was to rebuild the overall 2006 male biomass level by 35% in median terms by 2021 (i.e. B^{75m}(2021/2006) = 1.35).

Research and monitoring

Research and monitoring of West Coast rock lobster continues to provide and improve essential data inputs for assessing the sustainability of the stock, its management and setting annual catch limits for the fishery. Indices of abundance such as CPUE derived from the Fisheries-Independent Monitoring Survey (FIMS) and commercial catch statistics, annual assessments of somatic growth rate, and estimates of recreational and Interim Relief catch, are used as input data to the OMP assessment model.

Catch monitors record fishing effort and catch landed by commercial nearshore and offshore right-holders and Interim Relief fishers on landing slips after each fishing trip. Recreational catch is estimated from catch and fishing effort statistics reported during an annual recreational telephonic survey.

Growth of West Coast rock lobsters is monitored by tagging pre-moult male lobsters (>75 mm CL) 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 to derive abundance indices of sub-adult, legal-sized male and female (>75 mm CL) 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 fisheries-independent survey data and analysis methods have been recently re-checked, and changes in weather conditions have been identified as a source of variation in Catch Per Unit Effort (CPUE). The associated effects of changes in bottom oxygen, temperature and current speed on catch rates is also currently being investigated.

The OMP assessment model provides projections of future biomass under the assumption that future recruitment and growth will follow trends similar to those observed in the past. New research projects are being developed to provide indices of future recruitment, growth and catch to refine Operational Management Procedure (OMP) projections of future biomass. Studies on the recruitment of post-larval and juvenile lobster have been initiated to establish a long-term index of pre-recruit abundance that could 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 under investigation, to formulate energy-growth-reproduction conversion factors for predicting future trends in growth and reproductive potential.

Current status

Four indices are used as input data to the OMP in order to set the TAC. These are trap CPUE, hoop net CPUE, abundance estimates from Fisheries Independent Monitoring Surveys (FIMS) and somatic growth.

In 2013 results obtained from the analysis of these data indicated that the EC threshold had been breached for Super-Area 7 under the low abundance rule of the OMP, which necessitated a substantial TAC decrease in this Super-Area for the 2013/2014 season. In line with the OMP provisions, an immediate OMP review commenced together with updated assessments that took into account recent catches and revisions of poaching level estimates. These assessments confirmed that the status of the resource in Super-Area 7 was alarmingly low. Given the time constraints, a full revision of the OMP was not possible and an interim approach was developed and used

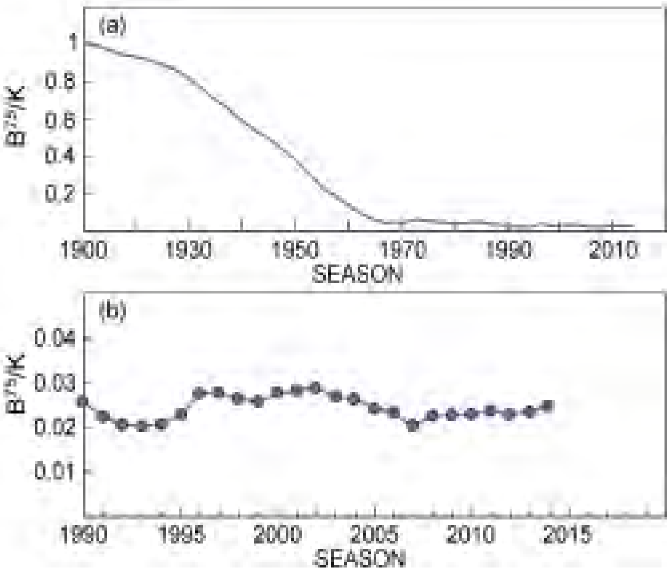


Figure 54: (a) Current biomass in relation to pristine or pre-fished (B75/K) values for the resource as a whole (i.e. summed over the five Super-Areas) and (b) values for 1990+ only

to provide the TAC advice for the 2013/2014 season. This approach led to the closure of Super-Area 7 to all lobster fishing, with two exceptions: (a) the continuation of the regular FIMS survey and (b) a programme of controlled offshore commercial fishing using traps (20 t per month for the four months starting in December and ending in March) under direct DAFF supervision of the Directorate. These restrictions were to remain in place until the monitoring provided clear evidence of substantial recovery in this Super-Area. The most recent resources indices calculated in OMP 2015 indicate that Super-Area 7 is still below the EC threshold (Table 10) and that the restrictions should remain in place for the 2015/2016 season. However, the resource in this Super-Area does appear to be recovering and it is possible that these EC restrictions could be lifted in the next season.

Application of OMP 2015 resulted in a Global TAC of 1 924.45 t for the 2015/2016 season, which represents a 6.83% increase from the 2014/2015 season.

Catch estimates reported from recent telephone surveys have indicated that the annual recreational catch has not decreased substantially since 2000, but rather remained in the vicinity of its estimated level for earlier years of some 300 t. However, over recent years there are indications of some catch decrease with catches in the 2011/2012 season estimated at 125 t. This is in line with the intended decrease in recreational catch brought about by a severe reduction in recreational season length.

The biomass of male West Coast rock lobster above the 75 mm CL minimum size limit is currently at 2.5% of pristine (pre-fished) levels (B75m/K =0.02.5) (Figure 54). If the recovery target of 35% is met, the resource biomass will increase to 4.8% of pristine by 2021. Every effort to reduce illegal harvesting, including substantially improved compliance with permit conditions for reporting of catches should be instituted to ensure responsible resource management and that resource rebuilding is not compromised.

Ecosystem interactions

Bycatch is not an issue of concern in this fishery. There are, however, negative interactions between lobster fishing gear (traps, ropes and buoys) and whales, with entanglements reported each season. The reported number of these incidences has reduced over the past few seasons as a result of an awareness programme directed at encouraging lobster trap fishers not to leave excess trap rope untied during fishing operations.

The general decline in lobster abundance (especially in shallow reef areas) and the distributional shift in the lobster population has been linked to the decline in the numbers and breeding success of the endangered bank cormorant (*Phalacrocarax neglectus*), which relies on lobsters as a major food source. In recent years there has been a major southward shift in lobster distribution including the movement of lobster into the area east of Cape Hangklip (or Zone F in Figure 53) with major implications for the benthic ecology in that area. Recent studies have shown that the situation in this area is stable with no further eastward movement.

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Useful Statistics

	TAC (t)					
Season	Global TAC	Offshore Allocation	Nearshore Allocation	Interim Relief	Recreational	Total Catch[3]
1998/1999	2 300	1 780			258	2 051
1999/2000	2 156	1 720		145	291	2 152
2000/2001	2 018	1 614		230	174	2 154
2001/2002	2 353	2 151		1	202	2 410
2002/2003	2 957	2 713		1	244	2 706
2003/2004	3 336	2 422	594	1	320	3 258
2004/2005	3 527	2 614	593	1	320	3 222
2005/2006	3 174	2 294	560	1	320	2 291
2006/2007	2 857	1 997	560	2	300	3 366
2007/2008	2 571	1 754	560	2	257	2 298
2008/2009	2 340	1 632	451	2	257	2 483
2009/2010	2 393	1 632	451	180	129	2 519
2010/2011	2 286	1 528	451	200	107	2 208
2011/2012	2 426	1 541	451	251	183	2 275
2012/2013	2 276	1 391	451	251	183	2 308
2013/2014	2 167	1 356	451	276	83.5	1 891
2014/2015	1 800.85	1 120.25	376.1	235.3	69.2	1 688

[1] No Interim allocated
[2] Interim relief accommodated under recreational allocation
[3] Total catch by all sectors

RESEARCH HIGHLIGHTS

Research on impact of ocean acidification

Figure 1: Experimental set up for ocean acidification research on West Coast rock lobsters at the Directorate Marine Research Aquarium of DAFF in Sea Point, Cape Town

Man-made release of carbon dioxide (CO_2) into the atmosphere since the industrial revolution has led to its increased absorption by the oceans. This has resulted in a shift in the seawater's bicarbonate system and, in turn, to a lower pH. Globally, there has been a decrease from a pre-industrial pH of 8.2 to a current level of 8.1. This decline seems small but, due to the logarithmic scale of pH, represents an acidification of 26%.

In contrast to other aspects of global change, like temperature change, this on-going process is well proven and is called Ocean Acidification (OA). Much lower pH levels are expected in the future. In addition to this global, long-term aspect of climate change, there are local phenomena that lead to a lowered pH. The Benguela Current Large Marine Ecosystem (BCLME) is one of the largest Eastern Boundary upwelling systems, with water parameters continually changing over the short term. Upwelling moves cold, low-pH seawater to the surface during summer and, in autumn, the decay of massive algal blooms leads not only to low-oxygen waters but also to very low pH levels for a few days in certain areas of the West Coast.

In general, the impact of OA on marine species could be positive or negative, or there could be no impact. In addition, responses to pH changes can vary between species within a genus, or even between populations of a single species. It is therefore necessary to investigate as many species as possible, because extrapolation is possible only to a limited extent.

The effect of OA will set in subtly and will be difficult to monitor – and to separate from other effects – in the field. Therefore, an experimental, laboratory-based approach at the Directorate Marine Research Aquarium in Cape Town was employed to investigate environmental impacts on individual marine animals. Our first experiments investigated the impact on marine animals of low pH alone. Later, low pH was tested in combination with changed seawater temperature.

Our research is aimed at providing important initial indications for fisheries scientists to aid in predicting potential threats to the particular resources, as well as future research directions in times of global and regional climate change.

So far, we have conducted experiments that measure the impact of lowered pH on the following species: West Coast rock lobster (WCRL), puffadder shyshark, abalone and Cape sea urchin. These experiments included short-term (acute) as well as long-term (chronic) trials. In this regard, acute trials reveal how quickly a species deals with short-term changes in pH and what physiological mechanisms it applies to adjust to the new situation. These short-term mechanisms often also play a role in long-term adjustment, if they can be maintained.

At present, we have gained the greatest amount of knowledge from our research on the WCRL. It was found that male adult WCRL rapidly and fully compensated for an extracellular acidosis caused by sudden hypercapnia (high pCO_2, causing

Figure 2: Sampling of haemolymph (blood) from a West Coast rock lobster (left) and instrumentation to measure pH (top right) and CO_2 (bottom right) in lobster haemolymph

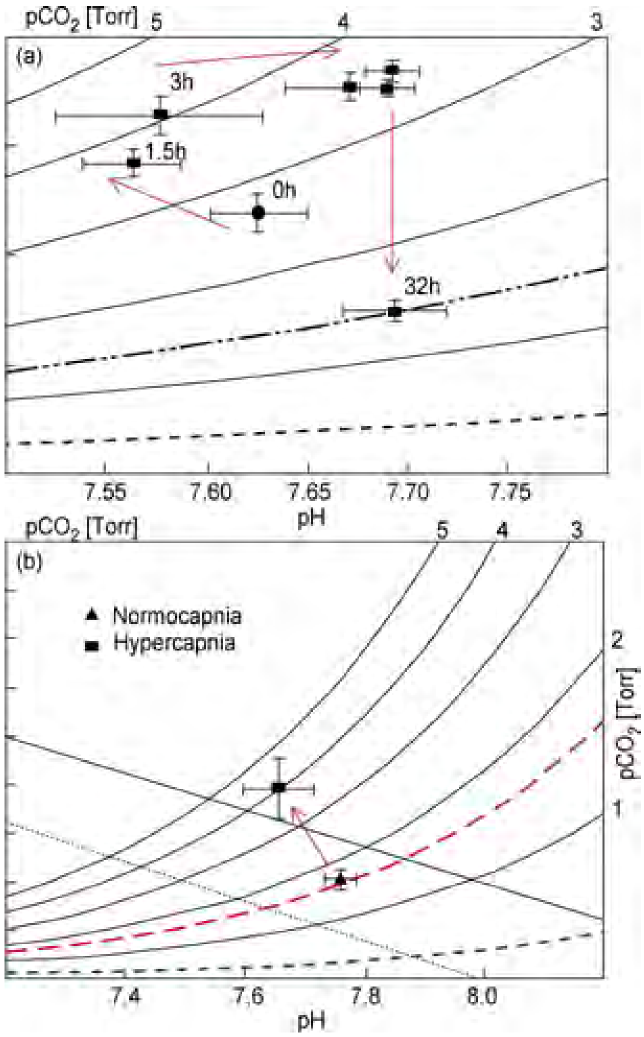

Figure 3: Regulation of the acid-balance in the haemolymph ("blood") of West Coast rock lobsters (WCRLs). (a) Short-term exposure of adult WCRLs to a lowered pH of 7.3: from an acid-base balance in "normal" pH of 8.0, shown as time point 0 h, lobsters undergo an acidosis when placed in low pH water. This is indicated by the arrow to the left within 1.5 h. Movement of data points upwards and to the right during exposure indicate active regulation by bicarbonate until the haemolymph is slightly alkaline (over-compensation). When the animal is returned to normal pH, bicarbonate levels drop and pH remains at the adjusted level (vertical arrow to the 32 h time point). (b) This regulation was also present during long-term acid-base regulation. When juvenile WCRL were exposed to pH 7.3 (hypercapnia) for 7 months, bicarbonate levels were increased (upwards arrow) and haemolymph pH remained close to that of animals that were kept in a normal pH of 8.0 (normocapnia)

lowered pH), such as experienced during severe upwelling events. This adjustment was achieved by a sharp increase in the bicarbonate levels in the haemolymph (the lobster's "blood") and was reversible. The increase protects the pH-sensitive oxygen-carrying capacity of the respiratory pigment haemocyanin under hypercapnic conditions, therefore equipping the species to deal with hypercapnic events that occur frequently in its habitat.

Not all crustacean species are capable of maintaining such an adjustment over a long period of time. Juvenile WCRL, however, can maintain this bicarbonate buffering of their haemolymph for several months of hypercapnia and can provide, therefore, optimum pH conditions for oxygen binding in the presence of a strong Bohr Effect (high sensitivity to lowered pH). More interestingly, the oxygen affinity of haemocyanin was improved by an intrinsic modification of its molecular structure. All these adjustments seem to have come at a cost. Growth was slightly decreased under hypercapnic conditions, indicating that there may indeed be a long-term risk for recruitment of the WCRL.

A preliminary study on the impact of acidification was also conducted on embryonic development in eggs attached to berried females. Egg growth was not affected, whereas there was a slight delay in embryonic development. During the berried period, females were also capable of maintaining their acid-base state. Furthermore, electron-microscopic observation showed that calcification of the exoskeleton was not affected.

Our results so far suggest that the WCRL is resilient to many aspects of climate change but such events could cause more damage in combination. Oxygen limitation, extreme temperatures and hypercapnia are occasionally experienced by WCRL along the West Coast. All or some of these conditions occurring together have been shown to limit aerobic (performance) scope and thermal tolerance in other crustacean species. In addition, vulnerability of the whole pelagic phase of the WCRL is completely unknown and very difficult to research. Yet, this life cycle stage is most likely the most vulnerable.

We have accumulated much less information from the other above-mentioned species so far. Preliminary results, however, indicate that puffadder shysharks efficiently compensate physiologically for short- and long-term exposure to low pH. Teeth and denticles (tooth-like structures on their skin) of sharks and rays consist of dentin (calcium phosphate), and, from human dentistry, it is known that acidic conditions are corrosive to dentin. Chemical analysis and electron microscopy revealed that shyshark denticles did indeed corrode in lowered pH conditions. Our data suggest that puffadder shysharks are physiologically adapted to adjust to rapid pH change, but not to the chemical effect of low-pH water on their external dentin structures, i.e. denticles and teeth.

South African abalone are not well equipped to deal with a declining pH, in either the short term or the long term. Internal pH cannot be adjusted in the way that it can in lobsters and sharks, and hence it remains low. In addition, the existing shell corrodes and formation of new shell material is reduced.

Preliminary results mentioned in this article are based on completed and ongoing BSc, BSc Honours, MSc and PhD theses of A Ritter, T Novak and J Dziergwa (Universität Düsseldorf), N Lester (UCT), and J Knapp (Stellenbosch University).

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Small-boat survey estimates of fish abundance around penguin breeding colonies and their contribution to understanding the mechanisms underlying the foraging behaviour of African penguins

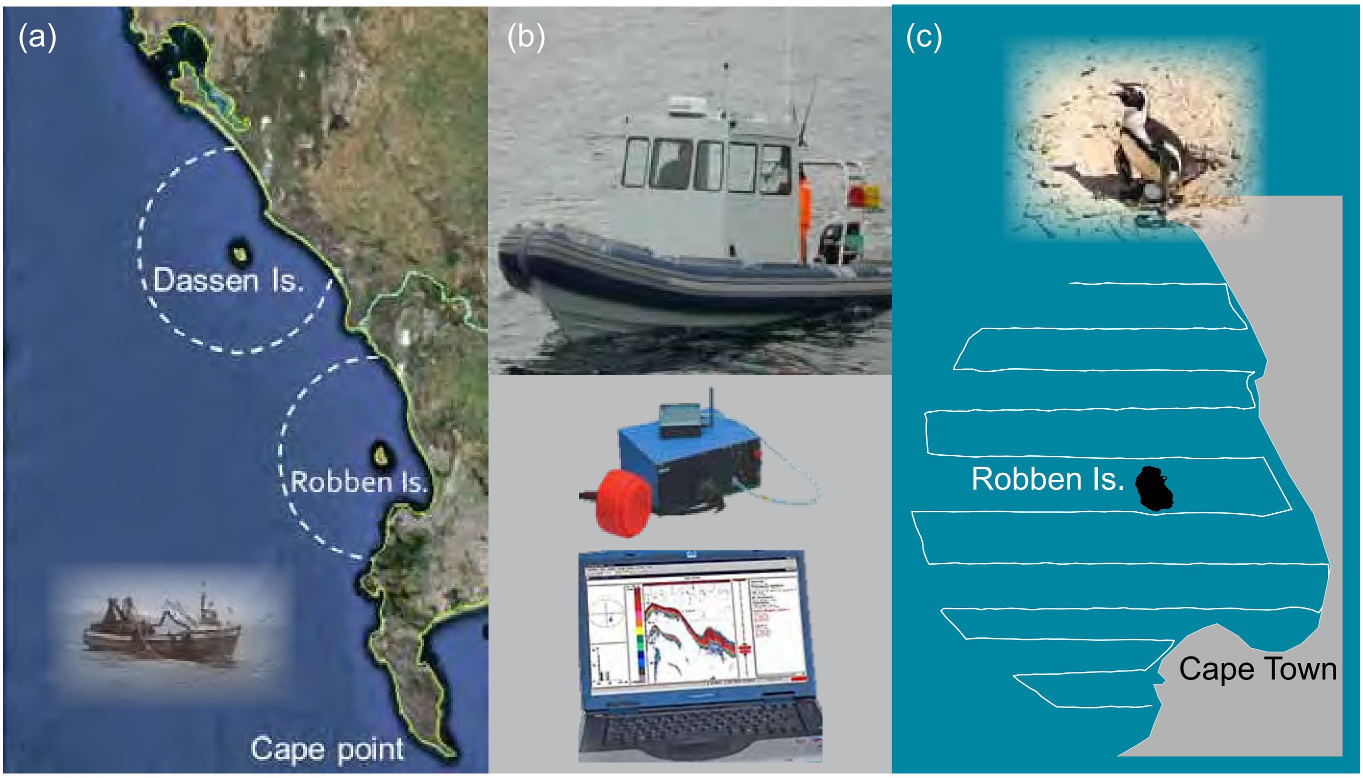


Figure 4: (a) The location and size (20 km radius around islands) of closed areas around Dassen and Robben Islands on the West Coast, (b) the survey vessel and equipment and (c) the survey design used

African penguins provisioning (feeding) chicks during their breeding season need a regular and abundant supply of fish in close proximity (<30 km) to their island nests, failing which breeding success may be compromised. Anchovy and sardine make up the bulk of the endangered African penguin's diet, so it is reasonable to suspect that there is the potential for South Africa's industrial-scale small-pelagic fishery, harvesting billions of these fish every year, to threaten the regular food supply of these and other vulnerable seabirds.

Given the rapid decline in African penguin numbers since the mid-1990s, a programme of fishery closures around sensitive penguin breeding-colony islands was initiated in 2008. This initiative, known as the Island Closure Feasibility Study, entailed alternating closures to fishing around pairs of islands off the West Coast (Robben and Dassen Islands, Figure 4) and in Algoa Bay (St Croix and Bird Islands). The study aimed to determine whether or not an experiment would have a reasonable chance of detecting effects of closure to pelagic fishing for a number of key penguin demographic metrics. This is an important step in the design of a future experiment and is essential because longer-term closures around islands are likely to be disadvantageous to the fishing industry.

One of the inputs required for evaluating the feasibility of a future experiment is knowledge of the availability of forage fish around the islands. It has long been speculated that measurements of fish abundance obtained during routine large-scale surveys are only "snap-shots" of fish availability at the time of the survey and are not representative of the availability of forage fish throughout the penguin breeding season. Establishing the extent to which large-scale survey biomass estimates and distribution patterns reflect conditions throughout the penguin breeding season is therefore important. This requires dedicat-

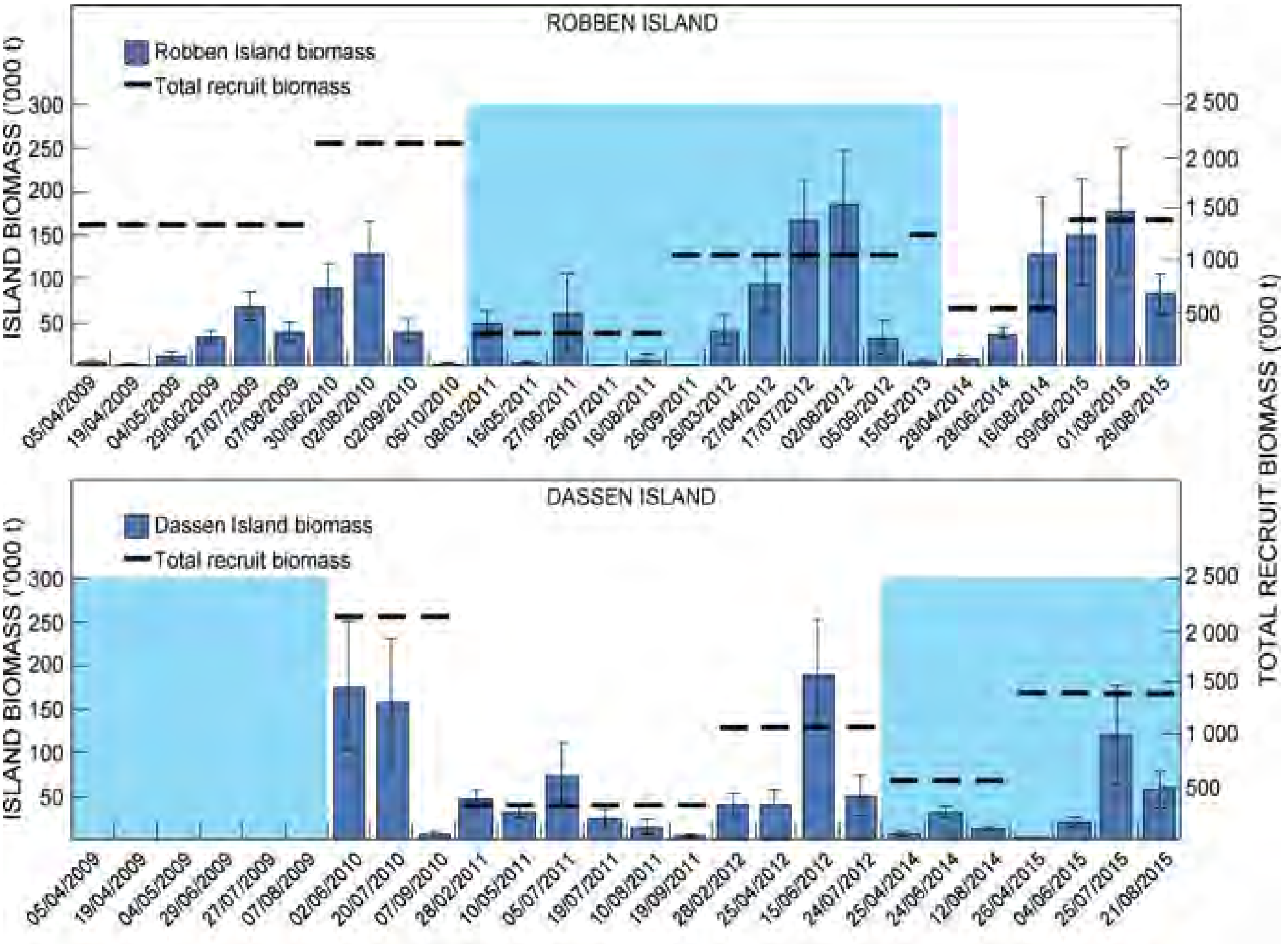


Figure 5: Timeline of biomass estimates derived from small-scale surveys around Robben (top panel) and Dassen (bottom panel) islands since 2009 (bars). Also shown is the total recruit biomass estimate from large-scale surveys conducted annually during May/June of each year (dashes). Shaded areas represent periods in which a particular island was closed to fishing. Note that only dates on which surveys were conducted are shown

ed hydro-acoustic surveys to be conducted regularly around penguin breeding colonies, at a higher spatial resolution than typically is possible during routine annual biomass surveys.

A small inflatable boat equipped with a scientific-grade echo-sounder has therefore been used to conduct these surveys since 2009, and a total of 58 surveys around the four Islands have since been completed. Of these, only 9 surveys were conducted around St Croix (6) and Bird Island (3) as the logistics associated with conducting regular surveys in Algoa Bay were impractical to sustain. The surveys were designed to cover an area of 20 km radius around each island (the size of the area closed to fishing, Figure 5) at least once a month during April-September, the penguin breeding season. Unfortunately, however, monthly surveys were not always possible and were often postponed as a result of adverse winter weather conditions, equipment failure or other logistical constraints.

The timeline of surveys conducted around Robben (29 surveys) and Dassen Island (20 surveys) shows that, despite the paucity of observations in some years, there is a general pattern in which the biomass around a particular island increases gradually from the start of each year as the annual migration of pelagic fish recruits moves southwards, peaking in June/July, before decreasing to a minimum by August/September as the recruits move out of the region towards the Agulhas Bank (Figure 5). These surveys have also shown that, once

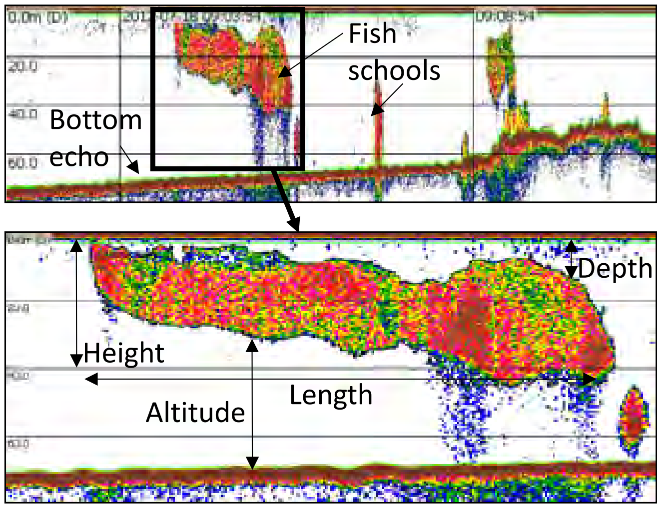


Figure 6: Echograms showing (top panel) fish schools, the bottom echo and illustrating different-sized and -shaped schools, and (bottom panel) some properties extracted from individual schools

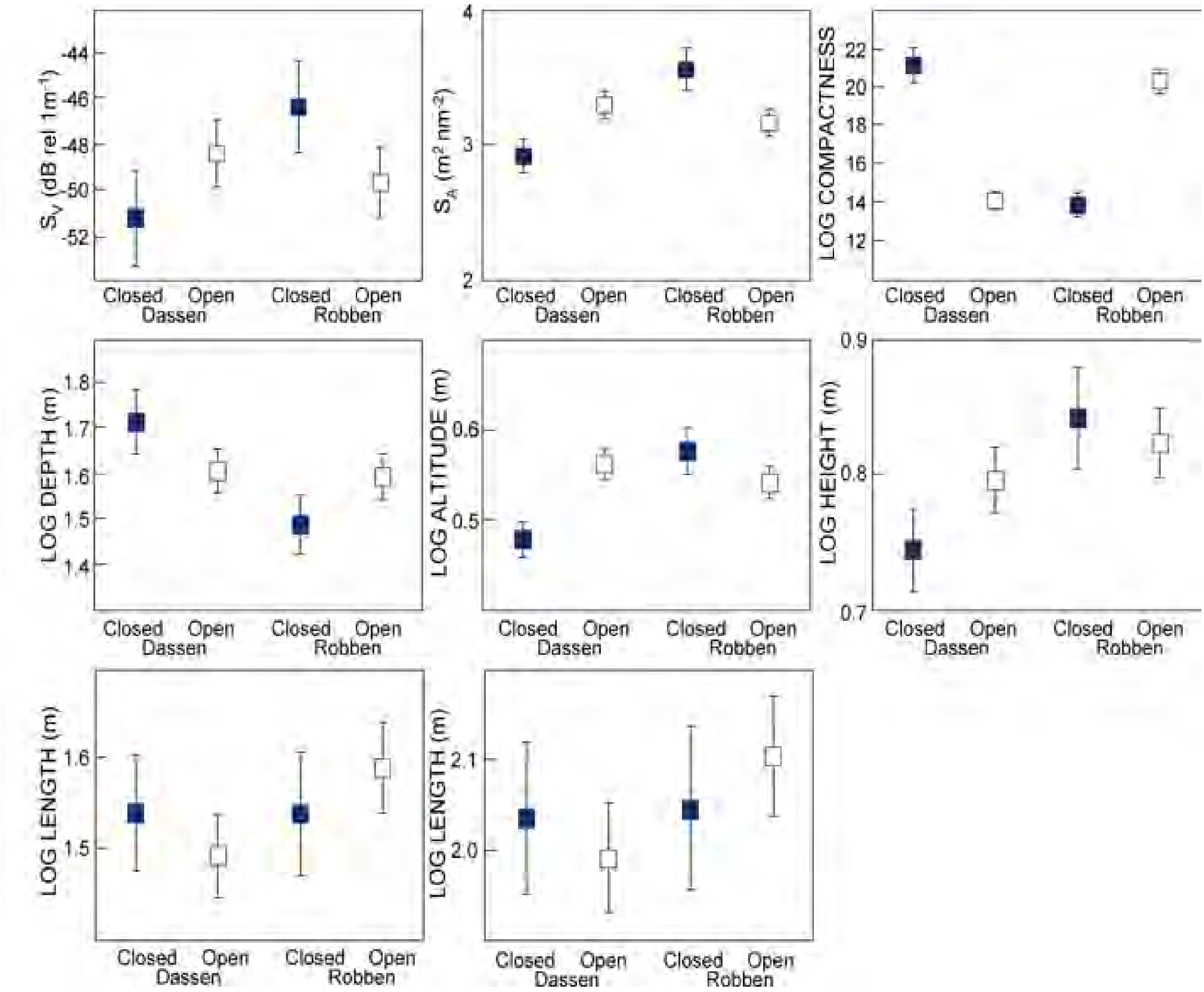


Figure 7: Comparison of mean school descriptors between open and closed periods for Dassen and Robben islands. Error bars represent confidence intervals of the means (SE 1.96). All means are significantly different (*t*-test, independent samples, $p < 0.05$) between closed and open periods

the anchovy and sardine recruits become available to penguins around these West Coast islands, there is a consistently high biomass available in very close proximity to the islands over the peak of the breeding season (June/July), irrespective of closure status. These results are compatible with the assumption that penguins from Dassen and Robben islands experience similar food environments in any year and are likewise significantly correlated with annual recruit survey estimates ($r = 0.47$). Unfortunately, however, without being able to increase the frequency of these small-scale surveys, the large sampling variances observed render them less precise than the annual large-scale recruit surveys and raises the question of whether they add value to the closure study.

Despite this drawback, additional outputs from this small-scale survey programme are proving to be useful in understanding: (i) how fish availability affects foraging behaviour; (ii) whether there are differences in fish shoaling behaviour between islands; and (iii) how fish shoaling behaviour might be influenced by fishing. In particular, the question of whether or not the act of fishing disrupts fish shoaling behaviour may be key to the interpretation of results from the closure programme. Preliminary evaluation of the results from the feasibility study indicated both positive and negative effects of closure on penguin-response variables. Whereas positive effects of closure are more readily accepted, negative effects from the absence of fishing are not. One explanation offered in support of the latter is that fishing breaks up large schools into many small schools, possibly making fish more vulnerable to predation by increasing the rate at which penguins encounter fish schools.

To investigate this hypothesis, school-identification algorithms were used to extract fish-school information from the echograms recorded during the small-scale surveys (Figure 6). Variables describing the size, shape, density and position of fish schools in the water column (i.e. depth below the surface and height above the seabed) were compared between open and closed periods for each island.

When comparing means of school descriptors between islands, schools around Dassen Island are denser (volume density, S_V and area density, S_A) and have a greater vertical extent (height) during open years, but are deeper in the water column, closer to the bottom (lower altitude) and have a larger perimeter and an increased compactness index during closed years (Figure 7). This pattern switches around for schools found around Robben Island. Here the density of schools is lower and they occur deeper in the water column and closer to the bottom during open years, whereas descriptors of school size and shape increase during closed years. The location of schools in the water column is likely to influence foraging success as penguins generally are limited by the maximum depth at which they can feed successfully and, in addition, because they attack schools from below, they will be disadvantaged by schools located close to the bottom. Penguins are also likely to forage more successfully on irregularly shaped (high compactness), small schools than on dense and highly organised (low compactness) large schools in which predator defence mechanisms are optimised.

The facts that shoaling behaviour appears to differ between closed and open periods, and that the direction of change in shoaling response to closure status changes between islands, are novel findings that are likely to complicate further the interpretation of results from the island closure study. Notably, these findings may even lend support to the rather contradictory hypothesis that the act of fishing actually aids penguin foraging!

Review of fisheries resource assessments

A recently published paper by de Moor et al. (2015) provides a review of the assessments of 11 important South African marine fish resources, each as evaluated in the period 2012–2013. The resources are abalone, anchovy, Cape hakes, chokka-squid, horse mackerel, kingklip, monkfish, Patagonian toothfish, sardine, South Coast rock lobster and West Coast rock lobster. These assessments are quantitative evaluations of the resources' status. Status is calculated in terms of current size of the resource as it relates to historical levels. It also involves the calculation of a resource's productivity, i.e. its annual growth, which is the amount that can be harvested sustainably (Figure 8). The outputs from these assessments are essential for determining appropriate management actions to ensure that exploitation of the resources is sustainable.

The assessment models applied vary in complexity, driven mainly by the data available for each resource. Relatively simple biomass-based models are applied to those resources for which limited data are available. More complex age- and/or length-structured models are applied to the resources for which such data are available in addition to indices of abundance obtained from fisheries-dependent data (catch rates from commercial fisheries) and/or fisheries–independent data

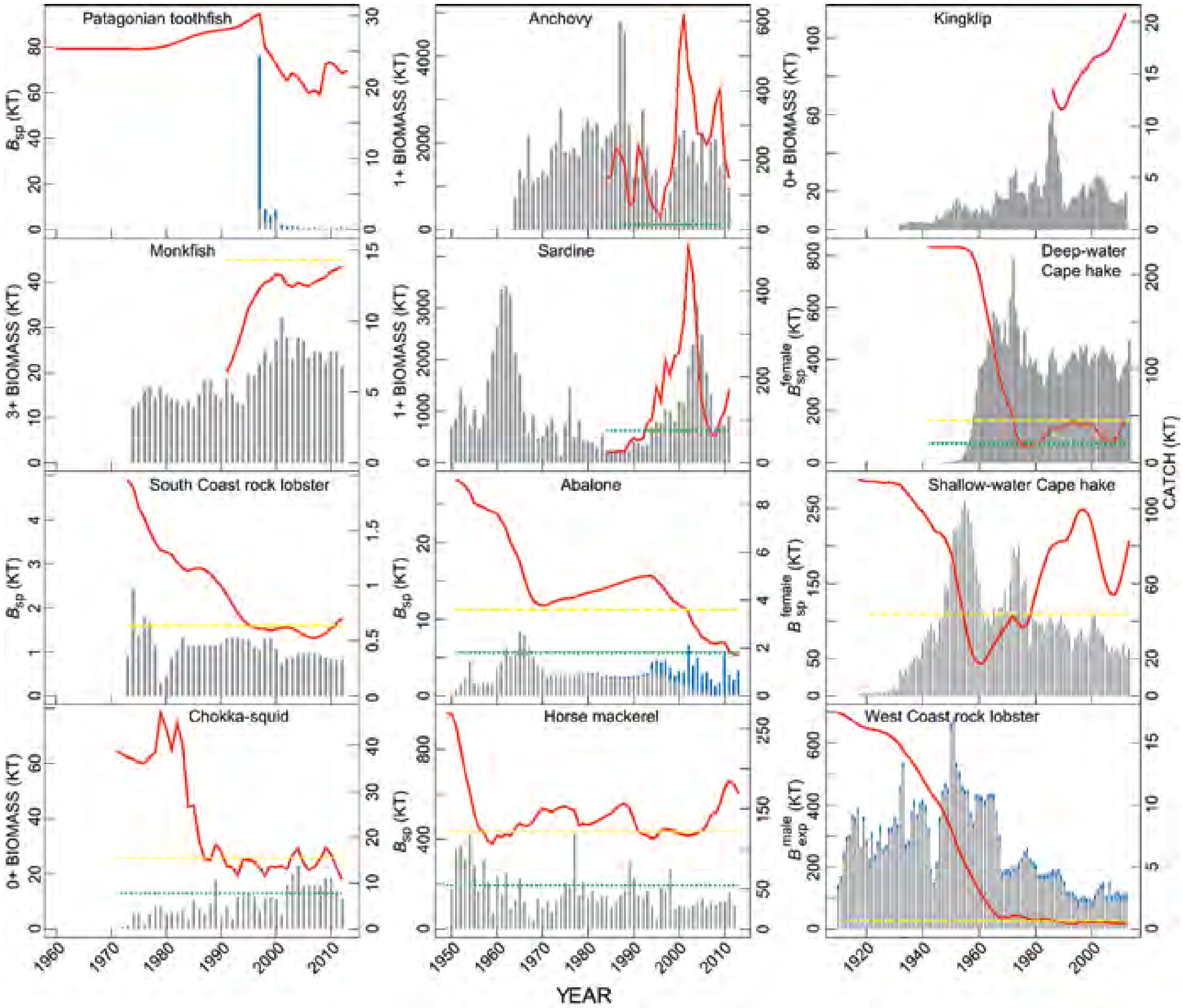


Figure 8: Time-series of baseline assessment-estimated resource biomass (line, left axis of each plot) and observed catches (columns, right axis) for the 11 resources (where hake is then split into species) reviewed. For assessments conducted by sex and/or area, the aggregated biomass is plotted. The dark stacked bars for abalone and West Coast rock lobster represent estimated IUU catches. Current target reference levels (level of biomass at which management is aimed) are indicated by dashed lines and limit reference levels (level of biomass that management wishes to avoid) by dotted lines. Units are given in 1 000 t (KT) (Reproduced from *African Journal of Marine Science* (2015) 37: 285–312 with permission © NISC (Pty) Ltd)

(from research surveys).

For example, monkfish is a relatively data-limited resource found on both the west and south coasts of South Africa. The only data available are annual catches and fisheries-independent estimates of abundance since 1991. These estimates are a by-product of research surveys designed to estimate hake abundance, which also provide estimates of abundance for those species taken as bycatch in the hake fishery, such as monkfish, kingklip and Agulhas sole. The simplest form of a biomass-based model, called a Replacement Yield Model, has been used to recommend catch limits that will maintain current levels of monkfish abundance.

On the other hand, the two species of Cape hake are data-rich. Annual catches are available from each of the sectors that harvest hake: offshore and inshore trawl, handline and longline. Multiple fisheries-dependent and -independent estimates of abundance are available for different overlapping periods commencing in the mid-1950s. These, together with information on the length structure of catches, sometimes disaggregated by sex, as well as age-at-length data in some years, provide information on the age structure and growth dynamics of the population. A complex sex-, age- and length-structured assessment is therefore applied to Cape hakes. As some data cannot be separated by species, a single model is used to assess both species simultaneously in a way that allows these data also to be incorporated in the analyses.

A key challenge facing fisheries assessments is that scientists do not have perfect knowledge about resource dynamics. For example, it is not possible to know with certainty how many fish die annually from natural causes or as a result of illegal catches.

The four most frequently encountered uncertainties in the assessments reviewed relate to: (i) the stock-recruit relationship; (ii) illegal, unregulated and unreported (IUU) catches; iii) natural mortality; and iv) the number of stocks that make up a particular fish population.

Recruitment refers to the entry of young fish into the population. A stock-recruit relationship defines the relationship between spawners and recruitment. Various functional forms exist to describe this relationship. In some of the assessments reviewed it was found that the functional form chosen and the extent to which recruitment is assumed to vary inter-annually impacts estimated future productivity substantially.

IUU catches, by their very nature, are difficult to quantify accurately and thus introduce substantial uncertainty in the assessments of some resources. IUU catches of abalone and West Coast rock lobster – known locally as poaching – have resulted in appreciable reductions in the abundances of these resources. While IUU catches of toothfish are known to have occurred in the past, no IUU activity has been reported since 2004.

The assessments for sardine and anchovy are sensitive to the assumptions made relating to natural mortality. There may have been changes in natural mortality over time. However, such changes cannot be estimated with an acceptable level of precision given data currently available. Toothfish are subject to an additional cetacean predation mortality, which is difficult to quantify; this occurs when large marine mammals remove fish from longline hooks.

There is uncertainty about the stock structure of particularly sardine, kingklip and monkfish. This arises from the presence of spawning aggregations on both the west and south coasts of South Africa. In addition, there are some differences in the survey abundance trends for kingklip and monkfish on each coast. Coast-specific assessments are therefore conducted for these two species as a precautionary measure, since the possibility of multiple stocks cannot currently be discounted. Sardine, on the other hand, has historically been assessed as a single stock. Multi-stock hypotheses are currently being explored. The single- and multi-stock hypotheses provide rather different perceptions of sardine stock status and productivity.

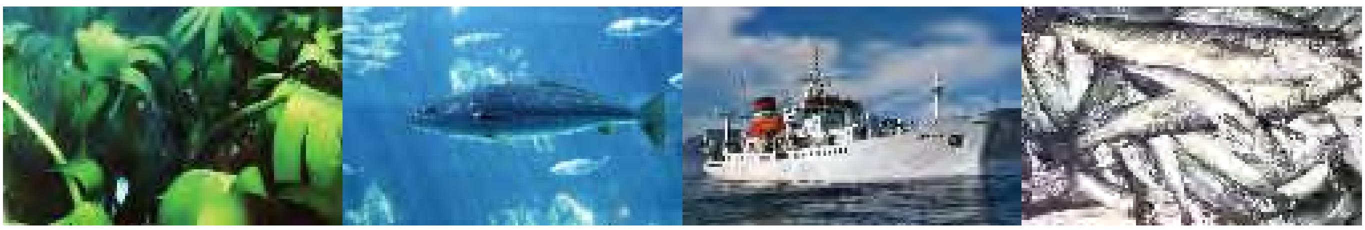
The sensitivity of assessment results to key uncertainties is often evaluated by running assessments with different assumptions for the uncertain factors. Management advice regarding appropriate levels of harvesting must take into consideration such uncertainty in the status and/or productivity of a resource.

The assessments reviewed indicate the statuses (relative to historical levels) of anchovy, Cape hakes, chokka-squid, horse mackerel, sardine and South Coast rock lobster to be reasonable to good. Those of kingklip, monkfish and Patagonian toothfish cannot be estimated with the information currently available. The statuses of abalone and West Coast rock lobster remain poor. For West Coast rock lobster, this is probably the consequence of a combination of poor recruitment during the early and middle decades of the last century and IUU fishing. The poor status of abalone is attributed primarily to continued unsustainable levels of IUU fishing, as well as poor recruitment in two areas since the early 1990s following additional predation that resulted from an invasion of lobsters.

Reference

de Moor CL, Johnston SJ, Brandão A, Rademeyer RA, Glazer JP, Furman LB, Butterworth DS. 2015. A review of the assessments of the major fisheries resources in South Africa. *African Journal of Marine Science* 37: 285–311.

This timely publication of de Moor et al. (2015) links to data provided to versions 2.5 and 3 of the RAM Legacy database (www.ramlegacy.org). This database comprises a compilation of stock assessment results for commercially exploited marine populations from around the world. The user-friendly website provides graphical displays of time-series by region (e.g. South Africa) or stock, as well as spreadsheets containing the underlying key assessment parameter values and outputs.



Notes