STATUS OF THE SOUTH AFRICAN MARINE FISHERY RESOURCES 2012

Department of Agriculture, Forestry and Fisheries

Foreword

South Africa has a long history of excellence in marine science, including in research and applied research relating to the management of marine living resources. The success of the latter depends on the endeavours of a dedicated group of scientists and technicians, many of whom have specialized in the fisheries biology and/or stock assessment of particular groups of resources. They collect data at sea and on the coast, provide reports and advice based on analyses of the data, and participate in the activities of Scientific Working Groups.

The scientific advice is considered when setting Total Allowable Catches and Total Allowable Effort levels for the all sectors of fisheries including the commercial, recreational and small-scale fisheries. The research conducted supports the implementation of the Ecosystems Approach to Fisheries Management (EAF) that South Africa has committed itself to at the 2002 World Summit on Sustainable Development. EAF as defined by the Food and Agriculture Organization of the United Nations (FAO) 'strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries." A primary implication is the need to cater both for human as well as ecosystem well-being. In essence it merges two paradigms: protecting and conserving ecosystem structure and functioning; and fisheries management that focus on providing food, income and livelihoods for humans.

South Africa is considered internationally to be leaders in the field of EAF and is one of the few countries that regularly does Ecosystem Risk Assessments (ERAs) for its important fisheries. The ERAs attempt to facilitate inputs from all stakeholders and find solutions to threats to sustainability.

The fisheries sector in South Africa is worth around six billion rand per annum and directly employs, in the commercial sector, some 27 000 people. Thousands more and their families depend on these resources for food and the basic needs of life. Within the context of food security, regular scientific work to understand the dynamics of these resources and the provision of reasonably accurate assessments of their status, is therefore important for information-based management to ensure that these resources can be utilized sustainably. Research remains one of the key components of the overall fisheries management system which includes resource management and monitoring, control and surveillance. The main challenge in fisheries remains creating a balance between maximizing the social and economic potential of the fisheries sector while protecting the integrity of the country's marine ecosystem.

For several years now, the Department has produced a report on the status of the key resources. Initially this was intended only for internal use, but it has been recognized that there is widespread interest in this information, not only among scientists and fisheries managers, but also among the many fisheries stakeholders, including the general public. More attention has therefore been given to preparing a user-friendly, easily readable report with some interesting facts and trends that can be made available publicly.

I would like to thank the hardworking scientists and technicians of the Department – the people who do the hard legwork of research project planning, fieldwork and surveys, analysis and reporting, whilst not always having adequate resources to their disposal. Well done for another year!

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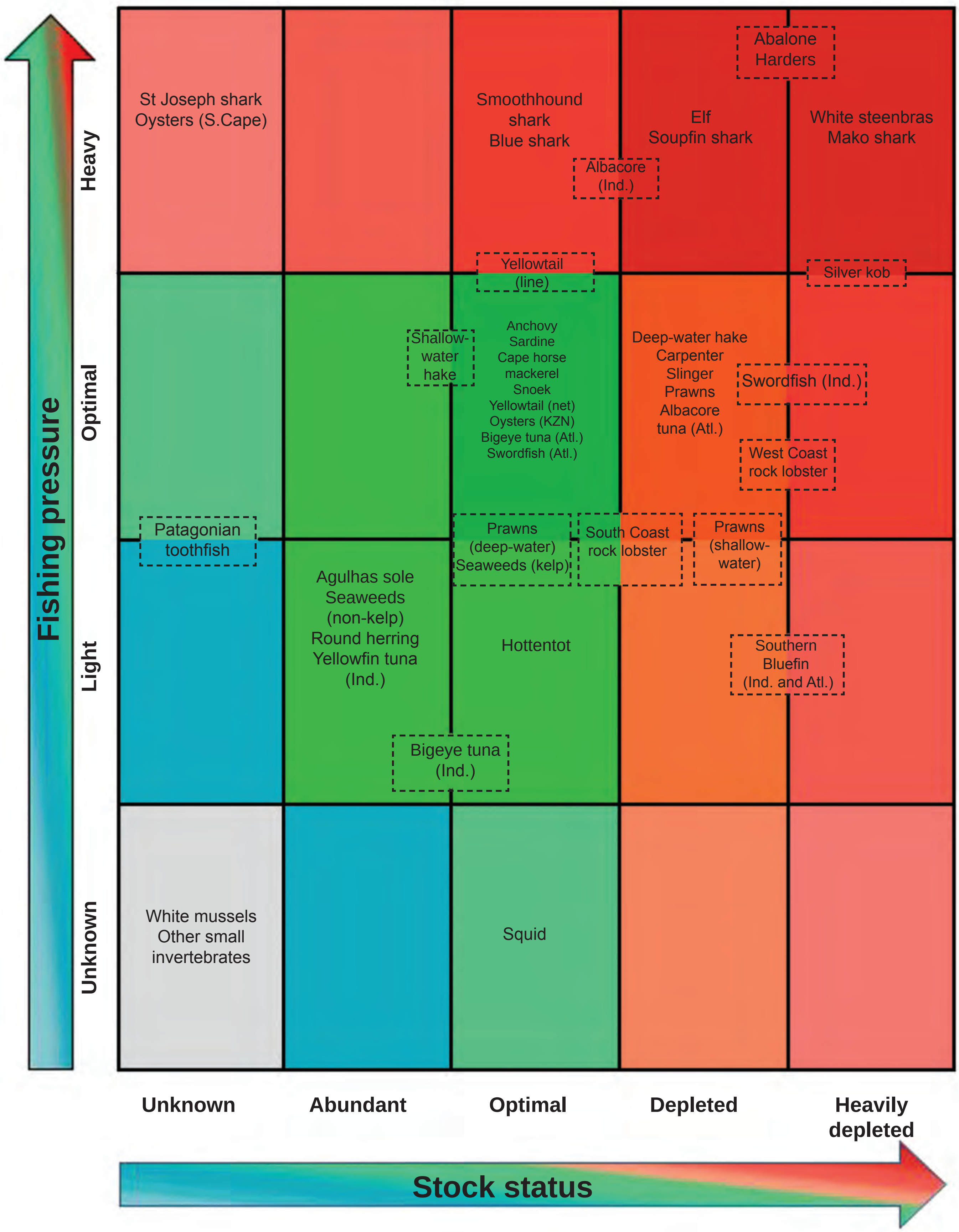
Acronyms and abbreviations

ASPM	Age-structured production model
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPUE	Catch per unit effort
DAFF	Department of Agriculture, Forestry and Fisheries
EEZ	Exclusive economic zone
FIAS	Fishery-independent abalone survey
FIMS	Fisheries-independent monitoring survey
GIS	Geographic information system
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICSEAF	International Commission for the South East Atlantic Fisheries
IUCN	International Union for Conservation of Nature
IOTC	Indian Ocean Tuna Commission
IUU	Illegal, unreported and unregulated (fishing)
KZN	KwaZulu-Natal
LMP	Linefish management protocol
MCM	Marine and Coastal Management
MLRA	Marine Living Resources Act
MPA	Marine protected area
MSY	Maximum sustainable yield
NLS	National linefish survey
NMLS	National marine linefish system
NRCS	National Regulator for Compulsory Specifications
NPOA	National Plan of Action
OMP	Operational management procedure
PMCL	Precautionary management catch limit
PUCL	Precautionary upper catch limit
RFMO	Regional fisheries management organisation
ROV	Remotely operated vehicle
SWIOFP	South West Indian Ocean Fisheries Project
TAB	Total allowable bycatch
TAC	Total allowable catch
TAE	Total allowable effort
TURF	Territorial use rights in fisheries
WWF	World Wide Fund for Nature

Executive summary

- This report presents the most up-to-date information and analyses of the status of the marine living resources in 17 fishery sectors in South Africa.
- The general trend of deteriorating resource status with accessibility continues, with near-shore resources more accessible and likely to be overexploited than resources farther offshore.
- The commercial fishery for abalone was reopened in 2010 after being closed in 2008, but this resource continues to decline due to increasing levels of poaching, and remains in a depleted to heavily depleted state.
- The abundance of Agulhas sole has remained relatively constant over the past 15 years and this resource is considered to be abundant, and undercatching of the total allowable catch (TAC) in recent years is primarily due to a reduction in effort.
- Deep-water hake remain depleted but the status of this resource is improving, whereas shallow-water hake are considered optimal to abundant. The implementation of precautionary management approaches in the hake fishery in recent years has resulted in a faster-than-anticipated recovery of deep-water hake.
- Cape horse mackerel have increased in abundance in recent years due to good recruitment, and the stock is considered to be in an optimal state.
- Linefish resources range from heavily depleted to optimal states depending on species, but there are signs of a positive response (increased catch per unit affort [CPUE]) of some species to the emergency management measures implemented in 2000. Given the low population sizes of many linefish species, however, present management measures need to remain in place for sufficiently long so as to allow stock sizes to increase.
- Harders, which are the main target of the beach-seine and gillnet fisheries, remain in a depleted to heavily depleted state. Increased illegal netting in some areas, and environmental anomalies that have negatively impacted recruitment in recent years, are likely to retard recovery of this species.
- Oyster resources in KwaZulu-Natal are considered to be in an optimal state and optimally utilised. A paucity of suitable data for oysters in the Southern Cape means that their status in this region is unknown, but their overexploitation, particularly in the intertidal zone but also in subtidal ‘mother beds’, is cause for concern.
- The status of Patagonian toothfish remains unknown although some data suggest that this resource is depleted and may be declining, and the TAC for 2011/2012 has been reduced by 20%.
- Prawn resources are considered to be in an optimal (deep-water) to depleted (shallow-water) state, with optimal to light fishing pressure. Continued low catches of shallow-water prawns are attributed to recruitment failure.
- The status of seaweeds ranges from optimal to abundant and fishing pressure from optimal to light. Kelp is regarded as optimally exploited in most areas but underexploited in some, whereas other seaweeds are considered underexploited.
- Sharks range from heavily depleted to optimal states, depending on species. High shark bycatch in other fisheries remains a major concern.
- Small pelagic resources are in optimal or abundant states and fishing pressure is optimal to light. Recruitment of all three species was relatively low in 2011 and the anchovy stock is at the lowest level observed during the past 15 years, but sardine and round herring stocks continue to increase.
- South Coast rock lobster is in an optimal to depleted state, fishing pressure on this resource is optimal to light and catches are stable.
- The status of the squid resource is considered optimal and catches in this fishery remain high. Uncertainties in CPUE data make it difficult to assess fishing pressure, but the total allowable effort (TAE) has remained unchanged for the past five years.
- Tuna resources range from heavily depleted to abundant in status depending on species and region, and swordfish are considered to be in an optimal state. Fishing pressure on tuna and swordfish is mostly light to optimal.
- There are some signs of recovery of the heavily depleted to depleted West Coast rock lobster resource under the current operational management procedure, but reducing illegal harvesting is critical to ensuring that stock rebuilding is not compromised.
- Despite steeply increasing harvests of white mussels in recent years a continuing paucity of data means that the status of and fishing pressure on this, and other small invertebrate resources, remains unknown.


Fishing pressure
Heavy
Optimal
Light
Unknown
St Joseph shark
Oysters (S.Cape)
Smoothhound shark
Blue shark
Albacore (Ind.)
Abalone
Harders
Elf
Soupfin shark
White steenbras
Mako shark
Yellowtail (line)
Silver kob
Shallow-water hake
Anchovy
Sardine
Cape horse mackerel
Snoek
Yellowtail (net)
Oysters (KZN)
Bigeye tuna (Atl.)
Swordfish (Atl.)
Deep-water hake
Carpenter
Slinger
Prawns
Albacore tuna (Atl.)
Swordfish (Ind.)
West Coast rock lobster
Patagonian toothfish
Prawns (deep-water)
Seaweeds (kelp)
South Coast rock lobster
Prawns (shallow-water)
Agulhas sole
Seaweeds (non-kelp)
Round herring
Yellowfin tuna (Ind.)
Hottentot
Southern Bluefin (Ind. and Atl.)
Bigeye tuna (Ind.)
White mussels
Other small invertebrates
Squid
Unknown
Abundant
Optimal
Depleted
Heavily depleted
Stock status

About the report

The purpose of this report is to make available information related to the current status of South Africa's major exploited marine living resources, and largely reflects the work of the Scientific Working Groups of Fisheries Research and Development up to and including 2011. Scientific Working Groups comprise both internal (i.e. Fisheries) and external (fishing industry associations, non-governmental organisations, etc.) parties who are appointed biannually to evaluate available data to assess the status of the fish stocks and make recommendations regarding the sustainable utilisation of South Africa's marine living resources. The Working Groups are also responsible for prioritising and directing research on the fisheries and/or target species with which they deal, primarily to increase the accuracy of the status assessments but also to improve understanding of the biology, ecology, population dynamics and other life-history attributes of exploited species.

This report is organised on a resource-by-resource basis, with the following information provided for each resource:

Quick-view assessment — This appears at the beginning of each section, is colour-coded for ease of reference, and provides an indication of stock status and fishing pressure. In contrast to the 2010 Status of the South African Marine Fishery Resources report, which provided only a single measure ranging from 'Underexploited' to 'Overexploited' and included a "Status uncertain" category, two measures are used in the 2012 report, each of which refers to a distinct, and different, attribute. The first, as the name suggests, indicates the present status of the resource, which is something than cannot be managed directly as it is the result of a combination of different pressures over time, including fishing and environmental fluctuations. The second measure indicates the present level of fishing pressure exerted on that resource, which is something that can be managed directly. The aim of sustainable management is to have resources that are in an optimal state and that are fished at optimal levels. However, historical overexploitation may have reduced some stocks to depleted or heavily depleted levels, and rebuilding of these stocks would 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 and natural recruitment fluctuations. Additionally, short-lived species (e.g. anchovy and squid) typically show high levels of recruitment variability that can result in substantial interannual fluctuations in population size; these could lead to that resource's status changing from being depleted in one year to being optimal the next. Five categories are defined for stock status, ranging from 'Abundant' through to 'Heavily depleted', and including an 'Unknown' category for which there are insufficient or conflicting data to enable an estimate to be made. Four categories of fishing pressure are defined, from 'Light' through 'Optimal' to 'Heavy', and again including an 'Unknown' category for data-poor resources. The definitions used to assign a resource to a status 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	

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

Whilst MSY is the target for optimal utilisation, recognised by the United Nations Law of the Sea Convention and other related legal instruments, in practice it is either or both difficult to define (particularly for resources that show substantial natural fluctuations) and to estimate for many stocks. This necessitates the use of proxies for specifying both B_{MSY} and F_{MSY} in many cases, and a number of conventions are used internationally towards this end. Typically, the criterion used here has been the Schaefer model assumption that B_{MSY} is 50% of the pre-exploitation abundance, though that is adjusted in cases where the assessment of the resource indicates a lower value. 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.

Introduction — A brief introduction to the resource, providing salient information on its biology, ecology, and other aspects.

History and management — A description of the history and management of the fishery for that resource.

Research and monitoring — A more detailed description of pertinent research (including previous research and possibly future planned research), how the resource is monitored and the data collection processes used in such monitoring, and what information is used to assess resource status.

Current status — Provides an in-depth assessment of the current status of that resource and, where available, projections for the future of that resource or the fishery it supports.

Further reading — Lists some references that are pertinent to either the resource or the fishery it supports.

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 <20 m depth, but the highest densities occur in waters <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 along the East Coast. Historically, the resource was most abundant in the region between Cape Columbine and Quoin Point, where it supported a commercial fishery for almost 60 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, harvesting of abalone along the East Coast was allowed for a number of years through the allocation of experimental permits and subsistence exemptions. The recreational sector also targeted abalone for many years, but due to the decline in the resource, this component of the fishery was suspended in 2003/2004.

Once a lucrative commercial fishery, earning up to approxi-

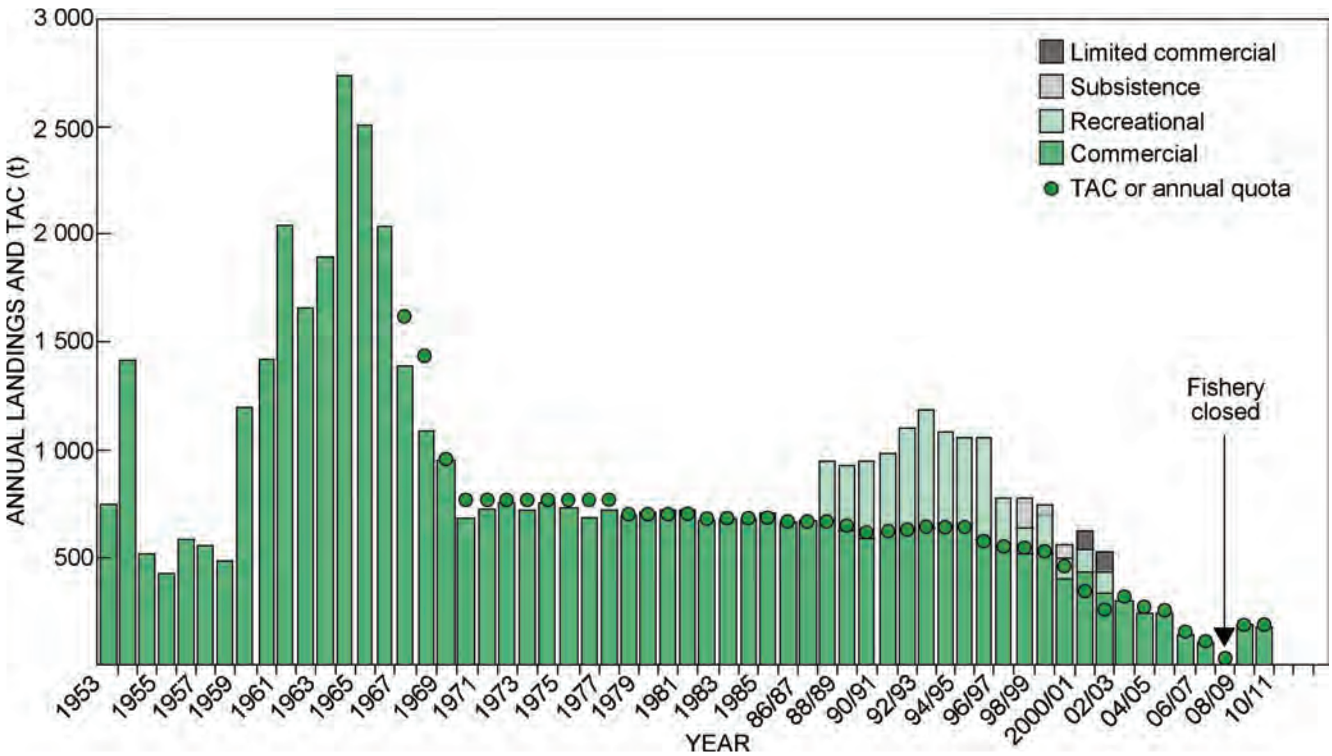


Figure 1: Total allowable catch (TAC) and recorded (legal) annual landings for the abalone fishery from 1953 to 2010/2011. Landings for the recreational sector are only available since 1988/1989. Note that the substantial recent illegal catches are not shown

mately R100 million annually at the turn of the century, rampant illegal harvesting and continued declines in the abundance of the resource resulted in a total closure of the fishery in February 2008. The resource has also been heavily impacted by an ecosystem shift that was brought about by the migration of West Coast rock lobster into two of the main, most productive abalone fishing areas.

The commercial fishery subsequently reopened in July 2010. Controlled experimental fisheries for abalone are currently being undertaken in False Bay and the Eastern Cape Province - areas that are not presently part of the commercial fishery. The purpose of these experiments is to determine the spatial distribution and abundance of the resource and whether these areas may be viable for sustainable fisheries in the future. The experiments are planned to run over a period of 3 seasons, and although there were delays in the date of implementation commenced in October 2011 in False Bay and in June 2012 in the Eastern Cape. A 12 t experimental catch has been allocated per season on the eastern side of False Bay, from Cape Hangklip to the Steenbras River, which is further split across 3 sub-areas. A 31.5 t experimental catch has been allocated per season in the Eastern Cape, and split across seven areas ranging from the Groot River to Dwesa. Sub-area catch allocations are in place to ensure that the experiment does not overly deplete the resource in any one particular area, and to ensure the geographical coverage necessary to provide answers to the questions.

History and management

The 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 almost 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 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 a 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 regard 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 through listing of South African abalone on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

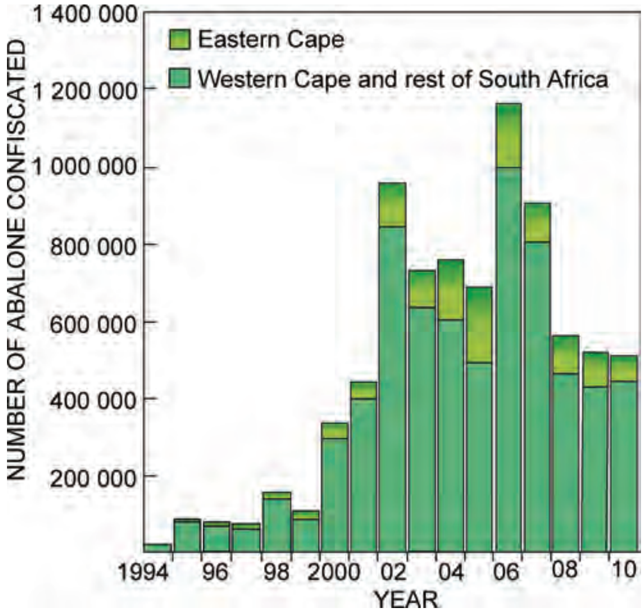


Figure 2: Number of abalone confiscated annually from 1994 to 2010

Confiscations of illegally caught abalone increased rapidly from the turn of the century, with a record high of more than one million abalone being confiscated in 2006 (Figure 2). It is estimated that an average of around 14% of all poached abalone are confiscated, and this can be used to estimate the total number of abalone caught illegally. It is thus estimated that the illegal catch of abalone far exceeded the commercial catch (by as much as 10 times) over the past decade.

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 almost two-thirds of confiscated abalone is below the minimum legal size of 11.4 cm SB. Therefore, most of the illegally caught abalone is 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 total allowable catch (TAC) allocations that were conditional on an appropriate reduction in poaching. This was based on the management objective for the sustainable utilisation and recovery of the abalone resource to prevent the abalone spawning biomass in each zone from dropping below 20% of its estimated pre-exploitation level (a ‘limit reference point’), and to see it recover to 40% of that level (a ‘target reference point’) within 15 years, i.e. by the 2024/2025 season.

Research and monitoring

Data from both the fishery and 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. Twenty fixed-line transects are surveyed annually 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 3). Surveys are also undertaken around Dyer Island. The number and size of all abalone >100 mm shell length are recorded to provide an index of abundance. Recruitment surveys were undertaken annually from 1988 to 1993 and provided evidence of an ecosystem shift, with a decline in urchins and juvenile abalone in some areas, and a simultaneous increase in the abundance of West Coast rock lobster.

The illegal sector is monitored by sampling confiscated abalone to obtain estimates of poaching trends and total illegal catch per zone. In the last assessment, additional data on poaching trends was sourced from TRAFFIC (the wildlife trade monitoring network), the Department of Agriculture, Forestry and Fisheries (DAFF): Compliance section, and Seawatch.

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, FIAS and catch-at-age information inferred from catch-at-length data. 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 inspection of trends in CPUE, size composition data and research survey data, where available.

Priority research areas for the future include extending the full population surveys geographically and with depth, 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. A repeat of the joint Marine and Coastal Management (MCM, now DAFF)/industry survey that was undertaken in 2002 is being planned to confirm whether recruitment of juvenile abalone is still at similar (low) levels as factored into past and current assessments. A further improvement in illegal catch estimates is also a priority requirement and a review of the decision rules used for the assessment of the resource in the fishing zones along the West Coast (Zones E–G) is also being planned.

Figure 3: Abalone fishing zones A - G with TURF sub-zones indicated

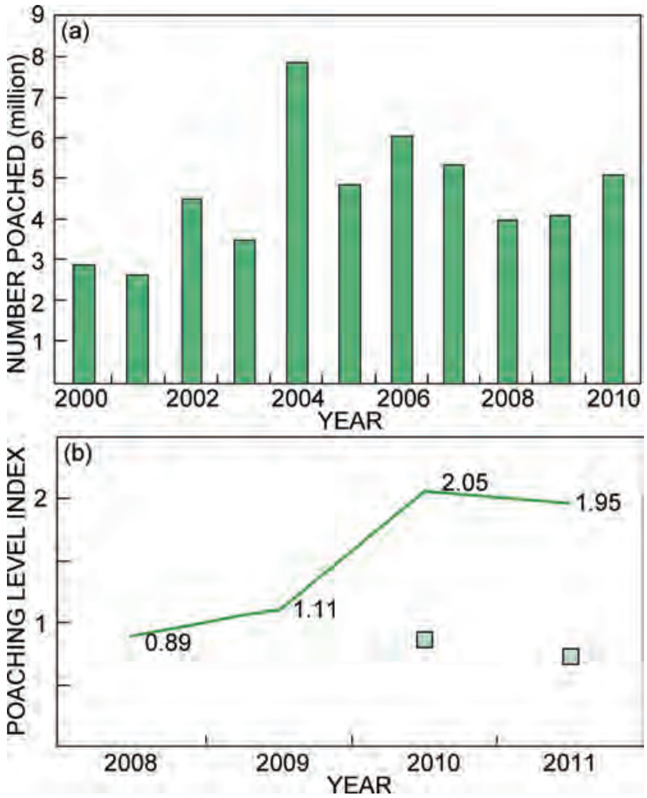


Figure 4: Poaching trend estimates, based on (a) international trade data on imports of abalone into key importing countries, with the estimated number of abalone poached for the period 2000–2010 shown and (b) a GLM analysis of the DAFF: Compliance data for the Western Cape, showing the poaching level index as the ratio of the number of confiscations and abandonments to policing effort for all zones, normalised to the 2008 and 2009 (model year) average ratio. The squares reflect the 15% annual decrease in poaching sought under the current abalone recovery plan

Current status

Zones A and B

The recommendations of a TAC of 50 t in Zones A and B for the past two seasons were conditional on a 15% per annum reduction in poaching at that time (the average of estimates for 2008 and 2009 model-years). In the absence of any reduction in poaching, projections indicated that resource decline would continue even without any commercial catch.

Poaching levels were estimated from three indicators. The

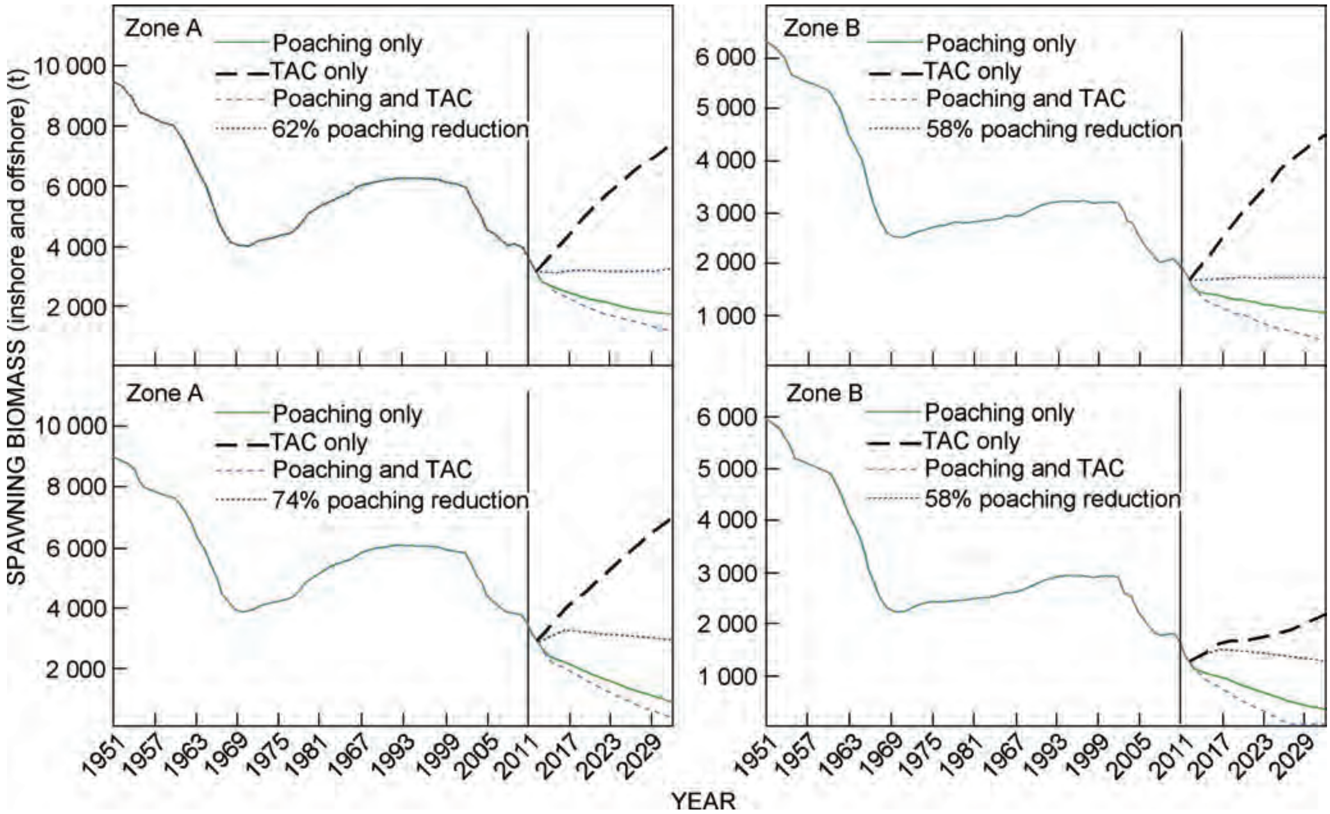


Figure 5: Total (inshore + offshore) spawning biomass trajectories shown for Zones A and B. The 20-year projections shown (after the vertical bar) represent four different scenarios of future commercial and poaching catches. Unless set to zero, future poaching levels are assumed to remain at the estimated current level (average of 2010 and 2011) and future commercial catches are set to the current TAC of 50 t in each zone. The top two plots show projections when no Allee effect is taken into account, whereas the bottom two plots include an Allee effect. The first projection scenario (solid line) assumes that poaching remains at current levels and a zero TAC is allocated. The additional three scenarios are included to illustrate spawning biomass trajectories if: (i) the current TAC remains allocated but poaching were to be completely stopped (bold dashed line), (ii) the current TAC remains allocated and poaching continues at current levels (dashed line) and (iii) the required reductions in poaching necessary to keep the resource stable at its present level under the current TAC, with the required reductions shown in the legends, i.e. to meet a sustainability objective, though not the resource recovery objective (dotted line)

first, using international trade data from TRAFFIC, estimated that the number of abalone poached in 2010 was 26% greater than the annual average over the previous two years (Figure 4a). The trade data for 2011 were not available in time for this analysis. It is important to note that these estimates are conservative because the records used only reflect consignments that are declared as abalone. They do not include consignments of abalone that are declared as something other than abalone. These amounts are not known and are assumed constant over the years. The second indicator, using the DAFF: Compliance data for the Western Cape, estimated an approximate doubling in poaching over the past two years (2010 and 2011) compared to the average for 2008 and 2009 (Figure 4b); results are similar for Zones A–D and for Zones E–G. The third indicator, using records of the number of abalone and lobster poaching incidents (combined) from Seawatch, indicated that poaching from Rooiels to Kleinmond was about 25% higher over the last two years compared to the previous two-year average. All three methods indicated increases in the level of poaching since the last assessment.

It is important to recognise that these increases have taken place despite an increase in policing effort by the DAFF Compliance Section. Available estimates show increases in policing effort, covering all zones, by this section over the past two years amounting to almost 40%. It seems that despite the increased compliance effort, the resources available to them for policing have proven inadequate to achieve the desired reduction in poaching.

Current spawning biomasses and future projections are shown in Figure 5. Viewed overall, the results of the 2011 assessment do not suggest any major revisions to perceptions of resource status and future trends under current poaching levels to those from the previous assessment in 2009. Results show spawning biomass projections of continuing resource decline at current estimated levels of poaching (the average of 2010 and 2011 estimates). Model results with an Allee effect included show even more pessimistic projections. The Allee effect is a reduction in reproductive efficiency that occurs at low densities. The review by the international assessment panel in 2009 noted that an Allee or depensation effect on abalone recruitment at low densities is a plausible scenario and should be evaluated by including a critical depensation effect in sensitivity tests (and used as the basis for projections). Current diving surveys show that on average, over a 30×2 m transect, only three abalone >100 mm shell length are found.

In summary, the management objective of a 15% per annum reduction in the level of poaching was not achieved – instead all estimates suggest increases in poaching since the last assessment. As a result, under current estimates of poaching, spawning biomass projections show continuing declines in the status of the abalone resource. Zero commercial catch allocations were recommended in each of these zones for the 2011/2012 season.

Zones C and D

Spawning biomass projections based on current estimates of poaching show continuing declines in resource abundance in these zones. The resource there is severely negatively impacted by both poaching and the incursion of West Coast rock lobsters into the area which has had a negative effect on abalone recruitment. Continued commercial catch allocations of zero were recommended for each of these zones for the 2011/2012 season.

Zones E–G

Based on an inspection of the commercial catch and survey data, and application of a set of decision rules in the 2011 assessment, no change to the current catch allocations was proposed for these zones for the 2011/2012 fishing season.

Therefore, allocations of 12, 20 and 18 t were proposed for Zones E, F and G respectively for the 2011/2012 season. It should be noted that the basis for setting the catch levels for Zones E–G is not as scientifically robust as for Zones A–D and there is consequently a greater associated uncertainty/risk of either over- or underfishing in these zones. In addition, there are indications of increases in poaching in this region over the past two years that are currently not included in the decision rules. Furthermore, recruitment of juvenile abalone in this area is sporadic and resource productivity in these zones has historically been much lower than in the South Coast zones (A–D) and therefore Zones E–G have been subjected to a lower commercial fishing pressure than Zones A–D in the past.

Further reading

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Agulhas sole

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

Introduction

Agulhas or East Coast sole *Austroglossus pectoralis* are referred to as flatfish because they lie on the seabed on their sides. During larval development, both eyes migrate to one side of the head, and 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. Although distributed primarily in depths of between 10 and 120 m, they have occasionally also been caught in deeper water during research surveys (Figure 6). The maximum total length has been documented as 58 cm, but the average size caught during research surveys over the period 1985–2011 is 25 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

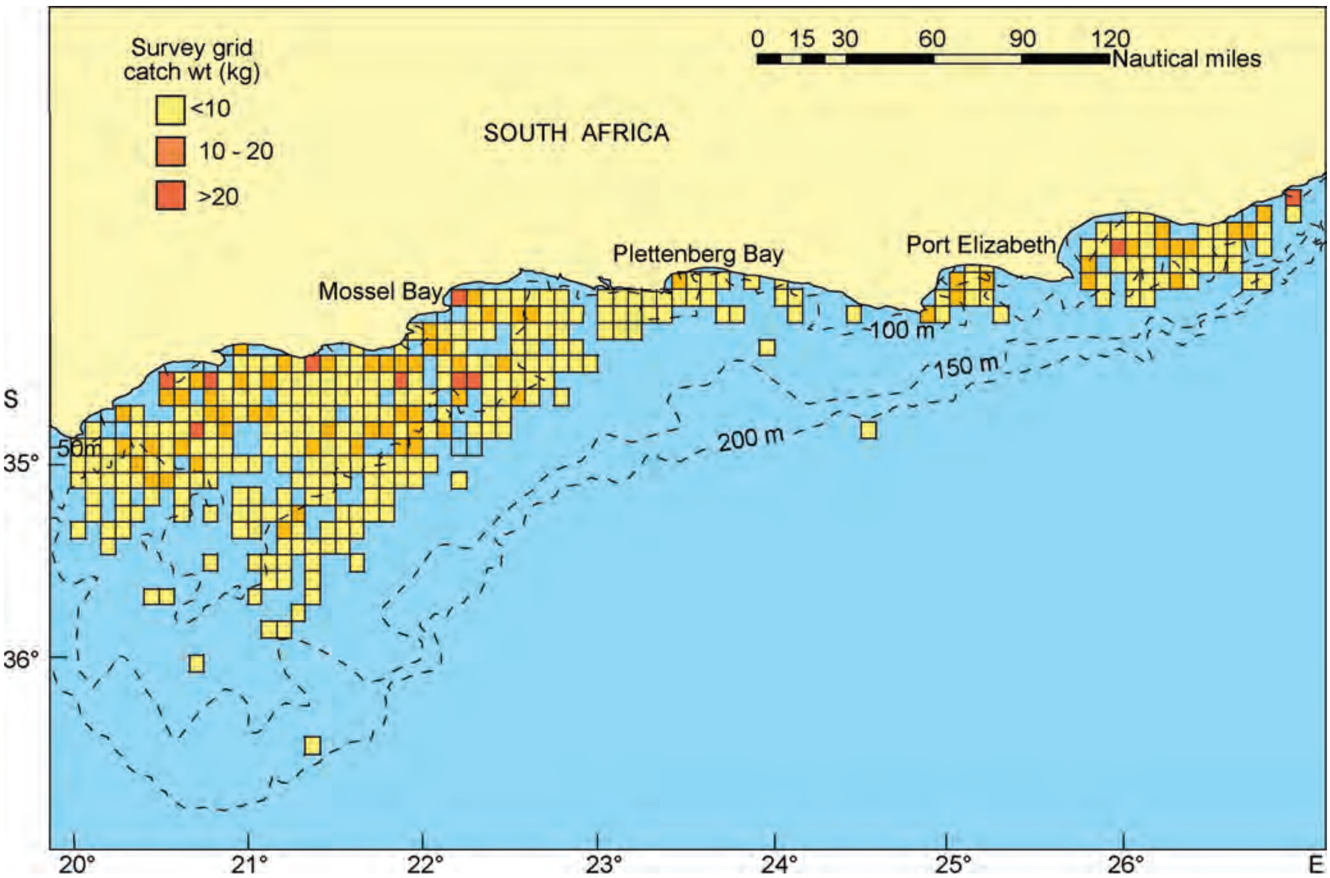

Figure 6: Distribution of Agulhas sole catches during research surveys conducted over the period 1985–2011

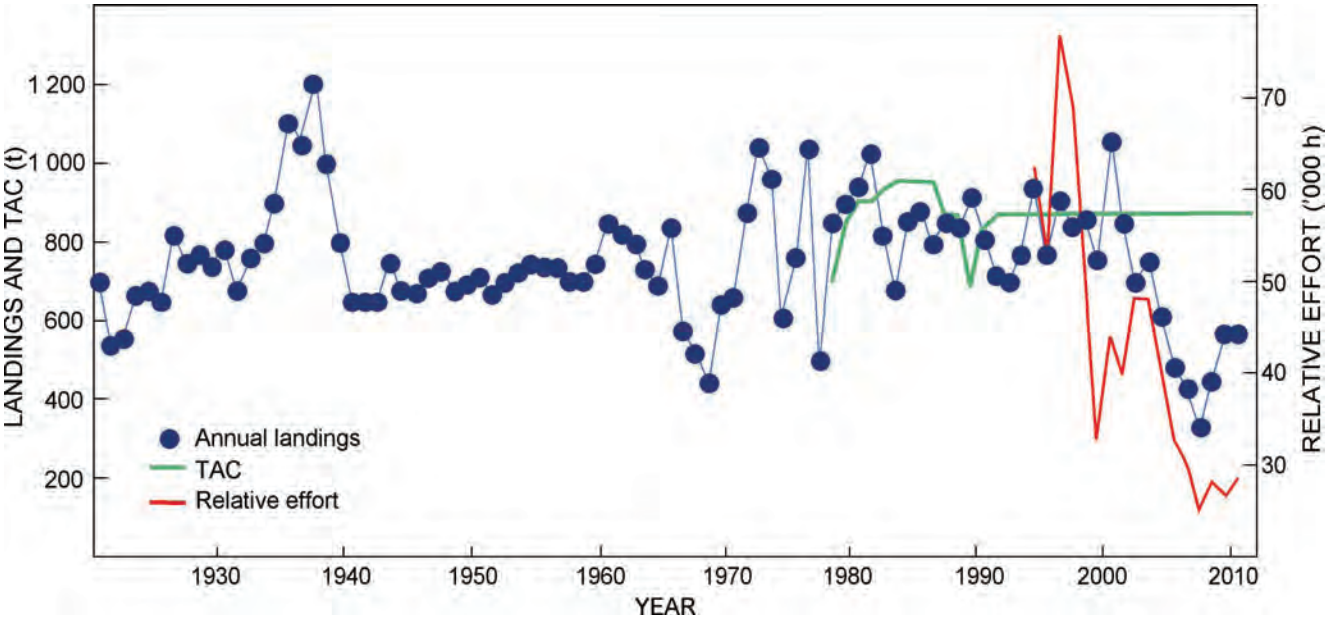

Figure 7: Annual landings, TAC and relative effort for Agulhas sole on the South-East Coast of South Africa, 1920–2010. Relative effort is calculated as the total landings of the fishery divided by the CPUE of the sole-directed vessels

target the sole resource (the remainder of the fleet either targets primarily hake or a mixture of both hake and sole). The annual sole TAC (if caught) is currently worth approximately R36 million.

History and management

The Agulhas sole resource has been fished since the beginning of the last 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.

Several factors have influenced the performance of the inshore trawl fishery over the years: the fishery has shifted from targeting Agulhas sole in the 1930s to targeting several species from the late 1970s; management interventions such as the introduction of a global quota system in 1978; individual quotas in 1982; stricter enforcement of the mesh size regulation; boat limitation; fleet rationalisation; closure of certain (nursery) areas to fishing to protect juvenile Agulhas sole; and, more recently, the prevention of within-season trading in quotas.

Agulhas sole catches per calendar year (since 1920) and the TAC (since 1978) are illustrated in Figure 7. It is important to draw a distinction between calendar year catch (as used in assessment models) and quota year catch (used for resource management purposes), as part of the allocation for a 'quota year' has in recent years occasionally been taken at the beginning of the following calendar year. Consequently, catches within a calendar year that are above or below the TAC in Figure 7 do not necessarily reflect over- or undercatch of the TAC. For example, the fleet was tied up for five months in 1999 and was subsequently allowed to hold catches taken before March 2000 against their 1999 allocations, resulting in the catch in the 1999 calendar year being below the TAC and the catch in 2000 above it. Similarly, management action in response to an overcatch of the 2001 allocation resulted in 37 t of the TAC being withheld and contributing to the apparent undercatch in 2002.

Although annual catches have generally been between 600 and 900 t, there is substantial interannual variability in the time-series (Figure 7). This variability is thought to be driven primarily by environmentally-induced fluctuations in Agulhas sole availability, linked to strong north-west fronts. The decline in catches over the period 2003–2007, however, is primarily attributable to a reduction in the number of active vessels in the sector, which is manifested as a decline in fishing effort (illustrated by the 'relative effort' in Figure 7). The reduction in the number of active vessels in the fishery has arisen from companies not replacing old/damaged vessels, the reasons for which are primarily attributable to the high costs of replacing vessels in a volatile industry (there have been substantial adjustments in this sector following the implementation of the Long-Term Rights Allocation Process in 2006) and recent changes in market incentives. The increase in fishing effort and resultant catches apparent over the past three years suggests that this situation is improving.

The first concerted 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. An annual TAC of 700 t was first introduced in 1978, and individual quotas

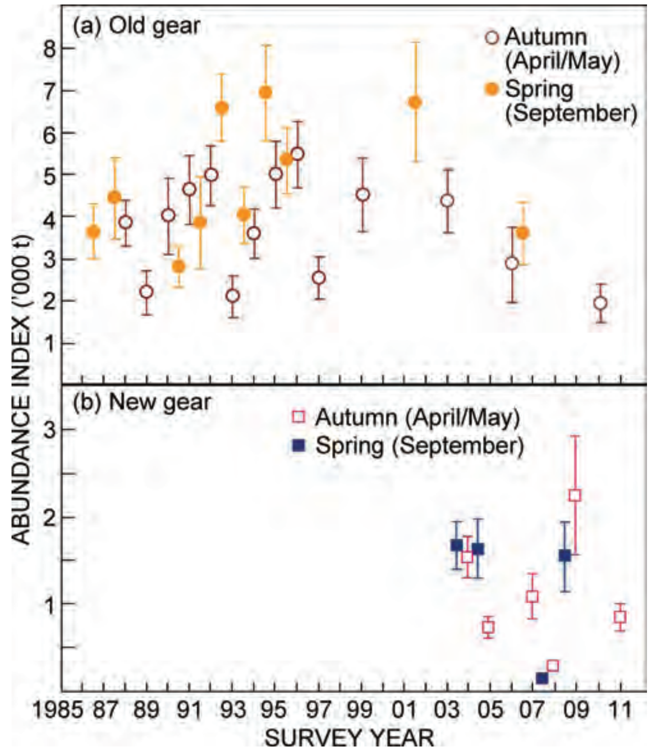

Figure 8: Survey abundance estimates (with 95% confidence intervals) for the Agulhas sole resource on the South-East Coast of South Africa. The time-series are illustrated separately for estimates obtained with the old and new trawl gear configurations

were introduced in 1982. The TAC remained fairly stable thereafter, varying between 700 t and 950 t between 1982 and 1992, after which the TAC has been maintained at 872 t (Figure 7).

The current management objective for the sole fishery is to maintain a stable TAC, provided that there is no indication that this is depleting the resource. Attention is being directed at developing a refined assessment to determine whether this TAC might be increased while still remaining sustainable.

Research and monitoring

Abundance estimates for Agulhas sole are derived from demersal research surveys using the swept area method. These surveys are designed primarily to estimate the abundance of hakes, but other demersal species (including Agulhas sole) are also included in the research. South Coast demersal abundance surveys were generally conducted twice a year (autumn and spring) over the period 1986 to the present (Figure 8). However, for technical reasons, only one survey per year was completed in 1996, 1997, 1999, 2001, 2005, 2009, 2010 and 2011, and none in 1998, 2000 and 2002. The trawl gear on the research ship (RS *Africana*) was changed in May 2003 and 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 8.

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.

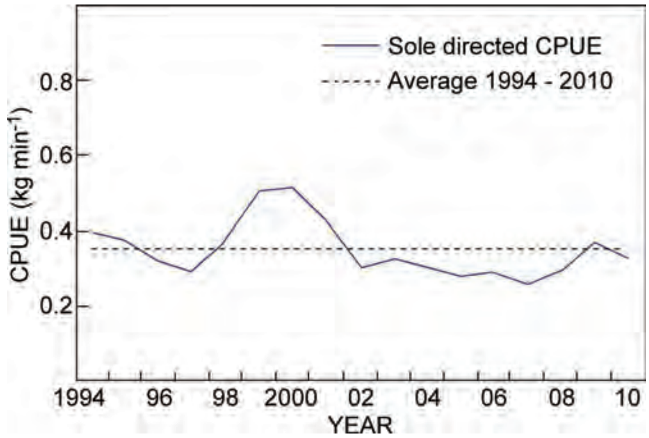

Figure 9: Standardised CPUE for seven vessels regularly engaging in sole-directed fishing. The average CPUE calculated over the period 1994–2010 is shown

The fishery has consequently been managed using a constant catch strategy (an annual TAC of 872 t) since 1992.

Current status

Survey-derived abundance indices show considerable variability (Figure 8). 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 availability of Agulhas sole to the research trawl during the surveys. In particular, the September 2007 and April 2008 surveys were compromised by bad weather that may have reduced the availability of sole to the gear, resulting in artificially reduced estimates of abundance. Estimates derived using the old gear suggests that the 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 as well as potentially reducing 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.

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

Another information source that can be used to assess trends in the status of the Agulhas sole resource is a standardised CPUE time-series based on seven vessels that target Agulhas sole. This time-series (Figure 9) shows that sole-directed CPUE has remained relatively stable since 1994 (apart from a period of higher catch rates around the turn of the century), suggesting that the abundance of Agulhas sole has remained relatively constant over the past 15 years.

In summary, both survey abundance and CPUE trend indications do not suggest any negative impact of the fishery on the stock.

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Cape hakes

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

Introduction

The South African hake resource comprises two species, shallow-water Cape hake *Merluccius capensis* and deep-water Cape hake *M. paradoxus*. The Cape hakes are distributed on the continental shelf and upper slope around the coast of southern Africa. Deep-water hake are distributed from northern Namibia to just east of East London. Shallow-water hake are distributed mainly from southern Angola to northern KwaZulu-Natal (KZN). As the names suggest, the distri-

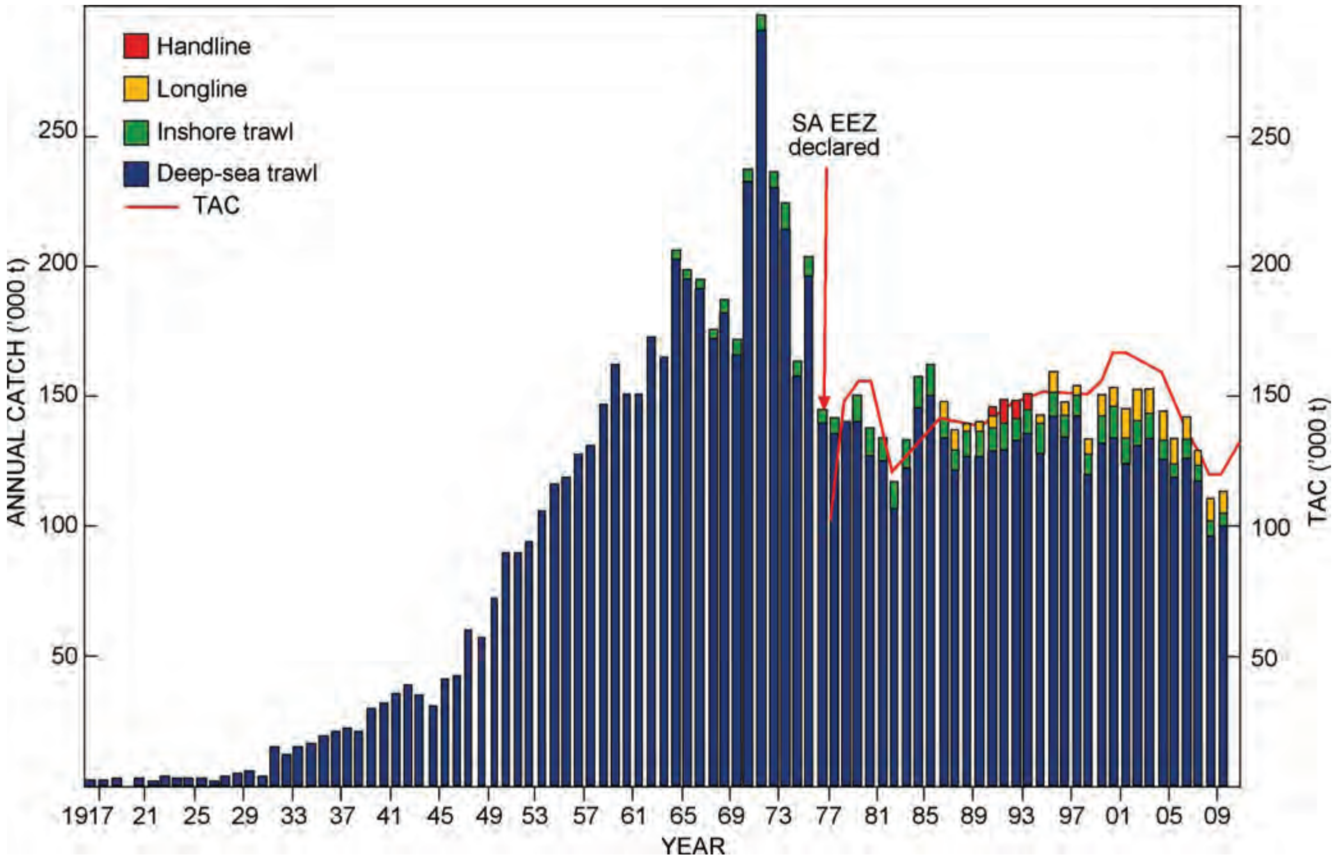

Figure 10: Annual catches of Cape hakes landed by the various fishing sectors off South Africa, 1917–2010

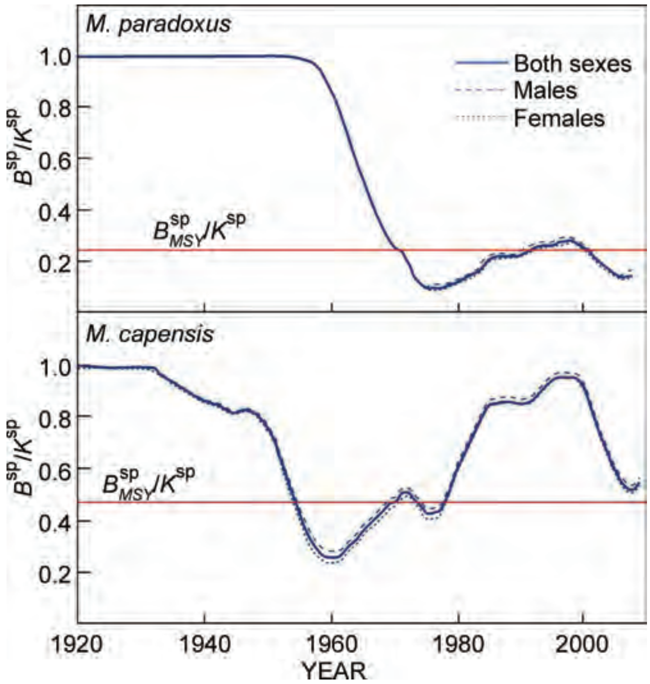

Figure 11: Spawning biomass trajectories for Cape hakes (relative to their estimated pre-exploitation levels) estimated in the 2010 baseline assessment. The estimated maximum sustainable yield level (B_{MSY}) for each stock relative to the pre-exploitation level (*K*) is indicated by a horizontal line

butions of the two hake species differ with depth, although there is a substantial overlap in their depth ranges. Shallow-water hake are distributed over a depth range of 30–450 m with most of the population occurring between >100 and 300 m. In contrast, the deep-water hake is distributed over a depth range of 150 m to >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 shallow-water hake co-exist with (and feed extensively on) smaller deep-water hake. It is difficult to distinguish between the two hakes, 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 10). 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 sectors. 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 deep-water hake. 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 the South Coast are shallow-water hake. While not the largest fishery in terms of tonnage (the small pelagic 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 only being caught as an incidental bycatch. Directed fishing for 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 the Second World War 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 almost 300 000 t in 1972 (Figure 10). By this time, effort had extended farther offshore and also into Namibian waters, with over 1.1 million tonnes 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 Economic Zone (EEZ) by South Africa marked the onset of direct management of the South African hake resource by the South African government and exclusion of foreign vessels (with the exception of a

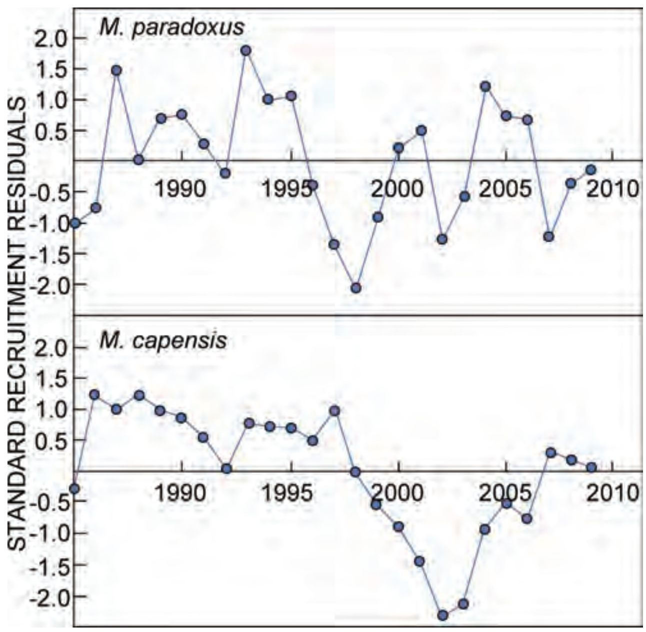

Figure 12: Time-series of standardised stock recruitment residuals (differences between actual and anticipated recruitment) as estimated in the 2010 baseline assessment of the South African hake resource

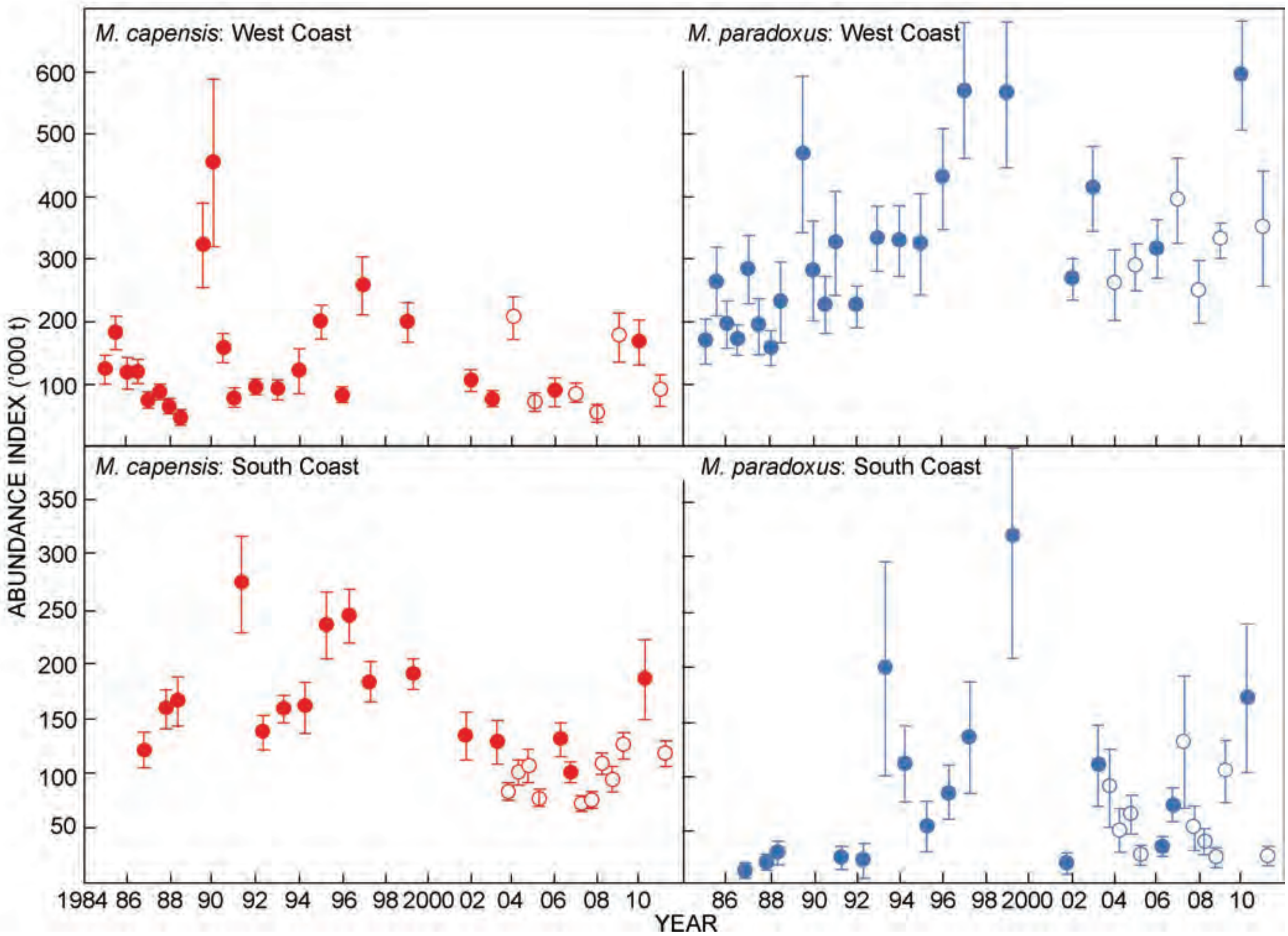

Figure 13: Swept-area based survey abundance indices for the two species of Cape hakes on the slope and upper shelf (0–500 m) on the West and South coasts. Indices obtained using the old and new gear configurations are indicated by dots and circles respectively. Error bars denote SE

few vessels operating under bilateral agreements and subject to South African regulations).

Subsequent to the declaration of the EEZ, South Africa implemented a relatively conservative management strategy in order to rebuild the hake stocks to the maximum sustainable yield (MSY) level. TACs were imposed on the fishery, aimed at keeping exploitation levels below what were considered to be optimal in order to promote stock rebuilding. The TACs were recommended on the basis of assessments of the resource using first steady-state, then dynamic production models, and finally age-structured production models that are used in the development of Operational Management Procedures (OMPs) The OMP approach was adopted in 1990 in a move to provide a sounder basis for management of the resource. The hake OMP is essentially a set of rules that specifies exactly how the value of the TAC is calculated from stock-specific monitoring data (commercial CPUE indices and indices of abundance derived from demersal research surveys – see below). Implicit in the OMP approach is a schedule of OMP revision (every four years) to account for possible revised datasets and understanding of resource and fishery dynamics. Assessments are routinely updated every intervening year to check that resource behaviour remains within the bounds considered likely when adopting the OMP.

Because 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 first 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. Efforts were therefore directed at developing 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 to calculate the TACs for the 2007 to 2010 fishing seasons (see below).

The management strategies implemented since the EEZ 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 10). In the early 2000s, however, the hake fishery experienced declining catch rates, indicating substantial depletion of the hake resource. Results of the species-disaggregated assessments revealed that the decline was primarily attributable to a reduction in the deep-water hake resource to well below its B_{MSY} level (Figure 11). Although the shallow-water hake resource had also declined,

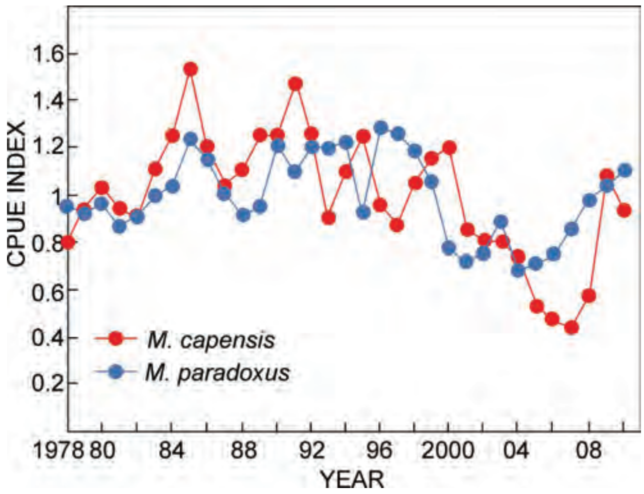

Figure 14: General linear model standardised CPUE indices for the Cape hakes. Each time-series has been normalised to its mean

the estimated biomass was still above B_{MSY}.

The decline was likely a response to several years of poor recruitment of both species in the late 1990s and early 2000s. *Merluccius paradoxus* showed below average recruitment levels over the period 1996–1999 and again in 2002 and 2003, whereas *M. capensis* showed very low recruitment over the entire 1999–2006 period (Figure 12). The reasons for these periods of poor recruitment are not known.

The OMP developed in 2006 was based on a fully species-disaggregated assessment then available for the first time, and amidst industry concerns about financial viability given the downturns in catch rates. This OMP was first implemented in 2006 and provided TAC recommendations for the period 2007–2010, aimed at recovering the deep-water hake 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 to the industry. Implementation of this OMP led to substantial reductions in the TAC from 2007 until 2009 (Figure 10), but TACs have subsequently increased as the resource has responded positively to the recovery plan, with both commercial catch rates and survey indices of abundance turning around to show increasing trends. In accordance with the agreed OMP revision schedule, a revised OMP was developed in 2010 and has been used to provide TAC recommendations for 2011 and 2012.

Uncertainty remains as to the extent to which the deep-water hake resource is shared between South Africa and Namibia, and the influence of catches by the two fisheries on the resource as a whole. At present, the two fisheries are managed independently, although the recently established Benguela Current Commission 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.

Research and monitoring

Data are collected from both fishery-independent surveys and from the commercial fishery. Fisheries-independent abundance indices are determined from annual research surveys

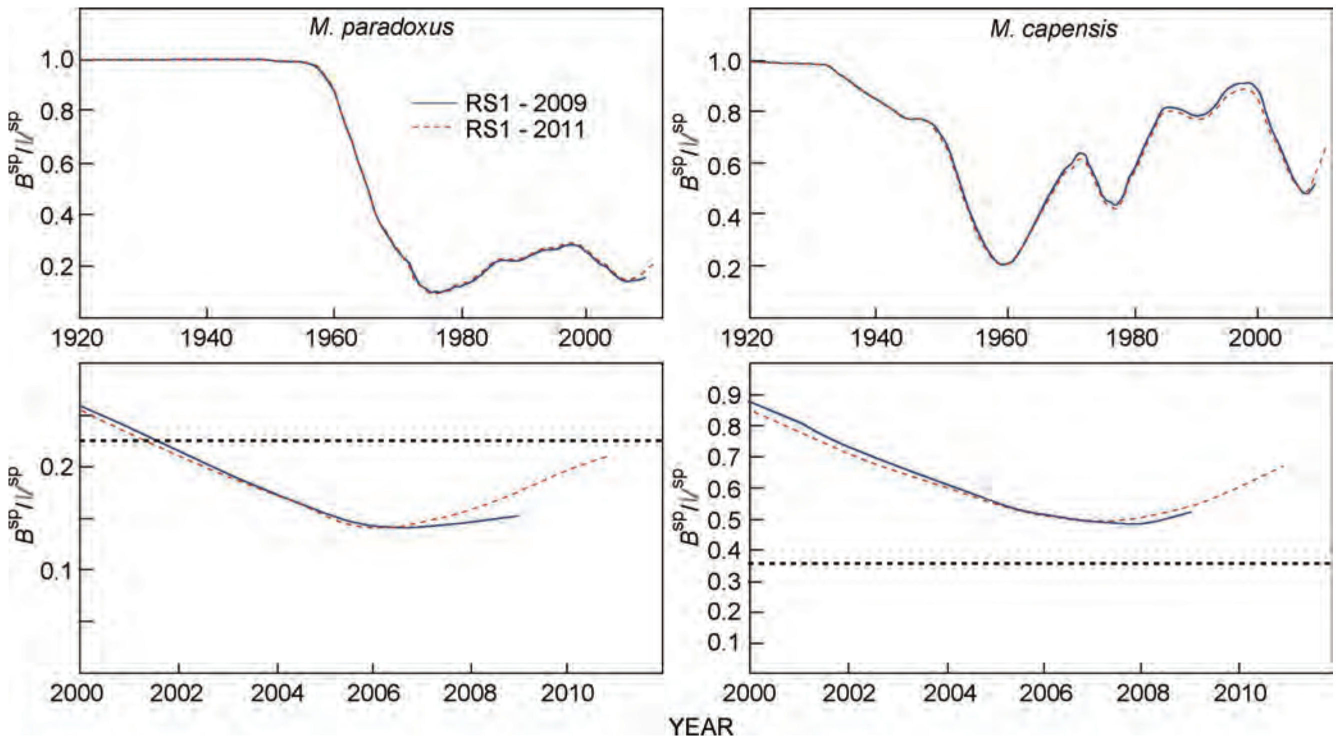

Figure 15: Trajectories of gender-aggregated spawning biomass relative to pre-exploitation levels estimated in the 2010 baseline assessment (‘RS1-2009‘) and the 2011 updated assessment (‘RS1-2011‘). The upper panels show the time-series for the period 1920–2012 whereas the lower panels focus on the period 2000–2012. The MSY level (B_{MSY}) estimates for each stock arising from the 2011 assessment relative to the pre-exploitation level (K) are illustrated by a dashed blue line

Table 1: Estimates of management quantities of the hake resources arising from the 2011 updated assessment. Note that analyses have indicated that the status of resources relative to B_{MSY} is more robustly estimated than status relative to K

	M. paradoxus	*M. capensis*
Pre-exploitation biomass (K) (t)	1 358 000	506 000
Depletion (B_{2011}/K) (current biomass relative to pre-exploitation levels; %)	21	68
Target (B_{MSY}/K) (MSY level relative to pre-exploitation biomass; %)	24	36
Current status (B_{2011}/B_{MSY}) (current biomass relative to target; %)	88	182 *

* The target for *M.capensis* is effectively above its MSY level to maintain catch rates at levels necessary for the economic viability of the *M. capensis*-dependent inshore trawl fishery on the South Coast

conducted on the West Coast for summer and winter and South Coast for spring and autumn. 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 depth and latitude (West Coast) or longitude (South Coast) into a number of strata, and the number of stations selected within each stratum is proportional to the area of that 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 that can be sampled. Trawling is conducted during the day only to account for the daily vertical migration of hake; hake move off the sea floor and into the water column at night to feed.

Abundance indices from surveys (Figure 13) are calculated using the swept-area method, which 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 used was unbalanced and was being over-spread. The change in trawl gear configuration resulted in non-comparability in the time-series. 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 to extend the survey area into deeper water (to 1 000 m) to encompass the full extent of the deep-water resource; however, abundance estimates for input to TAC evaluations are still calculated for the historic survey area only for consistency. It will be possible to incorporate abundance indices from the extended survey area into the assessment models only once a sufficiently long time-series is available. Biological sampling of research catches is routinely conducted to collect data on size structure, feeding, age and growth, and maturity and fecundity. Genetics research is also being conducted to investigate the stock structure of the Cape hakes to determine whether there are genetically discrete stocks off southern Africa, and to assess the extent to which the hake populations may be shared between South Africa and Namibia.

Catch and landing data for the two hake species combined are submitted by the industry, and these data are dissaggregated to species level using an algorithm based on the relationship of species ratios to fishing depth and fish size recorded during the research surveys. Species-specific CPUE time-series are standardised using general linear modeling techniques to account for differences in factors such as depth, area, and vessel power. This time-series is then used in the assessment as additional estimates of resource abundance and trends (Figure 14).

Current status

A full baseline assessment of the hake resource incorporating data up to and including 2009 was conducted in 2010, and a routine update incorporating new commercial data (catches and CPUE) for the period up to 2010 and survey (abundance estimates) data for the period up to and including 2011 was conducted in 2011. The results of the 2011 updated assessment (Table 1) indicate that the deep-water hake resource is approaching the MSY level (B_{MSY}) more rapidly than was projected two years previously (Figure 15) (it had been anticipated that this target level would be attained by about 2014). These observations indicate that the precautionary management approaches implemented since 2006 have yielded positive results and both stocks are improving, a conclusion also evident from the increasing catch rates realised by the fishing industry in recent years (Figure 14). The TAC for the 2012 fishing season has been set at 144 671 t (an increase of 9.78% from the 2011 TAC of 131 780 t).

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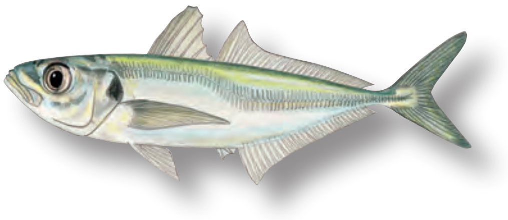
Cape horse mackerel



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

Introduction

Cape horse mackerel *Trachurus capensis* is a semi-pelagic shoaling fish that occurs on the continental shelf off southern Africa from southern Angola to the Wild Coast. It is replaced by the very similar Cunene horse mackerel *T. trecae* and African horse mackerel *T. delagoa* to the north and east respectively.

Horse mackerel as a group are recognised by a distinct dark spot on the gill cover and a row of scutes (spiny scales) along the lateral line. It is, however, not easy to distinguish between the three species that occur in southern Africa. Cape horse mackerel generally reach 40–50 cm in length and become sexually mature at around 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. Adult horse mackerel currently occur more abundantly on the South Coast than the West Coast of South Africa.

Adult Cape horse mackerel are taken as a 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 on the West Coast takes juveniles as a

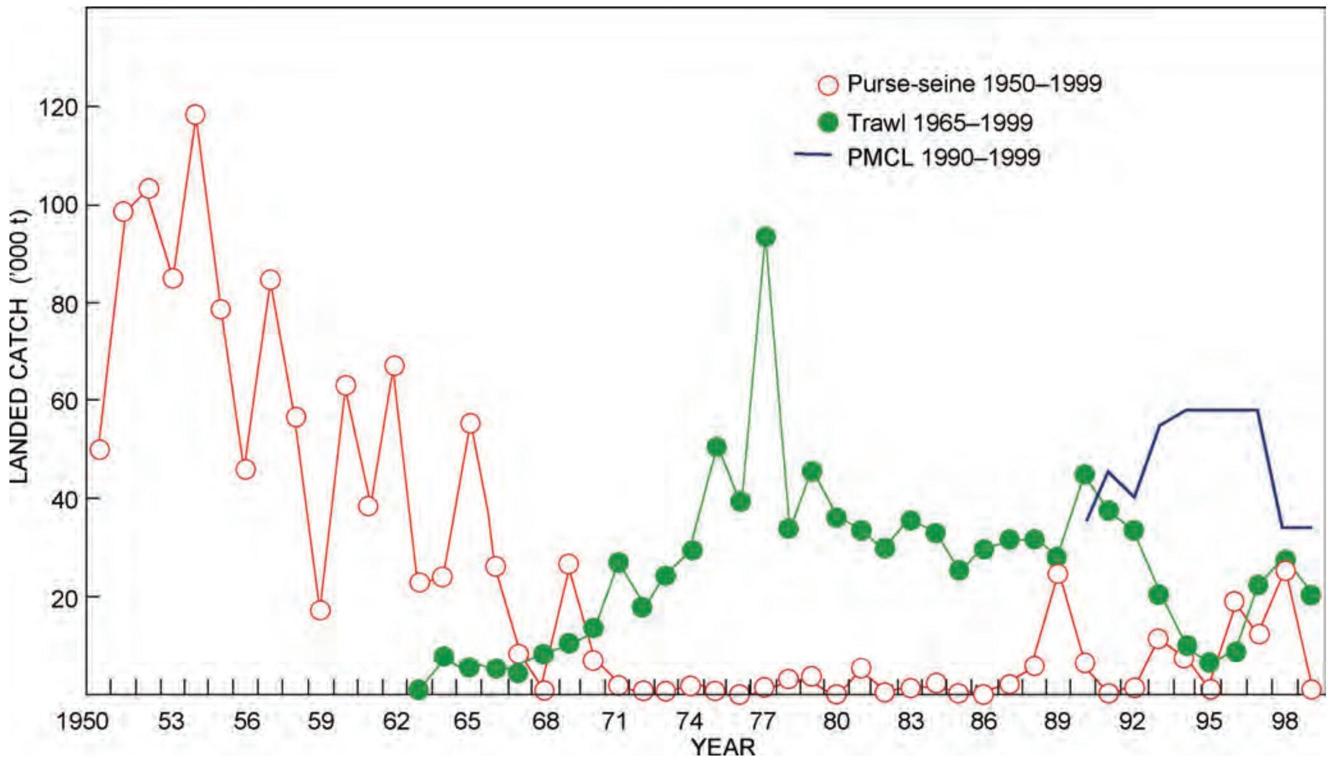


Figure 16: Annual horse mackerel catches by the purse-seine and trawl fisheries from 1950 to 1999. The blue line indicates the TAC/PMCL set for the trawl fishery since 1991. Note that 'Trawl' includes both bottom and midwater trawls

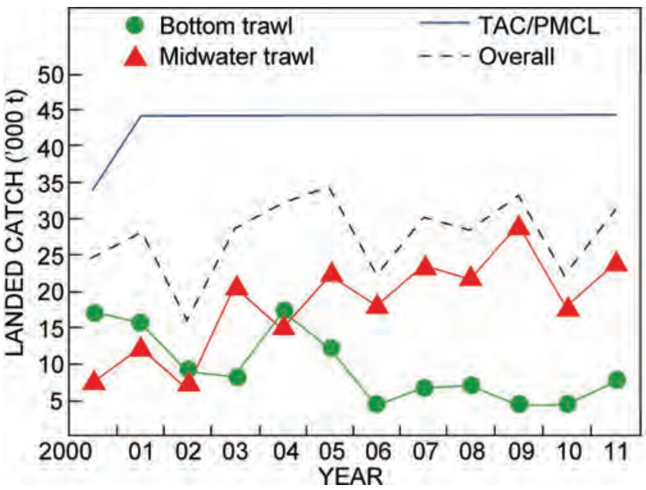


Figure 17: Annual horse mackerel catches of the trawl fisheries, 2000–2011. The trawl fishery is split between the bottom trawl bycatch fishery and the targeted midwater trawl fishery. The continuous line indicates the TAC/PMCL set for the trawl fishery whereas the dashed line indicates overall trawl catch. Note: the 2011 data are preliminary and subject to change

bycatch. Cape 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 and declined to negligible levels by the late 1960s (Figure 16). In the 1990s, purse-seine catches of juvenile Cape horse mackerel again showed an increasing trend, reaching 26 000 t in 1998 (Figure 16). Although this catch level appears low compared to historic levels, the number of fish per tonne of catch in the 1990s is much greater than was the case during the 1950s due to the smaller size of fish being caught. The increasing pelagic catches prompted modelling of the likely effects of large catches of pelagic juvenile Cape horse mackerel on the trawl fishery for adults. The results of the analyses led to the introduction of a 5 000 t precautionary upper catch limit (PUCL) for the purse-seine fishery in 2000, following which the average annual purse-seine catch has been 3 400 t.

Trawl catches occur primarily on the South Coast and commenced in the mid-1960s, peaking in 1977 at 93 000 t. Following the declaration of the EEZ in 1977, catches levelled off at between 25 000 t and 40 000 t. When foreign fleets were finally phased out annual catches (now by South African vessels only) declined to between below 10 000 t between 1994 and 1997. Whereas demersal trawl catches have remained low, the re-establishment of a midwater fishery for Cape horse mackerel in 1997 has resulted in an increase in the annual catch (Figures 16, 17).

Due to the behaviour of the species, the biomass of horse mackerel has not been determined with a high degree of confidence. Consequently, the accuracy of resource assessments is such that only precautionary management catch limits (PMCL) have been set for the horse mackerel fishery since 1992 (Figures 16, 17). A portion of the PMCL is allocated for directed midwater trawling and the remainder (28%) is held as a bycatch reserve for the demersal trawl sector. At present, the PMCL for directed horse mackerel fishing is set at 44 000 t, of which 31 500 t is allocated for directed midwater trawling while the remaining 12 500 t forms the demersal trawl bycatch reserve. As noted above, an additional 5 000 t PUCL has been imposed on the pelagic purse-seine fishery since 2000 to limit the bycatch of juvenile Cape horse mackerel during directed sardine and anchovy fishing (Figure 18).

In early 2011, unusually large numbers of juvenile horse mackerel on the West Coast presented the small pelagic purse-seine fishery with a serious obstacle to utilising their anchovy rights. Despite major efforts by the sector to manage the situation (including periodic closures of parts of the West Coast to fishing), bycatch of juvenile horse mackerel rapidly approached the PUCL while catches of anchovy were still well below the TAC. In order to prevent the fishery from being closed, the sector requested an *ad hoc* 5 000 t addition to the juvenile horse mackerel PUCL to enable continued fishing for anchovy. This request was approved by the Department, based on projected resource trends that indicated that such a once-off decision would not introduce any serious risk to the resource, and a PUCL that fluctuates around an average of 5 000 t could be considered. A second request for an additional increase to the now 10 000 t PUCL was submitted in May 2011 in response to the persistence of juvenile horse mackerel on the West Coast for longer than anticipated. A 2 000 t addition to the PUCL was approved by the Department on the basis of an analysis that indicated a general increase in horse mackerel abundance since the 1960s. The PUCL will remain at 5 000 t for 2012, but reasonable flexibility will be exercised regarding this limit during years when the high incidence of mixed-species shoals makes it very difficult for the pelagic fleet to avoid juvenile horse mackerel.

A comprehensive update of the horse mackerel assessment incorporating updated catch data and further abundance estimates, as well as additional data (a midwater CPUE time-series and length frequency data from both the commercial fishery and research surveys), was completed in October 2011. The assessment indicated a 20% increase in horse mackerel abundance over the last five years, primarily as a result of good recruitment in recent years. However, long-term projections of abundance under different levels of constant

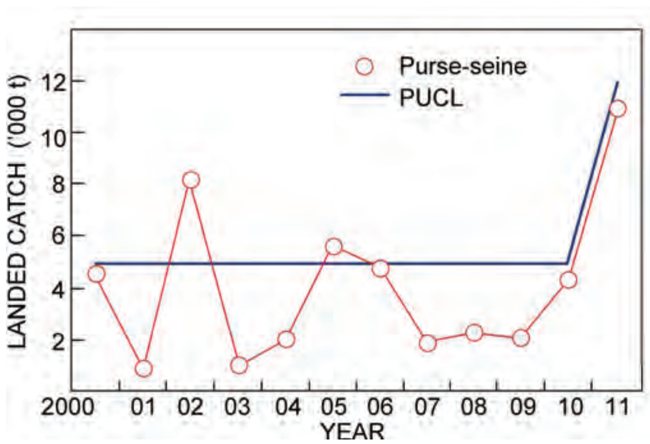


Figure 18: Annual horse mackerel purse-seine catches from 2000 to 2011. Note: the 2011 figure is from January to October 2011. The blue line indicates the PUCL set each year

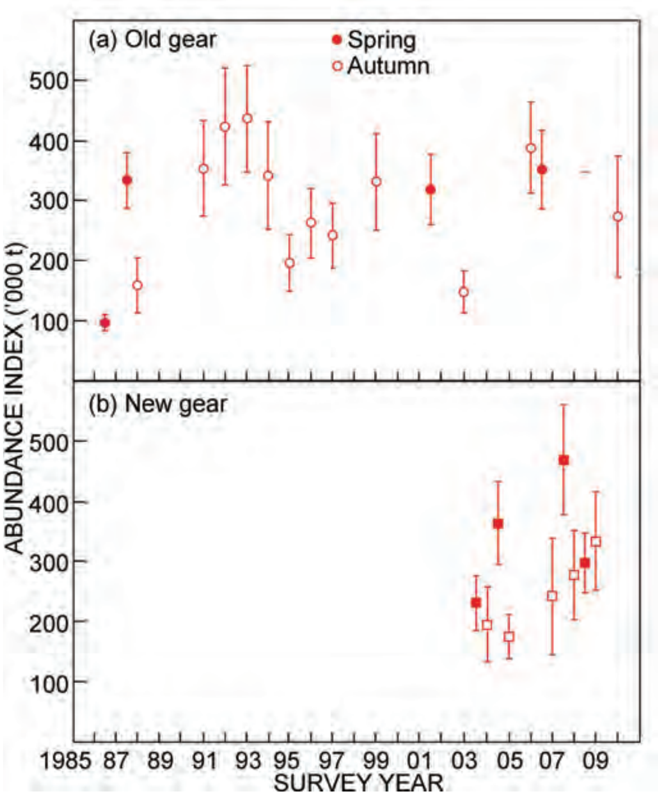


Figure 19: Spring and autumn survey abundance indices and associated standard errors for the horse mackerel resource on the South Coast of South Africa from the coast to the 500 m isobath using (a) old gear and (b) new gear

future catches remain similar to those indicated by the 2007 assessment. There is consequently no evidence to support an increase in the PMCL, which will be maintained at 44 000 t for the 2012 fishing season.

Research and monitoring

Cape horse mackerel are semi-pelagic, i.e. they range throughout the water column from near the surface to close to the seabed. The demersal trawl gear used during research surveys cannot sample horse mackerel that are above the headline of the net and acoustic methods cannot detect horse mackerel that are close to the seabed. Thus neither demersal trawl nor acoustic survey methods are capable of accurately estimating horse mackerel abundance. Furthermore, as the proportion of the resource detectable by either demersal trawl or acoustic methods is highly variable, there are substantial variations in abundance estimates between surveys. In an attempt to resolve this problem, a number of joint bottom trawl/acoustic surveys have been conducted over the past 15 years, the last in 2006. Further surveys have not been conducted due to budget and ships-time constraints. In light of

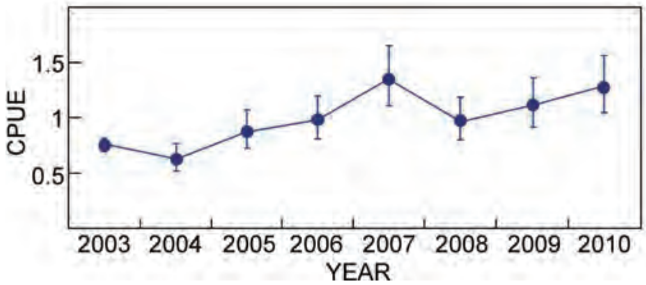


Figure 20: Standardised CPUE time-series (with 95% confidence intervals) derived from directed horse mackerel catches by the midwater trawler *Desert Diamond*

the issues surrounding the 2011 PUCL, a two-week dedicated multidisciplinary horse mackerel survey has been requested for 2012.

The surveys have met with variable success, but despite these limitations, the time-series of abundance indices from the demersal trawl surveys (Figures 19) are the best available fishery-independent abundance indices.

A second source of information concerning resource abundance has recently been developed from commercial catches taken by the *Desert Diamond*, a midwater trawler that catches the bulk of the directed horse mackerel catch. Catch per unit effort data for this vessel are standardised using general linear modeling techniques to account for factors such as depth, location, time of day, lunar phase and wind speed. The CPUE time-series suggests a general increase in horse mackerel abundance in recent years (Figure 20), consistent with the results of the updated assessment described above.

Current status

In 2011, an update of the existing assessment model was carried out, taking account of updated catch data (Figures 16, 17, 18, 20) and further demersal trawl survey swept-area estimates of abundance (Figure 19). The results and projections under current catch levels were very similar to those obtained previously, upon which past recommendations have been based. Thus, no negative impacts from recent levels of catch were detected, and maintenance of the current levels of catch limitation is considered appropriate.

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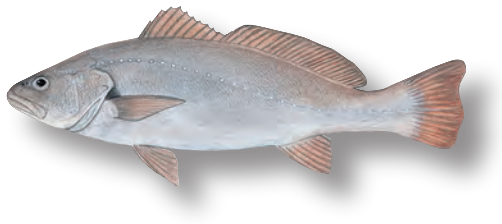
Linefish



Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
			Hottentot Snoek Yellowtail	Carpenter Slinger	Silver kob
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
		Hottentot	Carpenter Silver kob Slinger Snoek Yellowtail	Silver kob Yellowtail	

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.

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 exclusively targeted by this fishery, but form important components of the catch or the bycatch of other fisheries. This complicates the management of this resource.

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. Currently, 455 boats are in operation. Commercial 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. The combined value of the commercial, subsistence and recreational components of the linefishery is in excess of R2.2 billion per annum.

The recreational boat-based sector expanded rapidly after the introduction of the trailerable skiboat in the 1970s, with an estimated minimum of 4 000 vessels. Subsistence fishing was formally recognised in 2000 to accommodate those fishers who depend on the resource for food directly – usually poor communities or those using traditional methods. There are almost 30 000 subsistence fishers active along the South African coastline and 85% of them harvest linefish.

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 (>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 and the rapid development in fishing technology (echosounders, nylon line, etc.), 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 manage-

ment framework for the linefishery was only introduced in 1985. However, successive research surveys indicated continuing declines. In December 2000, the Minister of Environmental Affairs and Tourism, taking cognisance of the critical status of many linefish stocks, declared the linefish resource 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 to 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, which still 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, species targeted and flexibility of the operational range, the commercial linefishery is currently managed through a total allowable effort (TAE) allocation. The recreational fishery is managed by a number of measures, such as size and bag limits, closed areas and seasons, etc. The subsistence fishery is 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 indicate that a relatively small number (20%) of the vessels in the fishery accounted for the majority (80%) of the reported catches, and these highly efficient vessels have remained in the fishery. Moreover, the actual effort has consistently exceeded the TAE recommended for resource recovery due to high levels of illegal activity, effort creep through crew exemptions, interim relief measures and unregulated subsistence fishing in sensitive estuarine and nearshore habitats.

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 on the boat-based commercial fishery have been collected since 1985 and stored in the National Marine Linefish System (NMLS). A national observer programme was initiated in 2008, in which shore-based observers confirm recorded catch-and-effort data and collect size frequencies per species from the boat-based fishery at fishing hotspots around the country.

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. Not only do we have good estimates of morphometric and physiological parameters of the majority of target species, but the ecology and behaviour of many of these have now also been studied. In many respects we know more about the linefish target species than those of larger commercial fisheries, perhaps because these species are more accessible to study, and amenable to experimental techniques, than their deep-water counterparts. Scientists have taken advantage of cutting-edge telemetry and genetic techniques to

Table 2: Total reported landings for selected linefish resources, 2001–2010

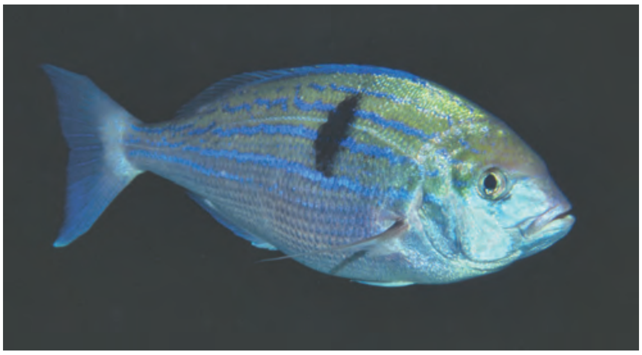
Resource	Landings (t)									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Snoek	6 839	3 837	4 532	7 278	4 787	3 529	2 765	5 223	6 322	6 360
Geelbek	395	315	513	672	580	419	448	403	495	408
Yellowtail	327	242	329	883	739	310	478	313	330	171
Kob	416	393	272	360	324	400	421	358	442	419
Carpenter	285	231	177	228	184	159	265	226	282	263
Slinger	139	101	88	184	169	192	157	194	186	180
Rockcods	38	28	22	39	44	44	36	43	36	30
Roman	11	12	13	21	15	18	30	18	21	15
Englishman	12	6	5	17	19	19	15	21	13	8
Elf	3	2	5	14	35	13	25	16	6	4
Red steenbras	7	8	3	3	2	3	7	2	5	3

answer questions about fish movement and stock structure. These studies have shown that linefish can consist of a single, unstructured population or can be highly structured with limited movements between separate stocks along the coast.

The existing information on linefish biology and ecology is constantly expanding and linefish species are subject to numerous research initiatives. Since its commission in 2008, the purpose-built research ship RV *Ellen Khuzwayo* has been used for research directed at assessment of offshore linefish resources. Based on traditional methods such as standardised fish trap and angling surveys and cutting-edge technology such as the use of a remotely operated vehicle (ROV), this research will provide fishery-independent information on species composition and population structure of demersal species such as red steenbras *Petrus rupestris*, carpenter *Argyrozona argyrozona*, blue hottentot *Pachymetopon aeneum* and panga *Pterogymnus laniarus* on offshore hard grounds on the Agulhas Bank.

Marine protected areas (MPAs) are an integral part of linefish management and provide reference areas for research on the effects of fishing and climate change. A thorough analysis of standardized CPUE data provides conclusive evidence that MPAs can, under certain circumstances, enhance and sustain surrounding fisheries and offset the negative effects for the fishery caused by the initial reduction in fishing area.

An initiative began in 2010 to revise the stock assessments of a number of important linefish species, drawing on the enormous body of spatially-referenced fisheries data in the NMLS, which constitutes the largest spatially referenced marine dataset in the world. The primary need for a new round of stock assessments was that some of the existing assessments were quite dated, with most assessments being over a decade old. A secondary need is to update the assessment methods.



Whereas most existing assessments are based on age structure only, and present Spawner-Biomass-per-Recruit (SB/R) estimates, we now have sufficient data to apply production models that incorporate standardised CPUE as an index of abundance. The new approach enables us to investigate the effect of the reduction of effort brought about by the emergency in 2000.

Although final assessments have not been completed, standardised time-series of CPUE are now available for some key species, and can be regarded as a reliable indication of trends in the fishery. CPUE data need to be standardised to ensure that the values serve as an indication of stock abundance and that they do not reflect changes in vessel efficiency, seasonal shifts in effort or shifts in targeting. General additive models were used to remove these effects. This new approach also allows us to provide a measure of uncertainty. Some challenges were presented by the mixed-species nature of the catches, because shifts in targeting strongly influence CPUE of individual species. A novel approach to incorporate multivariate techniques such as principal components analysis was used to quantify the degree of targeting on each species and to use this information to filter and standardise CPUE data.

The shore-based recreational and subsistence fishery, which accounts for a large number of species – many of them unavailable to boats – is also the focus of several relatively new monitoring programmes from the West Coast National Park to the Eastern Cape. These programmes are run and funded separately but are united under a common and standardised methodology, namely the roving creel survey. The resultant time-series of CPUE are presently very short, but will serve as the basis for assessments of several species in future, including some that have been deemed to have collapsed, such as dusky kob *Argyrosomus japonicus* and white steenbras *Lithognathus lithognathus.*

Current status

If the linefishery is carefully managed to return to sustainable levels, it has the potential to become one of the most ecologically and economically viable fisheries in South Africa, because of the following facts: (i) the fishing method can be highly selective and bycatch of undersized fish and unwanted species can be avoided; (ii) the labour-intensive, low-tech-

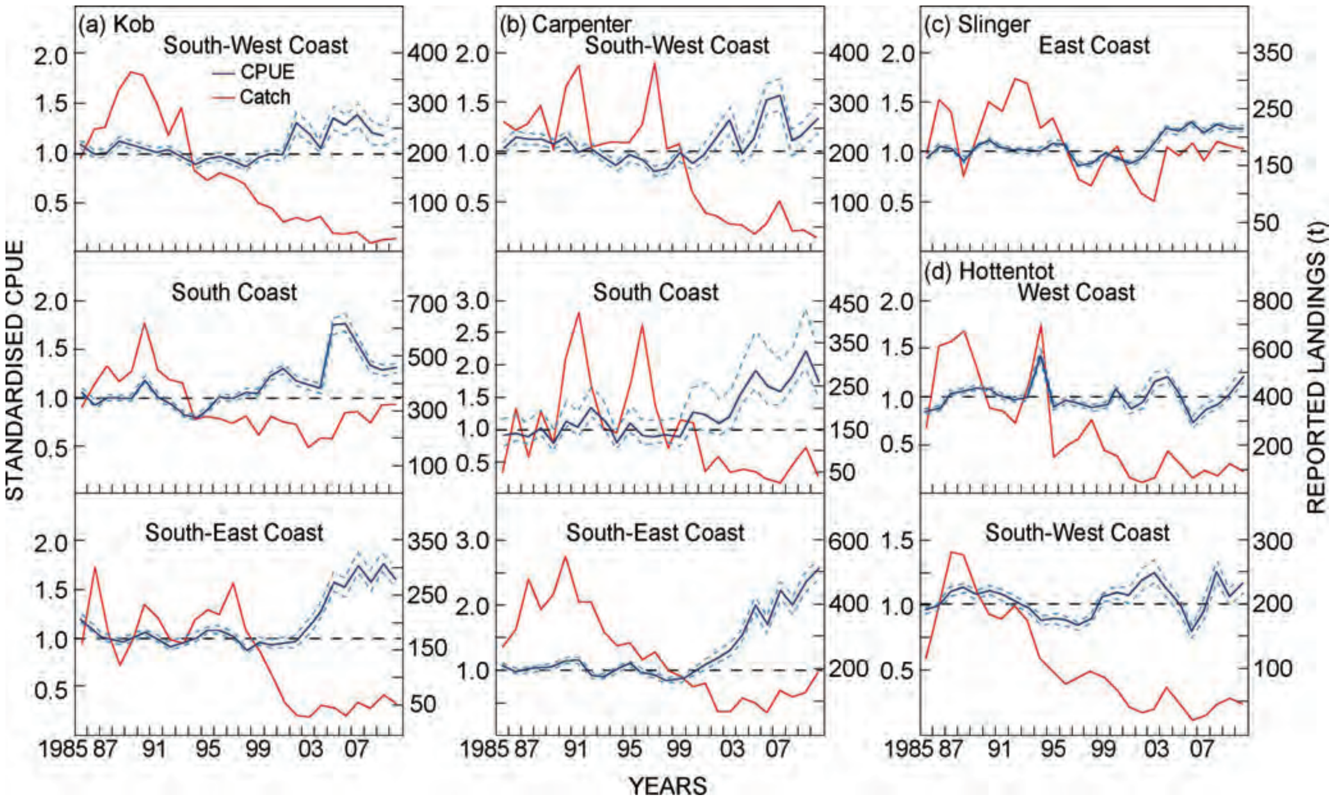


Figure 21: Standardised CPUE trends (blue, solid line) and total reported landings (red, solid line) for (a) kob *Argyrosomus* spp. (b) carpenter *Argyrozona argyrozona*, (c) slinger *Chrysoblephus punicus* and (d) hottentot *Pachymetopon blochii* by fishing area, defined as follows: West Coast: Orange River-Cape Point, South-West Coast: Cape Point-De Hoop, South Coast: De Hoop-Tsitsikamma, South-East Coast: Tsitsikamma-Kei River, East coast: Kei River-Mozambique border. The CPUE was normalised to the standardised mean CPUE for the period 1985–2000 (black, dashed line). The blue, dashed lines represent 95% confidence intervals estimated from non-parametric bootstrapping

nology, 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 physical damage to the ecosystem.

Comprehensive annual assessments of the status of linefish resources are not feasible due to the large number of species, their different life-history patterns and the nature of the different fisheries using these resources. Because the majority of linefish are long-lived and management changes will take considerable time to have an impact on stocks, it is sufficient to assess individual resources on a time-scale equivalent to half of their maximum life-span. Nevertheless, other stock status indicators such as a sudden change in 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 annual management actions. These indicators need to be considered in conjunction with the latest stock assessments.

Based on the newly available standardised CPUE time-series, there are signs of a positive response of some of the linefish stocks to the emergency measures, with CPUE for some linefish having begun to increase (Figure 21). However, it should be emphasised that these increases come from a very low starting level, because most linefish stocks are currently in a collapsed state (Table 2). Management measures need to remain in place for sufficient time to allow the stocks to rebuild to levels that will allow for sustainable catches at a higher level than at present. Should this be achieved, the potential of this sector to become one of the most ecologically and economically viable fisheries in South Africa may be realised.

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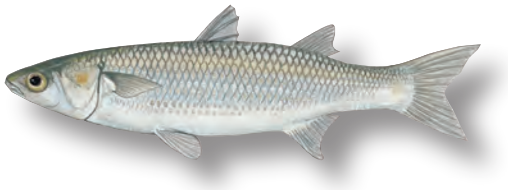
Netfish



Stock Status	Unknown	Abundant	Optimal	Depleted	Heavily Depleted
	St Joseph shark		Yellowtail	Harders Elf	Harders White steenbras
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
			Yellowtail	Harders St Joseph shark Elf White steenbras	

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 beach-seine and 162 gillnet right-holders from False Bay to Port Nolloth on the West Coast. This fishery is managed on a 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 overexploited, and sector conflict arises due to real and perceived impacts on linefish resources from associated bycatch. A substantial illegal component, which may in some years equal or exceed legal catches of harders and bycatch, results in negative perceptions of management and negates most attempts to rebuild these stocks.

History and management

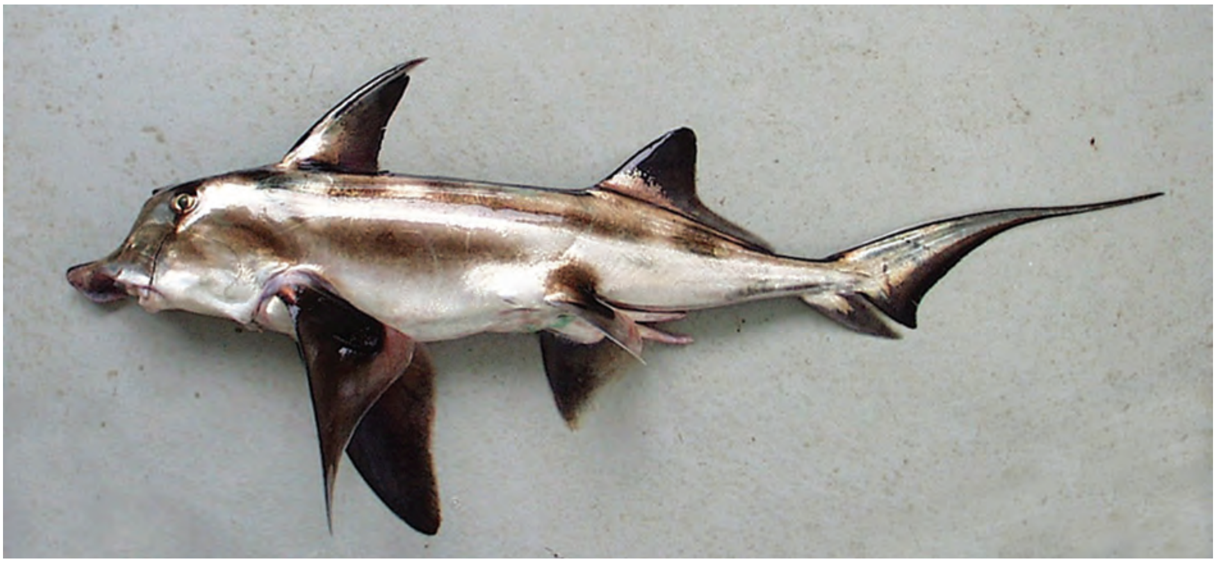
Beach-seine nets were introduced into the Cape during the mid-1600s and gillnets in the late 1800s. The main targets then were large linefish species, in particular white steenbras *Lithognathus lithognathus*, white stumpnose *Rhabdosargus globiceps* and geelbek *Atractoscion aequidens*, with reports of nets 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.

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) were 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 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 about harders being plentiful from the active participants. They then flooded the few small factories with fish, which maintained the price but refused to take in 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 shark 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 oversubscribed areas. The loss experienced by most fishers also indicated the 'recreational' nature of many of the participants. Indeed, in the Berg River Estuary, <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.

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 resulted in the removal of part-timers from the beach-seine and gillnet fisheries. The 80% reduction in the number of net permits amounted to an effective 40% reduction in fishing effort, the target set by the Minister in 2001 to facilitate re-building of the harder stocks. Further, recognising that estuarine gillnetting was severely comprising 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.

Research and monitoring

Fishery-dependent data sources consist of ongoing length-frequency measuring, observer data, compulsory monthly catch returns by right-holders and the National Linefish Survey (NLS). The most important of the fishery-dependent data sources has been the NLS, which 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 has, however, not been able to be repeated since 1995.

Fishery-independent data is currently collected through sampling estuarine and surf-zone fish assemblages to ascertain the links between environmental and fishery variables and juvenile recruitment. Sample fish densities are compared across estuaries and surf-zones in relation to the different levels of fishing and 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 will be developed. This is a relatively novel approach as the existing assessments are largely based on adults caught by the fishery and often ignore the anthropogenic and environmental influences experienced by fish in their earlier life-history stages. In all, 16 estuaries have been monitored twice annually from 2001 until the end of 2011.

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. 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

The measured negative relationship between effort (number of nets) and the size of fish caught 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 (Figure 22). Also relevant was the linefish bycatch, most of which comprised species regarded as overexploited or collapsed. In turn, most of this catch comprised juveniles below minimum legal size taken before they recruited into the linefishery and before they were able to reproduce and thus contribute to replenishment of the linefish stocks.

There is 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 has 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 has also been reported by fishers.

This success may, however, be short-lived as observer data suggest that the illegal gillnet fishery in the Berg River Estuary has escalated recently. These data suggest that at least 400 t are poached from the Berg River Estuary alone each year. A reduction of 500 t in reported catches strengthens the veracity of this and highlights the predicted impact on the legal fishery.

Exacerbating the problem has been an anomalous series of 1-in-50 year floods in quick succession on the South Coast, which have considerably reduced juvenile recruitment over

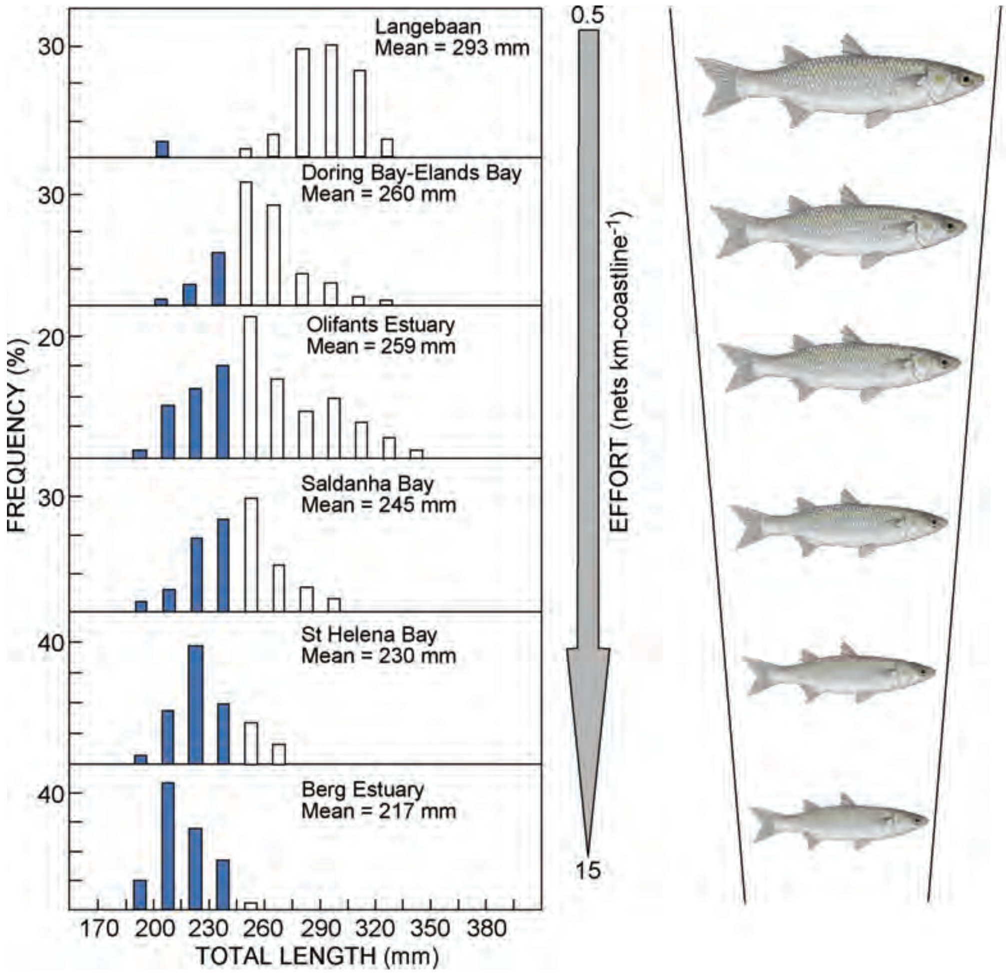


Figure 22: Length-frequency distributions of *Liza richardsonii* landed by commercial gillnetters in different regions. Potential effort levels and fish scaled to actual size are included for illustration. Shaded bars represent immature fish. However, the nets also tend to select for the onset of early maturity, which means that age at maturity also tends to vary according to the nature and magnitude of effort

the last four years. This will have a negative impact on the adult stocks of many species, 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.

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Oysters

Stock Status	Unknown (S. Cape)	Abundant	Optimal (KZN)	Depleted	Heavily Depleted
Fishing pressure	**Unknown**	**Light**	**Optimal** (KZN)	**Heavy** (S. 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. A cheaper oyster is the Pacific oyster *Crassostrea gigas*, which is imported and widely used in marine aquaculture. Cape oysters along the KZN coast have been found to take 33 months (almost three years) to reach marketable size (60 mm right valve length). Oysters are broadcast spawners, and those along the KZN coast spawn throughout the year with peaks during spring and summer. Harvesting takes place during spring low tides and has traditionally been restricted to the intertidal zone. In recent years, however, this has gradually been expanded towards the fringes of the subtidal zone (see below). Oysters are dislodged from rocks by means of a pointed steel crowbar. Harvesters are allowed to wear a mask, snorkel and weight-belt, and commonly use an oyster pick (crowbar) 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

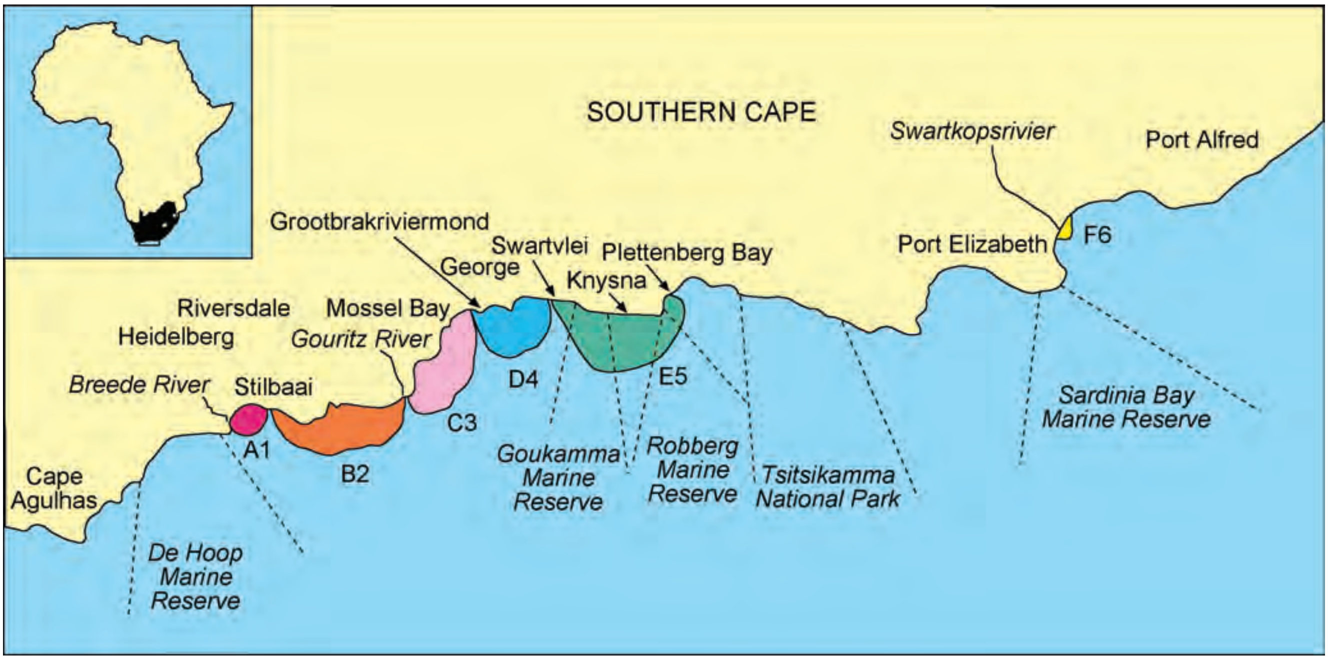

Figure 23: Oyster fishery in Port Elizabeth and the Southern Cape

people) held concessions to harvest oysters and employed large numbers of ‘pickers’ to assist with collections. In 2002, rights were redistributed and medium-term (four-year) rights were allocated to 34 right-holders, the majority of whom 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 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 the new 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 Port Elizabeth, the Southern Cape, KZN North and KZN South (Figures 23, 24). Regional differences regarding regulations and harvesting patterns have been retained.

For KZN (North and South coasts), the fishery is managed by means of effort limitation whereby the number of pickers are restricted to a daily bag limit of 190 oysters per picker per day. The oyster fishery in KZN is further managed by a system of rotational harvesting whereby the coast is divided into zones, and each zone is harvested on a rotational basis. This system accommodates both the commercial and recreational sectors. The system requires that each zone remains fallow for at least three years (the optimal length of time required for oyster recruits to reach marketable sizes) thereby allowing for recovery of the oyster stock.

An OMP was developed for the KZN North Coast for improved management of the oyster fishery in this region. This process also contributed toward the re-zoning of the KZN North Coast in 2007. At that time, insufficient information was available for the KZN South Coast, but a study that was later commissioned supported the re-zoning of this part of the coastline in 2010. In both cases, five zones were consolidated into four.

The oyster fishery along the Southern Cape Coast is managed by means of limiting effort by regulating the number of pickers. This effort is split across five sub-areas according to the extent of accessible oyster reef. The fishery in this region is not managed by means of rotational harvesting and there is no daily bag limit.

In Port Elizabeth, only washed-up oysters are collected. No harvesting of the oyster beds is undertaken.

Traditionally, commercial harvesting was restricted to the intertidal zone. However, in recent years the area harvested has extended offshore to include the fringes of the subtidal zone. This shift in harvesting depth is attributed to a decline in the number of oysters in the intertidal zone and/or to a gradual increase in gear efficiency.

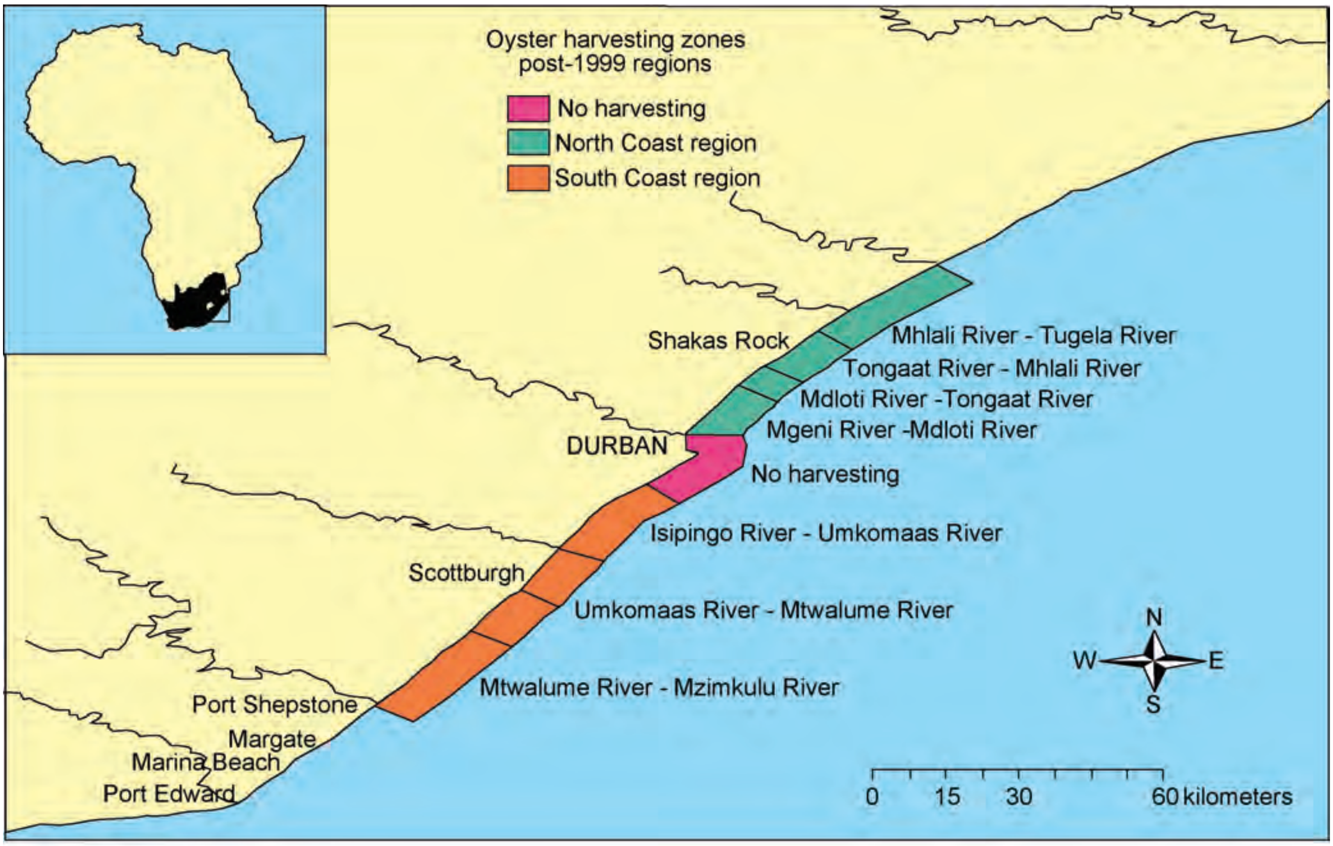

Figure 24: Oyster fishery in KwaZulu-Natal (rezoning of South Coast region included)

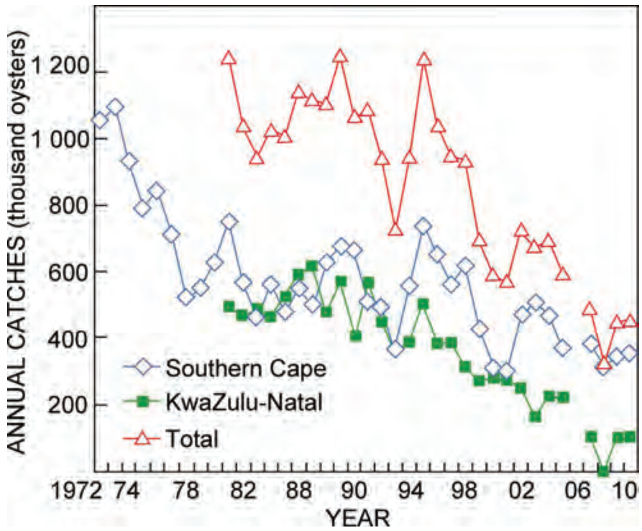

Figure 25: Total number of oysters harvested and harvests for Southern Cape and KwaZulu-Natal for the period 1972–2010

Research and monitoring

Research on the oyster resource has only begun recently. Since oysters are of relatively low value in comparison to the other commercially exploited species, the fishery has until recently not been prioritised in terms of research effort and management attention. The consequence is that the 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 overexploitation 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. Furthermore, attempts at establishing a collaborative working relationship with the commercial oyster industry have proven to be very difficult and problematic. Research and monitoring in KZN is carried out by the Oceanographic Research Institute 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

The overall TAE of 145 pickers has remained stable in this sector since 2002, and was based on the total number of pickers active at that time. The status quo is being maintained until further data become available.

Total catches between 2002 and 2005 were between approximately 600 000 and 730 000 oysters, the majority of which were harvested in the Southern Cape (Figure 25). Data for 2006 are not available because catch reporting was poor on account of the new rights allocation and the change of right-holders. Catches seem to have stabilised since 2007 in both areas, amounting to totals of between approximately 450 000 and 490 000 oysters. The low catches in KZN in 2008 (3 491 indviduals) was an exception, caused mainly by problems during the permit processing. It is noteworthy, however, that catches in KZN have nearly halved compared with the period 2000–2005, but this is thought to be due to problems with permit allocation and catch reporting.

The oyster resource along the KZN coast is considered to be optimally exploited. Preliminary resource assessments undertaken during 2006 indicate that although the oyster stocks have declined since 1980, they have been stable for around the past 20 years, suggesting that current harvesting levels are sustainable.

In the Southern Cape there is concern that the intertidal zone is being denuded of oysters as a result of being over-harvested. Recent surveys that measured oyster density and size composition suggest that the intertidal component of the oyster stock along the South Coast appears to be over exploited. Moreover, there have been escalating reports of divers illegally harvesting oysters from subtidal ‘mother beds’.

CPUE data for the Southern Cape oyster fishery are unsuitable for the purposes of stock assessment, and the status of this resource thus remains uncertain.

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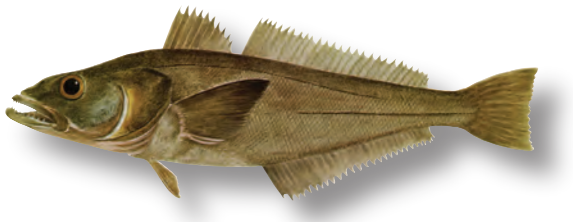
Patagonian toothfish



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

Introduction

Patagonian toothfish *Dissostichus eleginoides* 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 not found in waters colder than 2ºC, (they are replaced by Antarctic toothfish *D. mawsonii* in the colder Antarctic waters). Patagonian toothfish 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. They occur at depths between 70 and 1 600 m around sub-Antarctic Islands and seamounts, mainly between 40ºS and 55ºS. A fishery for this species has developed in the South African EEZ around the Prince Edward Islands (PEI-EEZ).

Patagonian toothfish fetch a high price on the 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 remote seamounts and islands, they have been, and in some regions still are, subjected to substantial illegal, unreported and unregulated (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 and has been estimated to be as much as 80% of the catch on a single day and 30%–50% of the catch during a trip in the fishery in the PEI-EEZ.

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 generally voluntarily applied the CCAMLR conservation measures within the PEI-EEZ. According to CCAMLR Conservation Measure 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.

History and Management

An experimental fishery for Patagonian toothfish in the PEI-EEZ was initiated in 1996. Five permit-holders participated in this fishery from its inception until 30 November 2005. The permits were consolidated onto two vessels because of the high cost of operating a fishery in such a remote locality. 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 Prince Edward Islands 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 commencement, the only fishing gear employed was a form of longline known as an 'autoline'. Apart from a brief period (2004–2005) when one vessel deployed pots, the period from 2000 onwards was characterized by an increasing shift to the use of Spanish longlines until autolines were eventually phased out altogether by 2008. 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. Use of this gear has subsequently increased to the extent that almost no Spanish longline gear has been used during the 2011 fishing season (Figure 26). These gear changes have complicated the assessment of the status of the resource (see below), and hence its

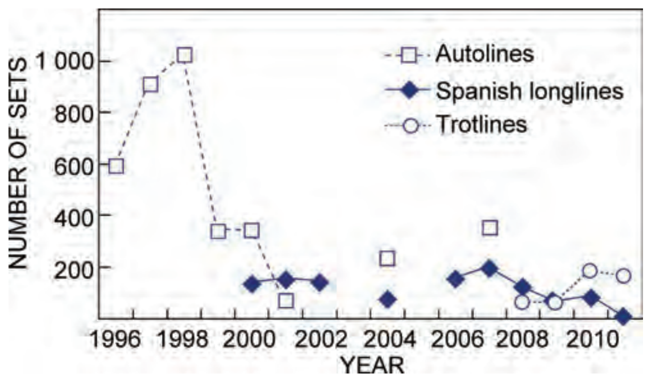


Figure 26: Number of sets deployed per annum in the Prince Edward Islands EEZ. Data are shown for the three different long line gear configurations deployed in the fishery for toothfish over time

Table 3: Annual catches of Patagonian toothfish estimated to have been taken from the Prince Edward Islands EEZ

	Season	TAC	Longline	Pot	Total legal catch	Estimated IUU catch	Total catch
EXPERIMENTAL	1996/97		2 921.2		2 921.2	21 350.0	24 271.2
	1997/98		1 010.9		1 010.9	1 808.0	2 818.9
	1998/99		956.4		956.4	1 014.0	1 970.4
	1999/00		1 558.7		1 558.7	1 210.0	2 768.7
	2000/01	2 250	351.9		351.9	352.0	703.9
	2001/02	600	200.2		200.2	306.0	506.2
	2002/03	500	312.9		312.9	256.0	568.9
	2003/04	500	194.9	72.6	267.5	156.0	423.5
	2004/05	450	131.2	103.5	234.7	156.0	390.7
	2005/06	450	168.7		168.7	156.0	324.7
COMMERCIAL	2006/07	450	237.5		237.5	156.0	393.5
	2007/08	450	133.3		133.3	156.0	289.3
	2008/09	450	66.8		66.8	156.0	222.8
	2009/10	450	319.7		319.7	156.0	475.7
	2010/11	400	380		380.0	0.0	380.0

management.

Prior to the start of the experimental fishery there were extremely high levels of IUU fishing, which likely had an adverse impact on the resource. Estimates of IUU catches declined subsequently and were assumed to be constant at 156 t per annum over the period 2003–2009 (Table 3). Recent information indicates that no IUU fishing is occurring at present in the PEI-EEZ.

Regulation of the fishery was initiated in 2000/2001 by means of a TAC restriction of 2 250 t. The first assessment of the status of the resource conducted in 2001 used an age-structured production model (ASPM) that was based on CPUE data derived from Spanish longline sets. The results of the assessment indicated severe depletion of the stock, and this estimated depressed status of the resource led to a decrease in the TAC from 2 250 t in the 2000/2001 season to 600 t in the 2001/2002 season. The CCAMLR Scientific Committee recommended that South Africa set a TAC of not more than 400 t for the 2002/2003 season. In consultation with industry representatives, a compromise was reached between the 400 t recommended by CCAMLR's Scientific Committee and the 600 t TAC that was set in the 2001/2002 season. This compromise recommendation was first to demonstrate South Africa's commitment to CCAMLR, and secondly to provide sufficient catch to maintain a year-round legal fishing presence in the Prince Edward Islands EEZ as a means of deterring further IUU fishing in the area. The TAC was thus set at 500 t for the 2002/2003 season and maintained at that level for the 2003/2004 fishing season.

The ASPM was extended to incorporate catch-at-length data as a basis for TAC recommendations in 2003. Despite refinements to the model, the two primary resource monitoring indices (CPUE and catch-at-length) yielded conflicting estimates of resource status. While the CPUE data indicated that the resource was severely depleted, the catch-at-length data suggested that the situation was not so serious. Attempts to reconcile these two indices have been unsuccessful. These circumstances have led to major difficulties in making scientific recommendations for appropriate catch limits for this resource, and a conservative approach was adopted that led to a reduction in the TAC to 450 t for the 2004/2005 season. The annual TAC was maintained at this level until a further reduction to 400 t for the 2010/2011 season was implemented due to uncertainties regarding the status of the resource. It should be noted (Table 3) that throughout the history of the fishery, annual catches have been well below the TAC. It is only in the most recent fishing season (2010/2011) that the annual catch has approached the TAC as a result of the re-introduction of a second vessel into the fishery, presumably coupled with the almost exclusive use of trotline gear, which substantially reduces the impact of cetacean depredation.

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. 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 of 400 t to 320 t.

An MPA in the PEI-EEZ that contains 'no-take' and limited access areas and is primarily aimed at the protection of biodiversity has been proposed. Fishing is currently not allowed within 12 nautical miles of Prince Edward and Marion islands.

Research and Monitoring

Catch-and-effort data are reported by the fishing vessels on a set-by-set basis. 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 (Table 4). Vessels are required to tag and release one fish per tonne of catch. Fish should be selected at random for tagging (say every 100th fish) so that a range of sizes are tagged. Unfortunately, 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.

Table 4: Number of Patagonian toothfish tagged and released per year in the Prince Edward Islands-EEZ, and the number of recaptures per year

Year	Tagged	Recaptured
2005	94	1
2006	128	1
2007	120	4
2008	140	0
2009	74	7
2010	?	?
Total	556	13

The size range of tagged fish has improved in recent years. To date 556 fish have been tagged and 13 have been recaptured (Table 4).

Assessment models incorporating tag data have been developed for many of the Antarctic and Patagonian toothfish stocks in the CCAMLR region. When there are sufficient tag data, the existing population model for the PEI stock will be extended to take account of these data in the model-fitting process. This may help resolve the conflicting results from the current models.

It has been recognised that the change of fishing gear in the fishery has seriously compromised the time series of the abundance index (Spanish longline CPUE) that is used to assess the status of the resource. A research strategy has consequently been implemented for the 2011/2012 fishing season with the objective of calibrating the trotline CPUE against that for Spanish longline to provide a short- to medium-term basis to calculate scientifically defensible TAC recommendations. Efforts are also being directed at continuing work on developing an OMP to enhance effective management of the resource and fishery in a manner that takes proper account of the current uncertainty about resource status.

Current status

The most recent analysis of the status of the resource was conducted in September 2011, and incorporated additional

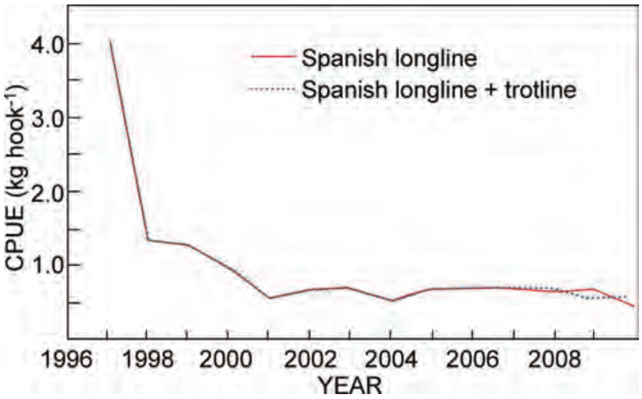


Figure 27: GLMM-standardised CPUE trends (normalised to the mean over the period 1997–2010 period). Trends are shown for data derived only from Spanish longline fishing only and for those derived from both Spanish longline and trotline fishing

catch data (2007 – 2010). Trends in standardised CPUE were used as indices of abundance. The analysis was complicated by the abovementioned gear change in the fishery in recent years. The previously employed general linear model (GLM) standardisation approach was considered to be unreliable due to the low number of Spanish longline sets deployed in 2008, 2009 and 2010 (Figure 26). A general linear mixed models (GLMM) analytical approach was consequently adopted as an alternative to account for gaps in the data. This analysis included the original vessel, year, month and area effects to account for spatial, temporal and vessel-related variability in CPUE, and incorporated an additional gear effect to account for differences in CPUE attributable to the switch from Spanish longlines to trotlines. The analysis indicates that trotlines are definitely appreciably more efficient (by a factor of 2.5–3) than Spanish longlines. Depending on whether or not the trotline data are included in the analysis, standardised CPUE dropped by between 16% and 34% in 2010 relative to preceding years (Figure 27). Although it is recognised that these results are derived from limited data, they do indicate that the resource probably remains in a depleted state and that abundance may be dropping further, which led to the recommendation to reduce the TAC by 20% for the 2011/2012 fishing season.

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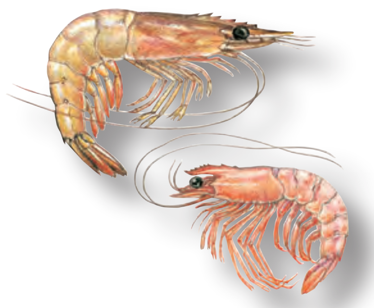
Prawns



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

Introduction

The 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 km2, and a deep-water fishery (100–600 m) between Cape Vidal in the north and Amanzimtoti in the south, covering an area of roughly 1700 km2 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 one-year life-span and the juvenile stages are spent in estuaries; recruitment therefore depends on rainfall and river run-off.

Species captured in the deep-water sector include pink and red prawns *Haliporoides triarthrus* and *Aristaeomorpha foliacea*, langoustines *Metanephrops mozambicus* and *Nephropsis stewarti*, rock lobster *Palinurus delagoae* and red crab *Chaceon macphersoni*. These 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 affected 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 TAE levels that reflect the high interannual 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 only fish in KZN when prawns are abundant, but then relocate 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. Most recently, however, the effort has been low with only four vessels operating in 2010. Recruitment failure on the Thukela Bank as a result of inadequate river run-off has severely impacted the shallow-water fishery in recent years.

Research and monitoring

There is ongoing research on the bycatch of this fishery and the fishery is monitored by observers funded by the Branch: Fisheries Management (DAFF). 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 for this fishery. 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 are available. The catch-and-effort data that were finally used were those provided by skippers on the daily trawl drag sheets, which are captured by the Department, 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 were therefore applied to the catch and CPUE data for the KZN crustacean trawl fishery in 2009. This included a simple equilibrium model,

Table 5: Total catches of the KZN prawn trawl fishery in the various species groups

	Total catch (t)						
	Inshore fishery	Offshore fishery				Both fisheries	
Year	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	123	49	31	5	47	276
2007	18	79	53	24	5	47	226
2008	9	105	31	17	5	35	202
2009	8	197	60	21	10	53	268
2010	7	172	51	23	22	69	345

fitting data separately to the Schaefer and Fox equations (on all four deep-water species combined and then individually). Unrealistically high levels of both MSY and the fishing mortality that would produce this yield (F_{MSY}) were obtained. Data were therefore fitted to both simple and complex non-equilibrium surplus production models (Schaefer, Fox and Pella-Tomlinson), also resulting in unrealistic estimates of MSY and F_{MSY}. The inability of the models to produce reasonable estimates of MSY and F_{MSY} is probably a consequence of the time-series of data only commencing several years after the fishery began. Consideration will be given to utilising alternative methods of stock assessment for this fishery in future.

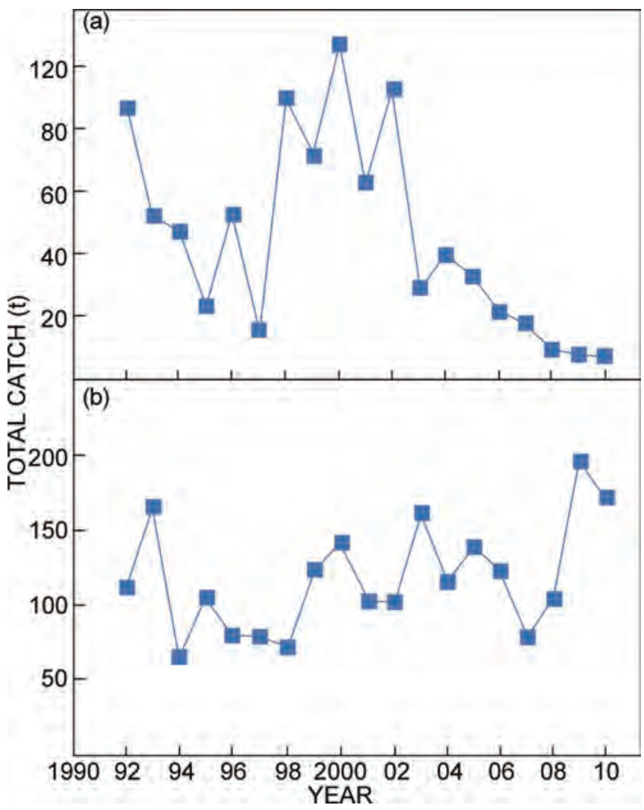


Figure 28: Total annual catches of (a) shallow-water prawns and (b) deep-water prawns off KZN for the period 1992–2010

Current status

The resource 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 by-catches. The 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 (only four vessels were active in the KZN fishery in 2010).

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 has been developed for the 1988–2000 period by the then Department of Water Affairs and Forestry. Very low catches in recent years (Figure 28) 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 was therefore blocked, leading to recruitment failure on the Thukela Bank in the last eight years. This has severely impacted the shallow-water fishery and resulted in the catch reaching a historic low of 7.3 t in 2010 compared with, for example, a catch of 107 t in 2000 (Figure 28, Table 5). As a consequence, it has been recommended that the exploitation levels be retained at the current level, but that fishing on the Thukela Bank should be restricted to between March and August.

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 172 t in 2010, confirming an increasing trend of catches during the past three years (Figure 28). Langoustine catches dropped from 59.8 t in 2009 to 51.2 t in 2010, whereas catches of rock lobster more than doubled from the previous year. Catches of red crab increased slightly from 20.9 t in 2009 to 23.2 t in 2010, remaining at the low level reached in 2002 (Table 5).

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Seaweeds

Stock status	Unknown	Abundant (non-kelp)	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 seaweeds *Gelidium* and *Gracilaria*, as well as small quantities of several other species. All commercially exploited seaweeds are found between the Orange and Mtamvuna Rivers. In the Western and Northern Cape, the South African seaweed industry is currently based on the collection of beach-cast kelps and harvesting of fresh kelps. Collection of beach-cast gracilarioids is localized 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 300–400 jobs. Much of the harvest is exported for the extraction of gums. The international seaweed industry is controlled mainly 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 are often forced to stockpile material for many months while negotiating acceptable prices.

Collection and drying of seaweed is a low-tech activity, whereas 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 supplies of agar from Japan became unavailable. Various potential resources were identified, but commercial exploitation only began in the early 1950s.

The South African industry is 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 29). 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 overexploitation of these resources. Different companies may hold the rights to different resources in the same area.

Management of most seaweed resources is based on TAE, except for fresh kelp, for which a MSY is set in annual permit conditions.

Kelps

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

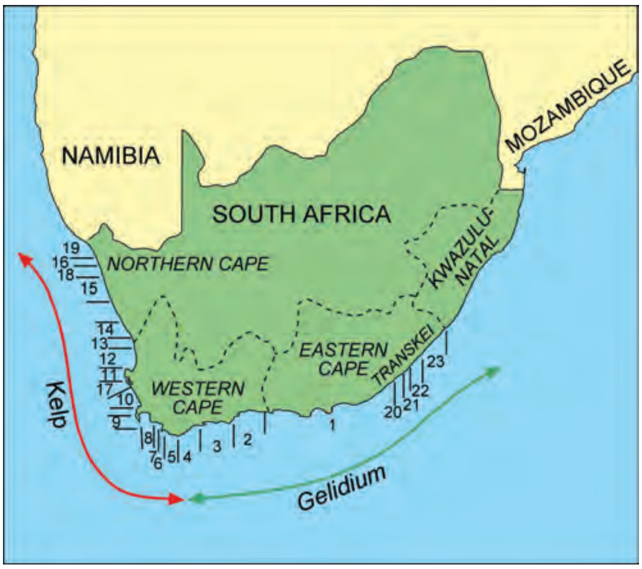

Figure 29: Map of seaweed rights areas in South Africa

Table 6: Annual yields of commercial seaweeds in South Africa, 2000–2010. '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

Year	*Gelidium* (kg dry weight)	Gracilarioids (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)
1999	147 927	269 819	1 443 178	1 501 680	0	273 030
2000	124 614	264 300	759 242	2 784 391	0	608 900
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
Total	1 140 374	633 089	8 034 189	45 494 533	4 903 038	10 008 012

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 more than 1 000 t dry weight per annum have been more usual (Table 6).

Since the early 1980s, a local company has been producing a liquid extract (plant-growth stimulant) from *E. maxima* and marketing this nationally and internationally. A second local company is now producing 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 2010 a total of 5 642 t of fresh kelp fronds were supplied to farmers. Demand for kelp as feed is currently centred around the two nodes of abalone farming activity at Cape Columbine and the area between Danger Point and Hermanus. Kelp harvesters are supplied with a 'Kelp Harvesting Manual', which sets out best practices to ensure sustainability.

Gelidium

Gelidium species contain agar, a commercially valuable colloid with many food and cosmetic uses, and the only medium for cultivating bacteria in medical pathology. The *Gelidium* resource in South Africa comprises *G. pristiodes*, *G. pteridifolium* and *G. abbottiorum*, all most abundant in the Eastern Cape (Areas 1, 20, 21, 22 and 23; Figure 29), where they have been harvested from intertidal areas since the mid-1950s. Yields vary with demand from a few tonnes to about 120 t dry weight annually. In 2010 there was no harvesting from Areas 20–23 (in the former Transkei) because of a fall in *Gelidium* prices.

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 2007.

Other resources

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

Research and monitoring

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

Estimates of kelp biomass are based on infrared aerial imagery, GIS mapping and diver-based sampling. Monthly harvest of fresh kelp is checked against the prescribed MSY as set in annual permit conditions. Since 2008, 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. Current research aims to improve our understanding of kelp biology in order to better manage the resource. Included in this is a study of the relative distributions of our two main kelp species in shallow water (0–5 m) on the West Coast in order to improve biomass estimates and to document their relative distributions in the event of possible climate changes in the future.

Assessment of the gracilarioids is performed on an *ad hoc* basis, because only beach-cast is collected and there

Table 7: Maximum sustainable yield of harvested kelp for all areas for 2010

Area number	Whole kelp (t fresh weight)	Kelp fronds (t fresh weight)
5	2 840	1 420
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	18 938	14 062

*Note: In Area 6, only non-lethal harvesting of fronds is allowed

is therefore no direct effect on the living resource.

Harvesting of *Gelidium* in the Eastern Cape and the biology of *G. pristoides* were comprehensively researched in the 1980s. Current monitoring is by annual inspections of several randomly-chosen harvested and non-harvested shores along the approximately 400 km of Eastern Cape coast where harvesting is done, and annual biomass and density measurements at a permanent study site in Port Alfred, which lies in the centre of Area 1 and is the most intensively harvested. Catch returns are also monitored to ensure that yields do not exceed historical levels: if they did, further inspections and monitoring would be necessary.

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 2010. No commercial activity was reported in five of these areas: in two of them right-holders could not access the resource.

Yields of dry beach-cast kelp totalled 697 t in 2010 (Table 6). A further 206 t wet weight of fresh beach-cast was supplied to abalone farms, together with 5 337 t wet weight 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 five abalone farms in the Gansbaai – Hermanus area, they are supplied by three Rights Areas (Areas 5, 6, 7 and 8), with a substantial potential MSY between them. The fact that there is still substantial potential harvestable biomass ('spare' MSY) bodes well for abalone farms that intend to expand.

In some areas harvests were well below MSY (Table 7). The underharvest 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 state of the resource in those areas. In Area 9, the production of Kelpak (plant-growth stimulant) used almost 1 265 t of fresh kelp (61% of MSY). In all rights areas except 11, the fresh kelp resource can be regarded either as well (but incompletely) exploited, or underexploited.

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

Gracilarioids

This variable and unreliable resource maintained an apparently very low biomass during 2010. Populations were reportedly small and wash-ups minimal. These periodic occurrences appear to have natural causes and have been recorded before. This resource must at present be regarded as commercially unreliable, although occasional wash-ups do still occur.

Gelidium

In 2010 commercial quantities of *Gelidium* were collected only from Area 1, where *G. pristoides* comprises more than 90 % of the harvest. The other species, which make up most of the harvest in Areas 20–23, were reportedly not worth collecting because of prevailing low prices on Asian markets. Catch returns from Area 1 (103.9 t dry weight) were similar to those for the previous year. Inspections and measurements done in April and June 2011 indicate very healthy *G. pristoides* populations with density and biomass values well within normal limits.

Other seaweed resources

There has been commercial interest in *Ulva* and *Porphyra* in Area 11, where research has shown there to be a small but viable resource, and small-scale harvesting may begin there in the near future.

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

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Sharks

Stock status	Unknown	Abundant	Optimal	Depleted	Heavily depleted
			Smoothhound Blue	Soupfin	Mako
Fishing pressure	**Unknown**	**Light**	**Optimal**	**Heavy**	
				Smoothhound Soupfin Blue Mako	

Introduction

There are more than 180 species of sharks, skates, rays and chimaeras identified in South African waters, of which 98 (54%) are caught in 12 fisheries: 10 commercial, one recreational and the KZN bather protection system. Approximately 4 000 t per annum are landed, two thirds as bycatch (e.g in the tuna and swordfish longline) as opposed to target (demersal shark longline) fisheries. Target fisheries for sharks include the demersal longline, pelagic shark longline, bather protection/ shark net, commercial handline, gillnet and recreational fisheries.

Bycatch fisheries include the inshore and offshore trawl, beach-seine, tuna and swordfish pelagic longline, midwater trawl, hake longline and prawn trawl fisheries. Sharks are landed at virtually all Western Cape ports and many other ports along the South African coast. A total of 98 species are impacted by these fisheries. Only the major fisheries in which data are collected by DAFF with their reported species will be included in this report. These fisheries include target fisheries: demersal shark longline, pelagic longline, commercial handline and bycatch fisheries: inshore and offshore trawl and large pelagic longline. Two main groups of sharks are targeted: demersal and pelagic sharks.

Both the demersal shark longline and the commercial handline fisheries target smoothhound sharks *Mustelus mustelus* and *M. palumbes*, soupfin shark *Galeorhinus galeus*, bronze whaler shark *Carcharhinus brachyurus*, dusky shark *C. obscurus*, hammerhead species *Sphyrna* spp., cow shark *Notorynchus cepedianus* and St Joseph shark *Callorhinchus capensis.*

The bulk of soupfin and smoothhound shark trunks and fins are exported to Australia for use in the fillet trade. The value of demersal shark fillets is restricted by the mercury content of larger animals with greater economic incentives to target sharks between 2 and 8 kg. Any larger sharks are purely targeted for the value of their fins. Current (2010) fin prices are unknown. The offshore and inshore trawl fisheries catch similar species to those taken by the commercial linefish and demersal longline fisheries as bycatch. The quantity of demersal sharks caught as bycatch in inshore trawl fisheries is higher than sharks caught by the directed demersal shark longline fishery.

On account of concerns of high pelagic shark catches in the developing domestic swordfish and tuna longline sectors, the pelagic shark longline fishery targeting pelagic sharks such as blue shark *Prionace glauca* and mako shark *Isurus oxyrinchus* was merged into the large pelagic longline fishery in March 2011. Fins from pelagic sharks are exported to Japan, with the mako shark flesh exported to Italy at R14 kg^{-1}. Blue shark flesh is classified as low-value and exported to Uruguay at R4 kg^{-1}.

History and management

Initially, the shark longline fishery was composed of both demersal and pelagic longline vessels. This was later divided into the distinct demersal and pelagic longline fisheries. The demersal shark longline fleet targets demersal sharks, using bottom-set gear in coastal waters (shallower than 100 m), whereas the pelagic longline fleet targets pelagic sharks using offshore pelagic drifting gear.

The demersal longline fishery targets smoothhound and soupfin sharks 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 to target demersal sharks. Due to poor fishery performance, these were reduced to 23 permits and then 11 in 2004. Since 2008, only six permits have remained. Owing to higher biodiversity along the east coast of South Africa, demersal shark longline vessels may not fish north of East London.

Under current management, the bycatch limit for the pelagic longline fishery was set at 2 000 t dressed weight. Once this limit is reached, fishing in the large pelagic fishery would

Table 8: Dressed weight of sharks caught by the demersal shark longline, pelagic shark longine, large pelagic longline, commercial linefish and trawl fisheries in 2010

Species	Weight (t)				
	Demersal shark longline	Pelagic shark longline	Large pelagic longline	Linefish	Trawl
Shortfin mako shark (*Isurus oxyrinchus*)	<0.1	514.6	65.7	0.6	0
Blue shark (*Prionace glauca*)	3.9	198.2	99.5	13.2	0
Soupfin shark (*Galeorhinus galeus*)	106.4	1.6	0	89.4	107.7
Spotted gully shark (*Triakis megalopterus*)	0	0	0	0.1	0
Smoothhound shark (*Mustelus mustelus*)	110.5	10.6	0	35.9	46.9
Requiem sharks (*Carcharhinus* spp.)	33.3	25.3	<0.1	64.3	0
Squalus spp.	<0.1	0	0	0.4	3 100
Broadnose sevengill cow shark (*Notorynchus cepedianus*)	1.8	0	0	7.7	0
Alopias spp.	0	0	<0.1	3.0	0
Sphyrna spp.	2.1	0	0	1.7	0
Zambezi shark (*Carcharhinus leucas*)	0	0	0	0	0
Unidentified skates	36.3	8.5	0	0	703.6
Unidentified sharks	0	0.1	2.2	59.6	53.8
Unidentified rays		0	0	0.6	0
St Joseph shark (*Callorinchus capensis*)	4	0	0	0	812.2

stop. The domestic pelagic longline fishery originally only targeted tuna and swordfish, although shark bycatch was also recorded. Foreign, pelagic tuna-directed fisheries are mostly comprised of Japanese and Chinese vessels targeting offshore oceanic species such as mako shark, blue shark, and carcharhinid sharks. Permit conditions for the large pelagic longline fishery include prohibition of wire tracers on vessels except for previous pelagic shark longline vessels. No thresher (*Alopias* spp.), hammerhead (*Sphyrna* spp.), oceanic whitetip (*Carcharhinus longimanus)*, and silky (*C. falciformis*) sharks may be retained on board the vessels. When fins are removed from trunks they may not exceed 8% of the trunk weight for mako and carcharhinid sharks and 13% of the trunk for blue shark.

The commercial linefishery is the oldest fishery to have targeted sharks in South Africa. Shark catches by this fishery have fluctuated dramatically in response to market forces. Since 1991, however, there has been a steady increase in catches that is correlated with a decrease in the availability of valuable linefish species. There are no catch limitations currently for the commercial linefishery; however, the recreational fishers have a daily bag limit of one shark, skate, ray or chimaera.

The inshore trawl fishery, concentrated around Mossel Bay and Port Elizabeth, is responsible for the greatest catch of demersal shark and other cartilaginous fish species. Cartilaginous fish landed by inshore trawlers include biscuit skate *Raja straeleni*, smoothhound sharks, soupfin sharks and St Joseph shark. The most common shark caught in trawl fisheries on the Agulhas Bank is the shortspine spurdog *Squalus megalops*. Although dogsharks of the genus *Squalus* are highly abundant, they are considered too small for processing, although *S. megalops* and *S. mitsikurii* are sometimes landed. Between 1979 and 1991, sharks comprised 0.3% of South Africa's total commercial landings by mass. Annual shark catches 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 fisheries is difficult to quantify. The incentives for trawlers to target sharks and other cartilaginous species have increased with the increasing market value of sharks.

Research and monitoring

Historically, there has been little co-ordinated research relating to the biology and stock assessment of commercially valuable sharks. Previous stock assessments conducted on such sharks from South Africa have been hampered by the lack of fishery-independent data, poor fisheries data and lack of life-history studies. Furthermore, the limited understanding of the movement and reproduction of these sharks complicates their assessment and limits the contribution of useful management advice (i.e. nursery grounds and stock boundaries).

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

Current research is directed mainly at collecting fishery-

Table 9: Dressed weight, and normalised CPUE of shark species caught by the demersal shark longline fishery between 2008 and 2010

	Weight (t)			CPUE (kg hook^{-1})		
	2008	2009	2010	2008	2009	2010
Soupfin shark (*Galeorhinus galeus*)	31.8	40.2	119.3	0.89	0.70	1.40
Smoothhound shark (*Mustelus mustelus*)	64.1	56.4	121.3	1.28	0.70	1.01
Requiem sharks (*Carcharhinus* spp.)	12.6	11.9	33.3	1.12	0.66	1.23
Broadnose sevengill cow shark (*Notorynchus cepedianus*)	2.0	1.0	1.9	0.76	0.56	0.68

independent data for demersal and pelagic sharks. A survey directed at demersal sharks was initiated in 2008, but on account of financial constraints the survey was restricted to around Robben Island. In 2011 this survey was extended to include the entire area between Mossel Bay and Dassen Island. This area represents the fishing area for five of the six vessels operational in the demersal shark longline fishery. Although initial surveys only included Robben Island, these data will still be useful for future assessments. A shark component was also included into the large pelagic fishery-independent survey. Data on catch composition, length, sex and other biological characteristics are currently being collected.

Life-history research includes the investigation of age and growth, maturity and reproduction of commercially valuable sharks. Age, growth and validation studies necessary for accurate and up-to-date stock assessments are being conducted for these sharks. In order to develop appropriate management strategies for shark resources, it is vital to elucidate pertinent aspects of their reproductive biology, such as size and age at maturity, fecundity, sexual segregation, pupping and mating migrations, and the use of nursery grounds.

Sharks are highly mobile and exhibit dramatic large-scale migrations, including vertical migrations and even trans-oceanic migrations. Such movement and migration of commercially important sharks will affect the supply of sharks to fishing areas, the density of fish in less-exploited areas and the effectiveness of MPAs as a management tool for sharks. Movement studies are thus currently being undertaken on smoothhound, soupfin, broadnose seven gill cow, blue and mako sharks. Research indicates that blue sharks are freely moving between the Atlantic and Indian oceans and may indicate the existence of a southern stock of blue sharks as opposed to separate southern Atlantic Ocean and southern Indian Ocean stocks. This proposed movement has significant consequences for previous stock assessments conducted by Regional Fisheries Management Organisations (RFMOs) and potentially for the movement of other large pelagic species. This research also highlighted the existence of a nursery ground for blue shark off Southern Africa in the Benguela/Agulhas Current transition zone.

Research on smoothhound sharks in Langebaan Lagoon shows that individuals of this commercially valuable species spend large portions (up to 80%) of their time within the confines of the MPA. These sharks use the MPA for reproduction, feeding and as nursery grounds. Occasionally, they leave the protection of the park and become vulnerable to fishing. The existence of eight other MPAs within the distribution of the smooththound shark could provide considerable protection provided that they spend a large portion of their time within the MPA and/or they use it for reproduction, nursery grounds and other vital life-history activities.

Research into life-history parameters, movement and stock delineation, as well as the collection of fishery-independent data and eventual assessment, is a long-term endeavor. Once a sufficient amount of data are collected, key species will be reassessed according to priority listing.

Current status

There is a paucity of data on life-history characteristics, movements and migrations, for most South African sharks. The 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 inconclusive due to poor-quality data and high levels of under-reporting. Despite the difficulties encountered with inadequate information for most sharks, stock assessments recently conducted on the commercially valuable smoothhound and soupfin sharks indicate that stocks of these are in optimal and depleted status respectively.

Fishery-dependent data are currently only being collected for eight species and a further seven groups (Table 8). This represents a small proportion of the 98 species of sharks impacted by South African fisheries. However, it does represent the most commonly caught and therefore highest tonnage groups. Certain species are difficult to identify and are currently being combined, including *Carcharhinus* spp., dogfish, skates and rays. Table 8 shows catches of these sharks, the largest being 3100 t of dogfish, 748 t of unidentified skates, 812 t of St Joseph shark, 580 t of mako shark and 315 t of blue

Table 10: Dressed weight, and normalised CPUE of shark species by the pelagic shark longline and large pelagic fishery between 2008 and 2010

	Weight (t)			CPUE (kg hook^{-1})		
	2008	2009	2010	2008	2009	2010
Shortfin mako shark (*Isurus oxyrinchus*)	464.6	500.8	581.0	3.09	3.03	3.22
Blue shark (*Prionace glauca*)	264.3	274.8	298.2	1.76	1.67	1.65
Requiem sharks (*Carcharhinus* spp.)	18.0	49.7	24.1	0.12	0.30	0.13
Thresher sharks (*Alopias* spp.)	3.8	<0.1	<0.1	0.03	<0.01	<0.01
Hammerhead sharks (*Sphyrna* spp.)	0.3	<0.1	<0.1	<0.01	<0.01	<0.01

shark. Sharks are caught by multiple fisheries, sometimes predominantly as bycatch rather than targeted catch.

Catches of soupfin, smoothhound and requiem sharks by the demersal shark longline fishery have increased dramatically over the past three years (Table 9). However, catches of broadnose sevengill cow shark have remained relatively stable and are mainly accidental. CPUE fluctuates between 2008 and 2010 for all species and it is thought that the fluctuations are largely in response to market trends. There is a strong seasonal and spatial component to catch and effort data for the two most valuable species, soupfin and smoothhound, with alternate targeting strategies for each.

Catches of pelagic sharks have increased since 2008 for shortfin mako, blue and requiem sharks, whereas catches of thresher and hammerhead sharks have decreased (as per permit conditions) (Table 8). CPUE has remained constant for these species during this period. Spatio-temporal analyses on nominal and standardised CPUE revealed seasonality in catches of blue shark. Largest abundances of these sharks were seen in summer and autumn off the West Coast of South Africa. Standardised CPUE for the large pelagic fishery revealed that blue shark abundance has remained relatively stable from 1998 to 2008. This is contradictory to findings reported from observer data from the tuna-directed longline fishery, which found a significant reduction in CPUE from 2001 to 2005. Catch-and-effort data from previous years have suggested that shortfin mako stocks may be overexploited in South Africa and that effort is being switched from mako to targeting blue shark. Such a change in effort is characteristic of a shark 'boom and bust' fishery. Such fluctuations in catch trends are common in shark fisheries, especially those with large species that migrate long distances.

Elasmobranch fisheries are widely accepted as being unsustainable as sharks have life-history strategies that make them inherently vulnerable to overexploitation. Stock assessments are the responsibility of RFMOs such as the Indian Ocean Tuna Commission (IOTC) and ICCAT. These organisations are currently unable to adequately assess the stocks due to poor life-history data. However, there is global concern as to the status of these stocks. The International Union for Conservaton of Nature (IUCN) red list status of sharks targeted or caught as bycatch by shark fisheries in South Africa have recently been changed; these include the oceanic white tip (Vulnerable), soupfin (Vulnerable), longfin mako (Vulnerable), great hammerhead (Endangered – not commonly caught in South Africa), and spiny dogfish (Vulnerable) sharks.

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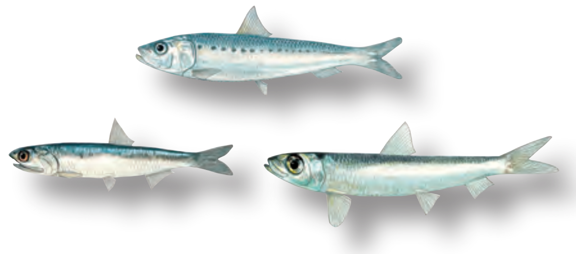
Small pelagic fish (sardine, anchovy and round herring)



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

Introduction

Anchovy *Engraulis encrasicolus*, sardine *Sardinops sagax* and round herring *Etrumeus whiteheadi* are small, forage fish species that live in surface and near-surface waters over the continental shelf off most of South Africa's coast. These fish form large schools that are targeted by purse-seiners that can catch up to 400 t in a single haul. Anchovy and most round herring caught are processed into fishmeal and fish oil in factories located primarily on the West Coast, whereas sardine are canned or frozen for human consumption, pet food and bait. The pelagic fishery is the country's largest in terms of landed catch and direct and indirect employment, and, after the demersal fishery, its second most valuable. In addition to sustaining this economically important fishery, small pelagic fish play an important role in the ecosystem, being significant predators of the plankton and important, and in some cases virtually the only, prey of a variety of species including bony and cartilaginous fish, marine mammals and seabirds. Their mid-level position in the foodweb means that small pelagic fish play a critical role in ecosystem functioning.

Small pelagic fish around the world are characterised by highly variable recruitment that results in large fluctuations in population size. Their short lifespans and planktivorous diets mean that they respond rapidly to environmental influences, which, when coupled with their high fecundity, means that these species can be highly productive and show rapid increases in population size under favourable environmental conditions and appropriate harvesting levels. Under unfavourable environmental conditions and/or when fishing levels are too high, however, their populations can show dramatic declines. Off South Africa both anchovy and sardine have shown this variability in recent decades; anchovy rebounded from a low of around 160 000 t in 1996 to close to seven million tonnes in 2001, whereas sardine exhibited a dramatic decline from over four million tonnes in 2002 to just over ¼ million tonnes in 2007.

Small pelagic fish populations can also exhibit changes in their distribution patterns that are often linked to changes in population size. Between the mid-to-late 1990s and early 2000s the sardine population grew steadily and showed a shift in relative distribution, with most of the biomass located off the West Coast (i.e. to the west of Cape Agulhas) during the 1990s but shifting farther east off the South Coast during the 2000s. The shift was followed by several successive years of poor recruitment that resulted in lowered sardine abundance particularly off the West Coast, and had a negative impact on the fishery, with purse-seiners having to travel farther east to catch sardine and hence incurring increased costs. The shift also had pronounced ecological impacts, with sardine predators such as the Cape gannet *Morus capensis* off the West Coast forced to switch from feeding primarily on sardine to feeding primarily on hake offal discarded by demersal trawlers. The lower energetic content of hake

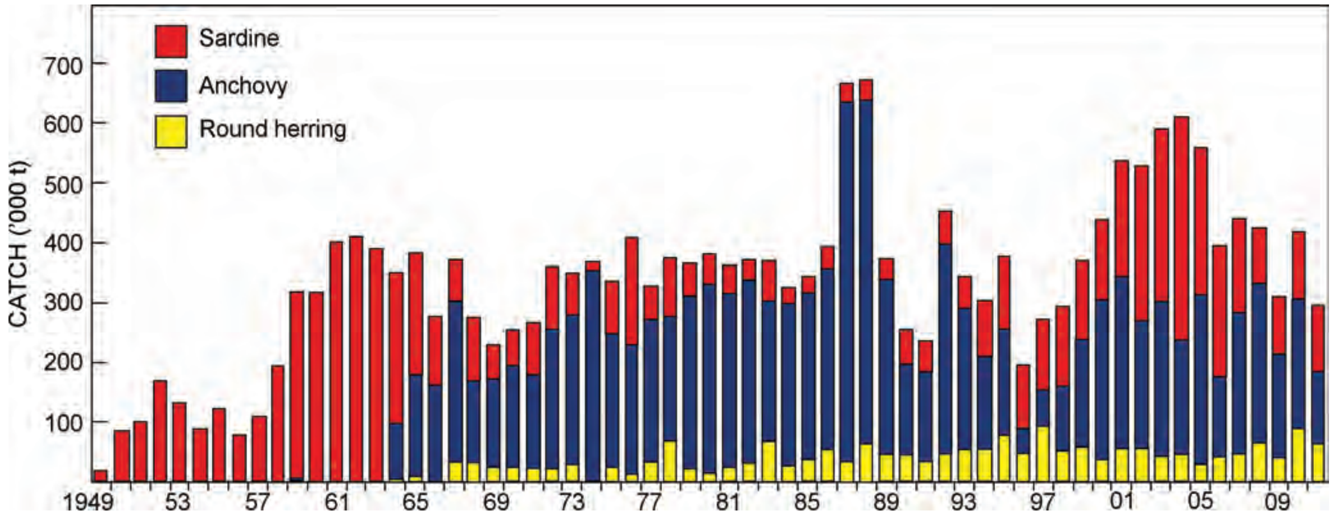


Figure 30: Annual catches of sardine, anchovy and round herring taken by South Africa's pelagic fishery, 1949–2011

compared to sardine and other small pelagic fish species, together with the increased distance that gannets had to fly to feed on hake discards, resulted in reduced breeding success of this species off the West Coast. Anchovy spawners have also shown a shift in their relative distribution, from being located primarily to the west of Cape Agulhas to being located primarily off the South Coast to the east of Cape Agulhas. That shift was abrupt, occurred in 1996 and has persisted since, and has been plausibly linked to an abrupt change in environmental conditions off the South Coast. No clear environmental signal has been linked to the change in sardine distribution although such may exist, and the higher fishing intensity on sardine off the West Coast compared to off the South Coast may also have been a contributing factor.

History and management

Purse-seining off the West Coast started in the 1930s, but significant effort in this fishery was only applied in the late-1940s in response to the post-World War II demand for canned fish. Vessels initially targeted adult horse mackerel and sardine off the West Coast, but catches of the former declined steadily and sardine soon dominated. Landings of this species peaked at 410 000 t in 1962 before declining rapidly (Figure 30), and purse-seiners started targeting anchovy using smaller-meshed nets. Juvenile (recruit) anchovy made up the bulk of landings, being caught as they moved from the West Coast nursery grounds to the spawning grounds off the South Coast. Anchovy dominated catches for the next three and a half decades, with annual landings varying between 40 000 and 596 000 t (Figure 30). Sardine catches rose steadily from the early 1980s to the end of the 1990s, and then increased substantially to 374 000 t in 2004 following rapid growth in the population size, with most of the sardine landed during this recent boom period being caught off the South Coast. Catches dropped sharply thereafter following the population decline.

Whereas anchovy are caught primarily off the West Coast during the winter, adult sardine are caught throughout the year and off the West and South coasts. Because sardine school together with anchovy as juveniles, the recruit-based anchovy fishery also catches some sardine (and to a lesser extent round herring) recruits. Round herring (West Coast red-eye) are more difficult to catch and hence have not been as intensely targeted as anchovy and sardine. Catches of this species have been reported from the mid-1960s but have never exceeded 100 000 t or dominated pelagic landings (Figure 30). This species is considered to be underutilised and at present supplements pelagic fish catches when anchovy and sardine are not available or when the population size of one or both of these species is low. Round herring are mainly caught off the South-west coast during autumn before anchovy recruits arrive on the West Coast fishing grounds.

Current management of the fishery for small pelagics is based on an OMP that consists of formulae that base TAC levels on observed stock sizes. Because they school together as juveniles, catches of both anchovy and sardine cannot be simultaneously maximised, since large anchovy catches will result in a high juvenile sardine bycatch that will reduce recruitment and hence sardine population size. OMP formulae have been selected to calculate a trade-off between anchovy and sardine catches that represents an overall pelagic industry preference as expressed during the allocation of long-term rights in this fishery. The formulae also aim to maximise average directed sardine and anchovy catches in the medium term whilst ensuring that the risk of collapse of either population is not above previously agreed levels. The OMP also includes constraints on the extent to which TACs can vary from year to year in order to enhance industrial stability. Models of anchovy and sardine are used to provide 20-year projections of their population sizes that are used in simulation testing of OMP prototypes, with the OMP that best meets criteria pertaining to stock depletion levels, average annual catch, and interannual catch variability being selected.

The OMP sets an annual TAC for fishing directed at adult sardine and an annual 'Initial' TAC for anchovy, both based on adult population sizes estimated from the spawner biomass survey conducted between October and December the preceding year. A 'Final' anchovy TAC is set mid-year, depending on anchovy recruitment strength observed during the May/June recruit biomass survey. An 'Initial' total allowable bycatch (TAB) limit set for juvenile sardine at the start of the year is also revised to a Final TAB, depending on recruitment

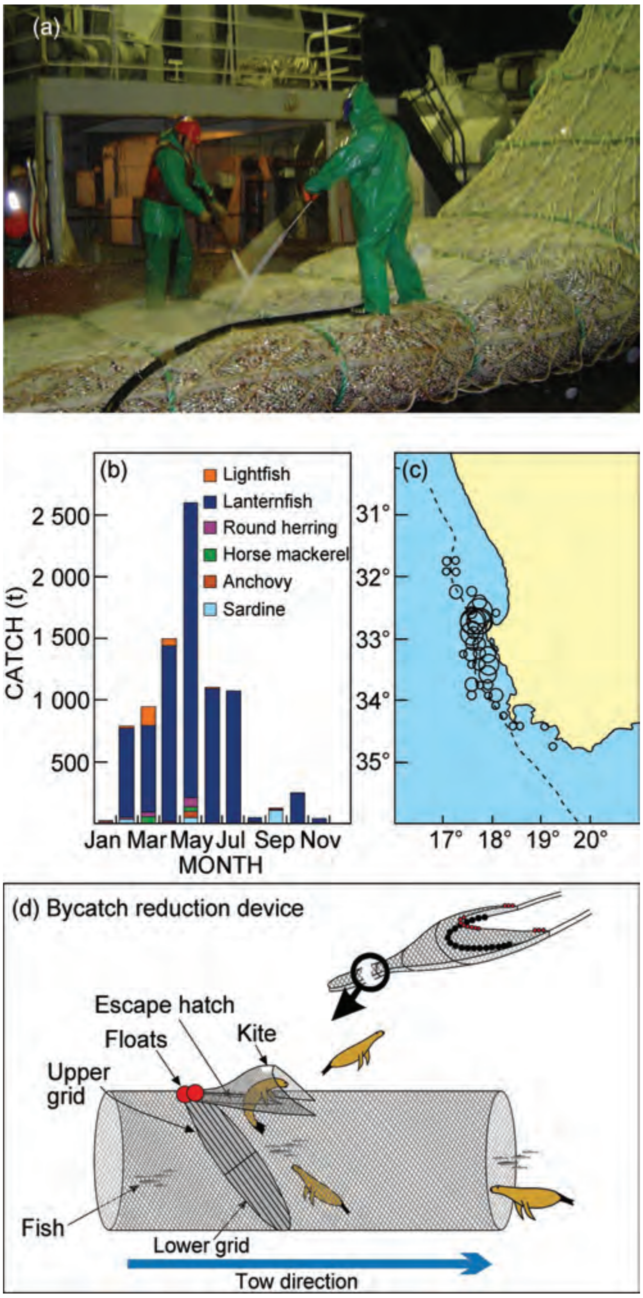


Figure 31: Experimental midwater trawling for small pelagic and meso-pelagic species, showing (a) a good catch of round herring, (b) the catch per species by month during 2011, (c) the distribution of catches of lanternfish during 2011 (circle size is proportional to catch), and (d) a schematic showing how seals use the bycatch reduction device fitted to the midwater trawl to escape

strength. A fixed PUCL of 100 000 t is set for round herring, irrespective of its population size, and a PUCL of 5 000 t for bycatch of juvenile horse mackerel (also taken in anchovy-directed fishing) is also applied. An annual PUCL of 50 000 t for meso-pelagic fish species has also been set from 2012 onwards in response to increased catches of lanternfish *Lampanyctodes hectoris* (see below).

A recent development in this fishery has been the granting of two experimental permits to investigate the feasibility of catching pelagic fish using single or paired pelagic trawling. Operations started in late-2010 and were initially directed at the small pelagic species, with just over 700 t (the majority of which was sardine and anchovy) caught using this method. In 2011, pelagic trawlers switched to targeting primarily the mesopelagic species and a total catch of 8 500 t was made, 91% of which was lanternfish caught off the West Coast primarily between February and July (Figure 31). Experimental pelagic trawling for pelagic and mesopelagic species has had 100% observer coverage, with observers reporting species composition and length frequency data per trawl in addition to making observations on bycatch and trawl warp strikes by seabirds. Tori lines to minimise warp strikes have been successfully deployed, and whereas seal mortality was initially a concern, the reconfiguration of trawl nets and bycatch reduction devices positioned in the nets has reduced this. Paired pelagic trawling has been attempted but with little success as yet.

Ecosystem considerations in this fishery focus on the need to consider impacts of the removal of forage fish by the fishery on dependent predator species, in particular seabirds such as African penguin *Spheniscus demersus* and Cape gannet. These seabirds are restricted to foraging close to their breeding colonies when rearing chicks and their reproductive success may be determined, in part, by the availability of small pelagic fish around those colonies. A feasibility study to investigate whether experimental closure of areas to pelagic fishing around some island penguin breeding colonies will have a detectable effect on penguin reproductive success was initiated in 2008. An area of 20 km radius around Dassen Island on the West Coast was closed to fishing for 2008 and 2009, and a similar-sized area around Robben Island was closed in 2011 and will again be closed in 2012. Off the South Coast, areas around St Croix Island and Riy Banks in Algoa Bay were closed for 2009, 2010 and 2011 and another area around Bird Island will be closed in 2012. Results from this study are as yet inconclusive and future closures around these and other penguin breeding colonies are being considered. A model of the population dynamics of penguins on Robben Island has been further developed, and indicates that adult penguin survival there is inversely correlated with sardine abundance west of Cape Agulhas. This model will be coupled with pelagic fish population dynamics models so that the impact on penguins of predicted future fish biomass trajectories under alternative harvest strategies can be evaluated. Inclusion of the penguin model is part of development of the new small pelagic fish OMP due to be implemented in 2013.

Research and monitoring

Anchovy and sardine populations are monitored by means of hydro-acoustic surveys conducted biannually since 1984. A summer biomass survey estimates the total size of the stock and a winter recruit survey estimates the number of fish that recruit to the population. Data for the estimation of a number of other key biological parameters (e.g. age structure, stock structure) are also collected, some of which are required as input for the OMP and can only be estimated accurately from data collected during fishery-independent surveys. Additional samples for a variety of studies on aspects of the biology and ecology of small pelagic fish species are also collected during these surveys. Currently, the quantity and quality of information provided by these surveys is among the best in

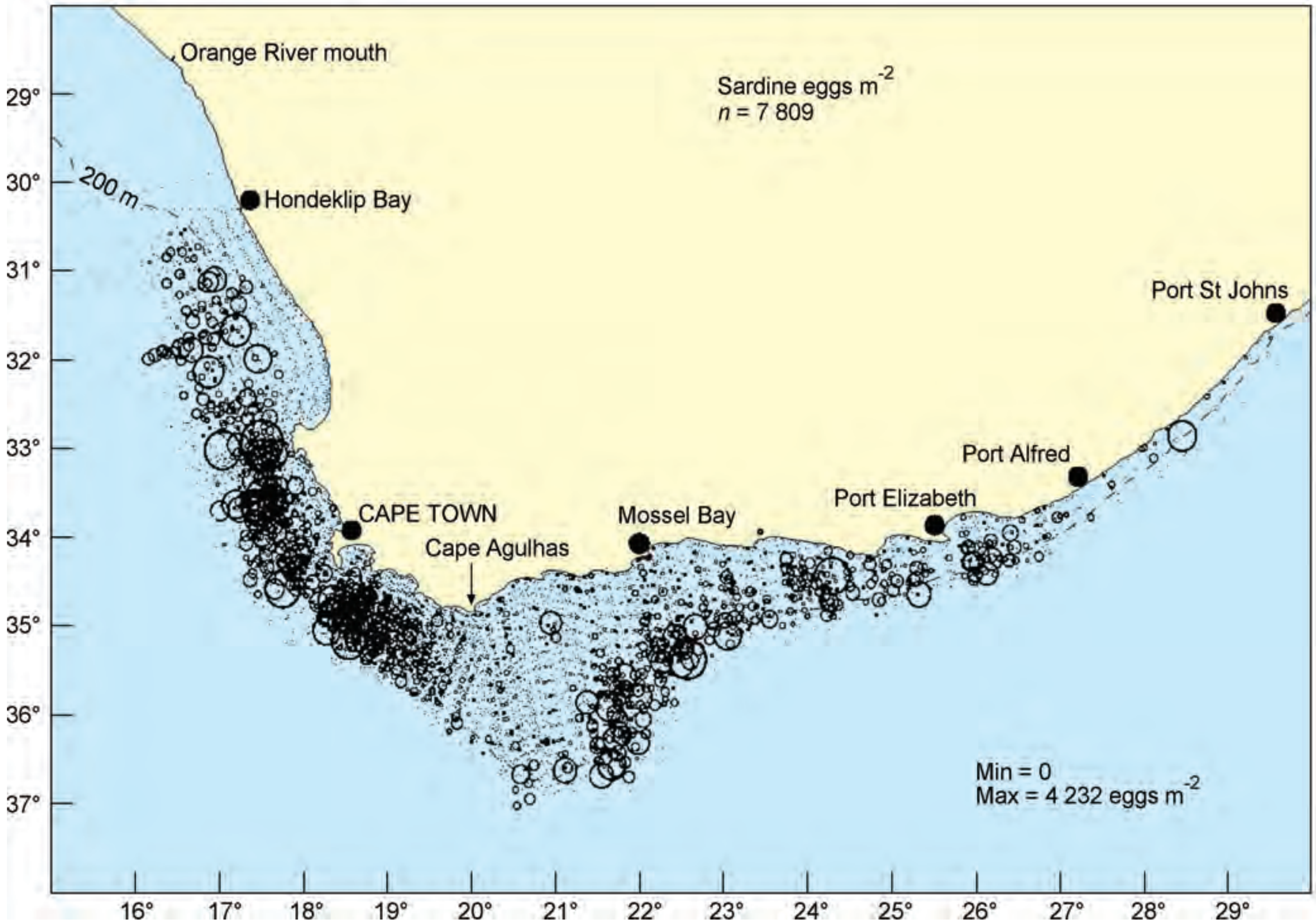


Figure 32: Composite sardine egg density map derived from CalVET net samples collected during pelagic spawner biomass surveys over the period 1986–2009

the world, and several recent studies have compared pelagic fish abundance and distribution patterns observed during these surveys with data on the foraging patterns and diet of various seabird species. Hydro-acoustic surveys of pelagic fish abundance around some penguin breeding colonies have been conducted using a small boat (semi-rigid inflatable) and were initiated in 2009 as part of the study to investigate the effects of closure to pelagic fishing on penguin reproductive success. Several of these surveys have been conducted, principally around Dassen and Robben Islands, but on a few occasions around St Croix and Bird Islands in Algoa Bay, and these have provided high-resolution data on fish abundance and distribution patterns that will be compared to penguin data. The small boat acoustic survey programme will continue in 2012.

In addition to these fishery-independent surveys, accurate data on catch statistics including landed mass, species composition, and catch position and date are obtained from the pelagic fishery. Samples from commercial catches are processed to obtain the length and age frequency distributions of harvested fish required as input in the pelagic population dynamics models, in addition to other data on biological characteristics such as sex and gonad maturity stage, and fish condition.

Research to assess stock structure of the South African sardine population has been conducted over the past few years using a multidisciplinary approach including studies on distribution patterns, spawning areas, meristics (number of vertebrae and gill rakers) and morphometrics (body shape, otolith shape, gill-raker length and spacing), parasite assemblages, and life-history characteristics (length-at-maturity and length-at-age). These studies have shown consistent differences in several biological characteristics of sardine from the West, South and East (KZN) coasts, suggesting the presence of at least two and possibly three phenotypically differentiated stocks. Sardine egg distribution data collected during summer biomass surveys clearly shows the separation in spawning grounds between the putative western and southern stocks (Figure 32). The putative eastern stock is that which undertakes the annual winter sardine run up the KZN coast. Since the amount of sardine caught during the sardine run is low (<1 000 t per annum) compared to that landed off the West and South coasts, that stock can be ignored for present management of the pelagic fishery. Preliminary results from genetic analyses show a large number of sardine haplotypes and do not indicate genotypic (i.e. genetically distinct) stocks. That the South African sardine population comprises multiple stocks that are not isolated but are linked, most likely through mixing of subadults between them, is now considered more plausible than the hypothesis of a single, completely mixed population. This large-scale stock structure in the sardine population will be incorporated into some OMP prototypes during revision of the OMP for the pelagic fishery, which may lead to spatially explicit management such as separate TACs for the western and southern stocks.

Current status

Annual TACs and landings

Combined landings of anchovy, sardine and round herring in 2011 were just under 300 000 t, down from the 400 000 t reported in 2010 and due primarily to a reduced anchovy catch. The combined catch for 2011 was slightly below the long-term average annual catch of 335 000 t. In 2011, anchovy accounted for only 120 000 t, the lowest landing of this species for the past 13 years. This was despite a TAC of close to 400 000 t (Figure 33a), itself reduced from the almost 600 000 t set in 2010 and reflecting the low anchovy recruitment in 2011.The low anchovy catch in 2011 was also partly caused by area closures due to high bycatch levels of juvenile horse mackerel (see below).The directed-sardine catch for both 2010 and 2011 was almost 90 000 t and filled the TACs set (Figure 33b) for these years. This TAC of 90 000 t is the minimum under OMP-08 (the present OMP) in the absence of exceptional circumstances, invoked when the sardine biomass falls below a pre-specified level, and reflects the still low size of the sardine population. Sardine bycatch, at around 25 000 t for both 2010 and 2011, was substantially less than the TAB set for 2010 (which at 110 000 t reflected the good sardine recruitment and high anchovy TAC set for that year) and half of that set for 2011 (Figure 33c). This under-catch of the sardine TAB is encouraging, because the OMP, whilst making provision for occasional high bycatch levels, assumes that the TAB will be under-caught on average.

Totals of 88 000 and 65 000 t of round herring were landed in 2010 and 2011 respectively (Figure 33d), being the second- and fifth-highest annual landings of this species and continuing an increasing trend in recent years of catch levels approaching the PUCL. This is likely in response to the low sardine TACs in the past few years and the recent initiation of processing of round herring for human consumption.

Whereas the annual PUCL of 5 000 t for juvenile horse mackerel was not caught in 2010, in 2011 the PUCL was increased twice during the year, first to 10 000 t and then to 12 000 t, in order to accommodate the high abundance arising from strong recruitment of horse mackerel off the West Coast during the anchovy fishing season. Almost 11 000 t of horse mackerel were caught, primarily from February to April and again in July 2011. This was despite local adaptive management measures that saw pelagic fishing blocks (PFBs; 10 n mi × 10 n mi blocks within which catch data are recorded and grouped) closed to purse-seining for a period of a week if horse mackerel bycatch exceeded 25% of the total catch for a given set. After the closure a 'voorloper' (or scouting) vessel would fish in the PFB and, if horse mackerel bycatch again exceeded 25%, the block would remain closed for a further week. This adaptive management saw significant portions of the anchovy fishing area closed during 2011, for prolonged periods in some instances, which had a serious negative impact on the anchovy fishery.

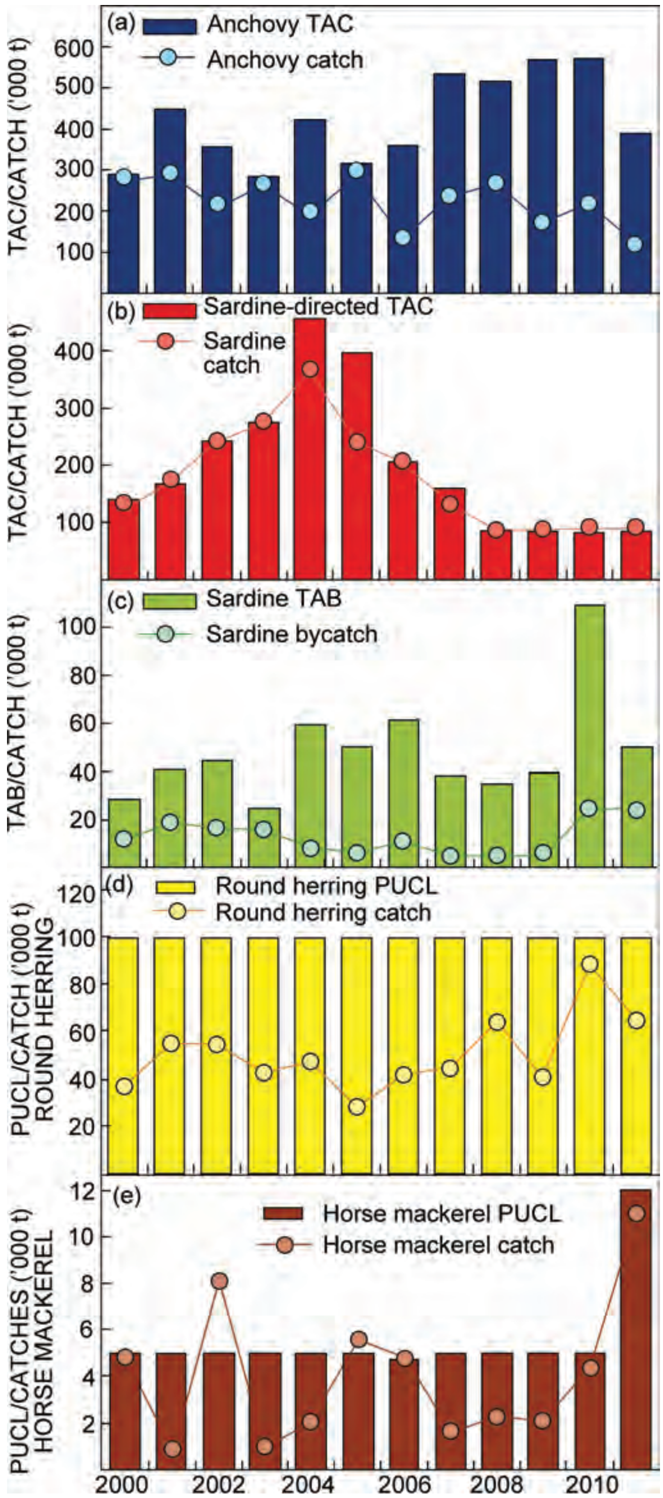


Figure 33: Total allowable catches (TACs), total allowable bycatch (TAB) and precautionary upper catch limits (PUCLs), and subsequent landings for each by the South African pelagic fishery for (a) anchovy, (b) directed sardine, (c) sardine bycatch, (d) round herring and (e) horse mackerel, 2000–2011

Recruitment strength and adult biomass

Whereas anchovy recruitment in 2010 was high, the subsequent estimate of adult biomass was surprisingly low and had dropped to 2 million tonnes from almost 4 million tonnes in 2009 (Figure 34a). In 2011, the anchovy recruitment strength of 104 billion fish was the lowest of the past 14 years. Consequently, anchovy biomass also dropped sharply in 2011, and at

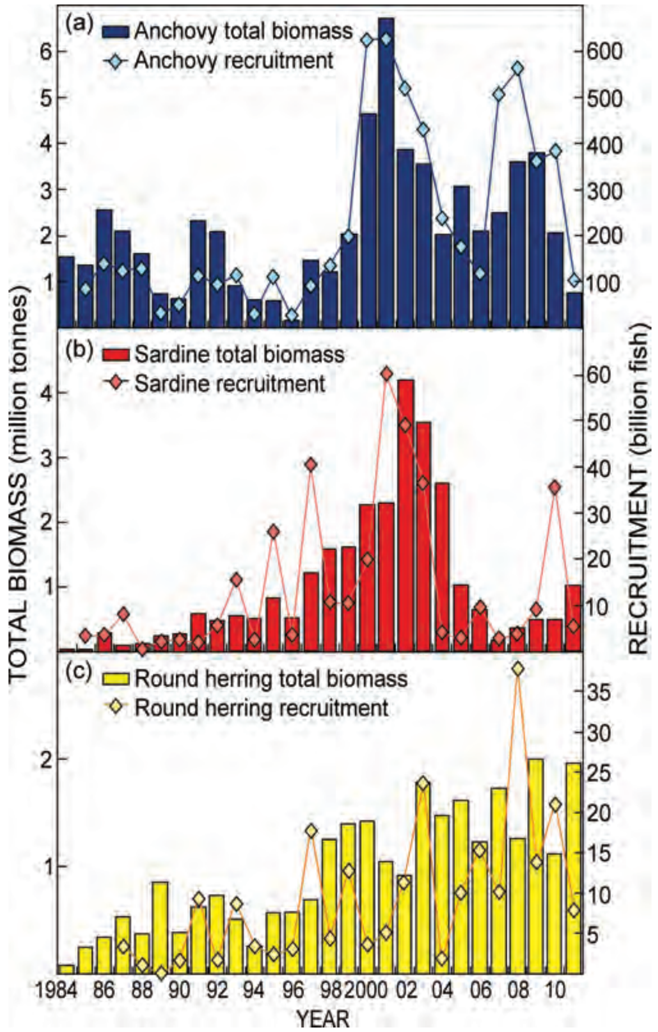


Figure 34: Time-series of acoustically estimated recruitment strength and total biomass of (a) anchovy, (b) sardine and (c) round herring, 1984–2011

750 000 t was the lowest observed during the past 15 years.

Sardine recruitment was also high in 2010, and at 36 billion fish this value is the fifth-highest of the 27-year time-series (Figure 34b). However, the estimated 500 000 t of sardine biomass in 2010 was not significantly different from that of the preceding year. Low sardine recruitment was observed during the 2011 winter recruit survey, but this was followed by a biomass estimate of 1 million tonnes. This increase is likely mostly due to the strong recruitment of 2010. Whereas some sardine adults were observed in 2011 between Hondeklip Bay and Lamberts Bay off the West Coast, a positive sign given the low availability of sardine there in recent years, over 80% of the sardine biomass was distributed to the east of Cape Agulhas, a situation similar to the mid-2000s. If indeed there are two sardine stocks, this would indicate that the western stock size remains low whereas that of the southern stock has increased. The low abundance of sardine off the West Coast will likely have negative impacts on both the fishery and predators in that region.

Recruitment of round herring in 2010 was estimated at 21 billion fish, the third-highest of the time-series (Figure 34c). As was observed for the other two species, however, this did not translate into an increased adult biomass in that year, which declined to half that estimated in 2009, the highest value yet recorded. Moderate round herring recruitment in 2011 was followed by a biomass that doubled to almost 2 million tonnes, an estimate not significantly different from the previous maximum. In 2011, round herring biomass was larger than either that of anchovy or sardine, only the second time this has occurred in the past 27 years. The observed steady increase in estimated round herring recruitment and biomass through time since the inception of the hydro-acoustic surveys reflects, in part, increased survey effort directed at sampling round herring, but the increase is also likely due to an increase in population size.

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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. For this reason, it is restricted to a commercial sector.

Products (be it 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 declining Rand to Dollar exchange rate make the sector lucrative. Prices for commodities fluctuate and the sales prices in the USA in 2007/08 were the equivalent of R350–R400 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, 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 2007/2008 was approximately R150 million.

History and management

The South Coast rock lobster was first described in 1900 and was recorded occasionally in trawler catches of soles taken at a depth of about 70 m. The commercial fishery only 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 stretching back to 1974. The fishery was initially regulated only by limiting the number of traps permitted per vessel. Catches and catch rates declined significantly between 1977 and 1979 (Figure 35). The introduction of management measures such as reduction of effort and catches during the early 1980s resulted in resource recovery (Figures 35, 36). 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 35), and a more rigorous procedure for stock assessment was developed in 1994.

The fishing season for South Coast rock lobster is year-round, extending from 1 October to 30 September of the follow-

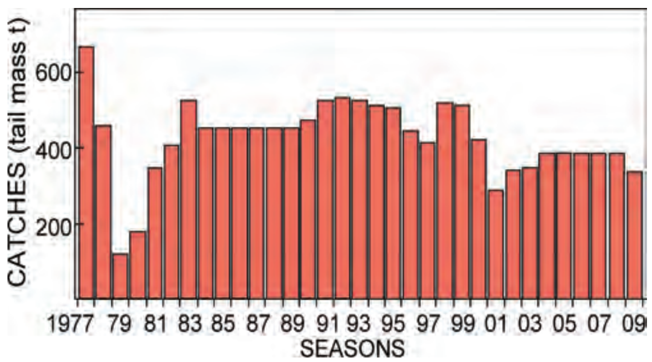

Figure 35: Annual catches of South Coast rock lobster, 1977–2009

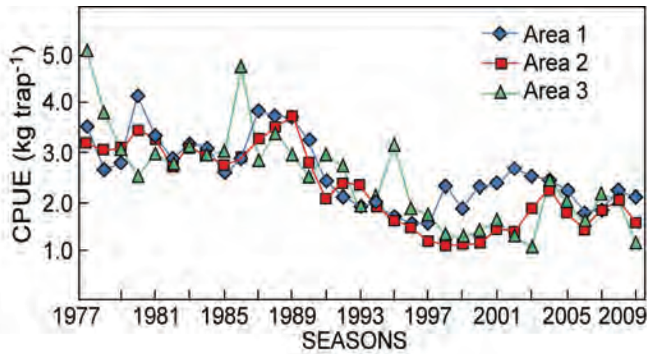

Figure 36: Trend in CPUE of South Coast rock lobster by area, 1977–2009

Table 11: South Coast rock lobster historical records of TAC, TAE and standardised CPUE by area

Season	TAC (tail mass,t)	TAE (Allocated seadays)	Standardised CPUE (kg trap^{-1})		
			Area 1	Area 2	Area 3
1977/1978			3.527	3.189	5.100
1978/1979			2.640	3.040	3.798
1979/1980			2.780	3.084	3.019
1980/1981			4.158	3.435	2.493
1981/1982			3.286	3.269	2.991
1982/1983			2.849	2.660	2.805
1983/1984			3.185	3.099	3.156
1984/1985	450		3.092	3.001	2.901
1985/1986	450		2.548	2.708	3.001
1986/1987	450		2.887	2.865	4.737
1987/1988	452		3.835	3.229	2.805
1988/1989	452		3.700	3.492	3.377
1989/1990	452		3.660	3.695	2.928
1990/1991	477		3.211	2.753	2.469
1991/1992	477		2.368	2.016	2.915
1992/1993	477		2.053	2.318	2.661
1993/1994	477		1.862	2.279	1.814
1994/1995	452		1.901	1.837	2.030
1995/1996	427		1.640	1.584	3.106
1996/1997	415		1.507	1.406	1.806
1997/1998	402		1.474	1.114	1.662
1998/1999	402		2.258	1.049	1.241
1999/2000	377		1.800	1.055	1.199
2000/2001	365	2 339	2.232	1.066	1.336
2001/2002	340	1 922	2.295	1.377	1.515
2002/2003	340	2 146	2.586	1.302	1.221
2003/2004	350	2 038	2.431	1.783	0.976
2004/2005	382	2 089	2.349	2.169	2.316
2005/2006	382	2 089	2.148	1.668	1.898
2006/2007	382	2 089	1.685	1.336	1.468
2007/2008	382	2 089	1.752	1.755	2.064
2008/2009	363	2 675	2.129	1.940	1.948
2009/2010	345	2 882	1.993	1.468	1.062

Area 1: Kei River - Port Alfred
Area 2: Port Alfred - Jeffrey's Bay
Area 3: Jeffrey's Bay - Mossel Bay

ing year. The management strategy is a combination of TAC and 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 Marine Control Officers, and are weighed at designated off-loading points. Skippers must, at the conclusion of each trip, provide DAFF with accurate daily catch rate statistics.

The scientific recommendations for catch limits are based on an OMP which was introduced in 2008 and modified ('retuned') in 2010. The objectives of the OMP are to keep the interannual TAC change restricted to 5% and to increase the spawning biomass of the resource by 20% over the next 20 years.

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. Recaptured lobsters are 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 proportions 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 method 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 DAFF and the South Coast Rock Lobster Fishing Industry Association aims to examine the spatial and temporal distribution of berried females throughout the known distribution range of the lobsters and to investigate the possibility for introduction of a fishery-independent survey for this resource.

The effect of benthic environmental factors on daily catches of the lobster has not been investigated to date. However, new research is directed at establishing these relationships.

Current status

In 1977–1979/1980, fishing effort was above sustainable levels, and catches declined rapidly to 122 t tail mass (Figure 35). The decline in catches was partly as a result of the withdrawal of the foreign vessels from South African waters in 1976 as well as 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 and quotas were allocated to companies that were active in the fishery. This measure effectively limited the number of participants in the fishery.

The TAC initially restricted the total catches to 450 t tail mass (970 t whole mass) per year (Table 11); 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 (Table 11).

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. In spite of the steady reduction in the TAC (from 477 t in 1994–1995 to 365 t in 2000–2001), the 2001 assessment of the resource indicated that the reductions had 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 (Table 11, Figure 36). The exploitable biomass is currently around 27% of pristine, spawner biomass is around 31% of pristine and maximum sustainable yield is approximately 359–440 t tail mass. The TAC declined from 382 t in 2007–2008 to 345 t in 2009–2010 (the maximum 5% reduction allowed by the OMP for two consecutive years) (Figure 34). The reasons for the decrease are because of the slight net downward trend in CPUE over the past five years (Figure 35) when a weighted average is taken over the three areas, and because the average CPUE over the past three years is less than the average over 2003–2005.

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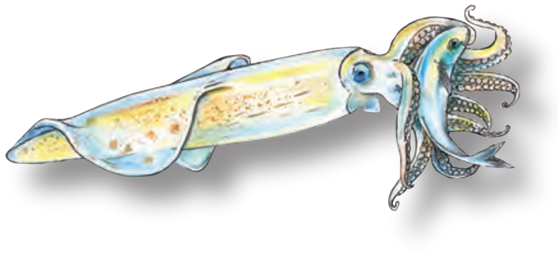
Squid



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 loliginid 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. Males can reach a maximum mantle length size of 48 cm and females 28 cm during this time. Chokka spawning occurs year-round 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 40 m depth, and occasionally in deeper waters. Their chief prey items are fish and crustaceans, but squid also sometimes feed on other cephalopods, and cannibalism is fairly frequent.

The abundance of squid fluctuates widely, mainly owing to biological events such as spawning distribution, survival rates of hatchlings and juveniles, and environmental factors such as temperature, currents, turbidity and large-scale events such as *El Niños*. Fishing pressure appears to play an increasing role in these fluctuations in abundance.

Chokka are mostly frozen at sea in small blocks. They are landed between Plettenberg Bay and Port Alfred and exported whole to European countries, notably Italy, and 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 R 480 million in a good year. Apart from the direct fishery, squid are also taken as a bycatch in the demersal trawl fishery that operates between Cape Town and Mossel Bay.

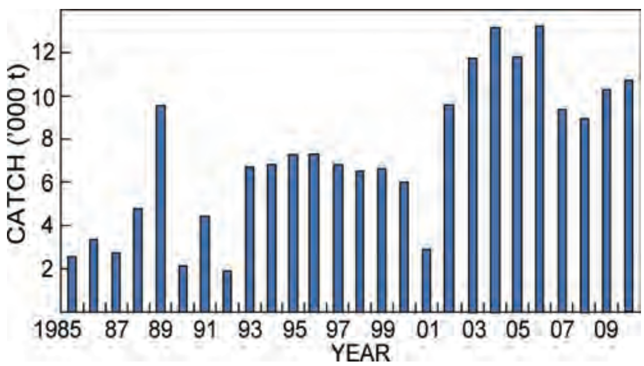


Figure 37: Annual catches of jig-caught squid off South Africa, 1985–2010. Data are from the South African Bureau of Standards (provided by Industry for the period 1985–2007) and NRCS (2008–2010)

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 phased out in the late-1970s and early-1980s following South Africa's declaration of an EEZ. Since then, squid and other cephalopods continued to be taken by South African trawlers. The squid bycatch in the demersal trawl fishery fluctuates annually between 200 and 600 t.

A commercial jigging fishery for squid began in earnest in 1984. Hand-held jigs are used to catch squid, making this a particularly labour-intensive fishery. In 2004 the jig fishery registered its highest catch of over 12 000 t (Figure 37). Catches in the 1990s ranged between 2 000 and 7 000 t, and in the 2000s between 3 000 and 13 000 t. Between 1986 and 1988, a licensing system was introduced with a view to limiting the number of boats participating in the fishery. The chokka squid fishery is effort controlled and current fishing effort is capped at a maximum of 2 422 crew or 136 vessels, whichever occurs first. 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 for the following year. Provision is also made for the Minister to impose additional closed seasons if assessments suggest that such closures are warranted.

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

Fishery-independent research surveys are conducted annually to collect information for assessment of the status of the squid resource and to further understand their biology and their relationships with environmental factors. Biomass estimates are also determined from data collected annually on demersal trawl research surveys where chokka are caught as bycatch.

The spring biomass estimates (Figure 38) fluctuate because during this time of year jig-fishing is more intensive and squid also tend to start aggregating in depths less than 40 m. The demersal trawl research cruises, primarily targeting hake, tend not to survey these areas intensively. It is of concern that these spring surveys have been cancelled for the past three years owing to budget constraints and therefore data for updating the biomass assessment model are lacking. The autumn survey index illustrated in Figure 38 shows a steady increase in squid biomass estimates between 2004 and 2008, increasing from approximately 15 500 t to 31 000 t. This is a more reflective estimate of biomass and also suggests a healthy population that is being fished sustainably.

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). The NRCS catch data indicate an increase in squid catches over the period 2001 to 2004, followed by catches stabilising at approximately 9 000 t between 2005 and 2008, and then increasing again to just over 10 000 t in 2009 and 2010 (Figure 37). These trends suggest that current catch levels are sustainable.

In the past, squid data were recorded along with catches of linefish, and archived in the NMLS. In 2006, a new log-book 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 system has indicated that the previous data may not be as reliable as had originally been assumed, and efforts are currently underway to assess the reliability of those data. It is due to these current data discrepancies that management of the fishery is conservative at present. Efforts to improve the quality of the data used for assessment of the resource, and to develop reliable indices for input to future assessment models, are ongoing.

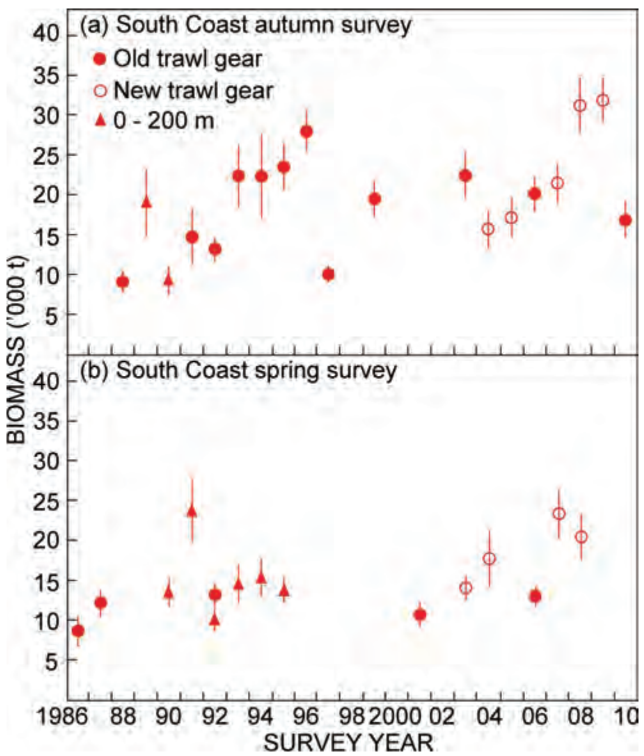


Figure 38: Survey abundance indices with 95% confidence intervals from the (a) autumn and (b) spring demersal trawl research surveys. Note that the trawl gear was changed in May 2003 and the time-series using the old trawl gear is not directly comparable with the time-series using the new gear. Triangles reflect surveys restricted to 200 m depth

Chokka 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. Current research is focused on the distribution and survival of paralarvae, genetics of adults (stock identity), environmental influences on stocks, as well as the importance of the deep spawning grounds on the South Coast. It is envisaged that results from these studies will assist in enhancing the management of this resource.

Current status

Uncertainties in the reliability of the available catch-and-effort data make it difficult to assess the current status of the resource with any degree of confidence. In the absence of an updated and reliable assessment, the TAE has been maintained at a constant level over the past five years.

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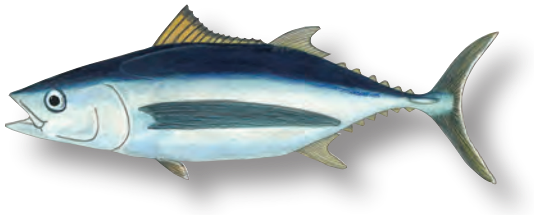
Tunas and swordfish



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

Introduction

South Africa has three commercial fishing sectors which catch tuna and tuna-like species in the Atlantic and Indian Oceans. These sectors are the longline, pole and rod and reel fisheries. There is also a boat-based recreational fishery.

Tuna species, including albacore *Thunnus alalunga*, yellowfin *T. albacares*, bigeye *T. obesus*, southern bluefin *T. maccoyii*, and swordfish *Xiphias gladius* are highly migratory. They are distributed throughout the Atlantic and Indian Oceans, except for southern bluefin which are confined to the Southern Hemisphere. Southern bluefin are the largest of the tuna speciesand can reach a length of up to 2 m and a weight of 200 kg. Albacore are found in more temperate waters of the Atlantic Ocean, with two different stocks being recognised; a South andNorth Atlantic stock, separated at 5°N. Swordfish have recently been separated into three different stocks; namely Mediterranean, northern and southern stocks. They can reach a weight of up to 500 kg by age three.

Bigeye tuna, yellowfin tuna and swordfish are the main targeted species in the longline sector. Blue *Prionace glauca* and mako *Isurus oxyrinchus* sharks are the main bycatch species in the longline sector. Juvenile albacore and, to a lesser degree, yellowfin tuna, are the main targets in the pole and rod and reel sectors. Species not commonly caught in either sector are the billfish species. With South Africa having such a low quota for southern bluefin tuna, this species is not targeted by longline vessels.

Spawning of yellowfin, southern bluefin and bigeye tuna takes place in tropical and subtropical waters when environmental conditions are favourable. Juveniles of bigeye and yellowfin are often found together, and pop-up satellite tagging studies have revealed that bigeye tuna exhibit daily migration patterns, inhabiting deeper water during the day and coming closer to the surface at night. These tuna species feed on a variety of fish, molluscs, and crustaceans. Swordfish feed on a variety of fish and invertebrate species and they also spawn in the tropics.

History and management

Pelagic longline

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 low quality bluefin and albacore tuna landed by South African fishers. Interest in targeting tuna using longline gear was expressed again 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 fishers expressing interest in longlining for tunas, 30 experimental longline permits were issued for South African waters towards the end of 1997, primarily for catching tuna. Annual 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 increase South African participation in the fishery. In this allocation process,

18 rights were issued for the swordfish-directed fishery and 26 for the tuna-directed fishery (1 right = 1 vessel).

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 ICCAT since 1967. The country is also a Cooperating Non-member of the IOTC and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). South Africa received a swordfish catch limit of 932 t for 2010, 962 t for 2011 and 1001 t for 2012 from the ICCAT. The country was also allocated a southern bluefin quota of 40 t per annum from the CCSBT for 2007–2012. Subject to ratification, South Africa will receive an increased quota from 40 t to 80 t in 2013 and 150 t in 2014 from the CCSBT. In preparation for bigeye tuna quotas, which were meant to be allocated by the IOTC in 2010, South Africa has been limited to a maximum of 50 longline vessels in the Indian Ocean. No other quotas have been allocated to South Africa thus far.

Pole and rod and reel

Traditionally, albacore is the main target of the South African baitboat (tuna pole and rod and reel) fleet, which operates in waters up to 1 000 km off the south and west coast of South Africa and off Namibia, from November to May.

The fishery started in the late 1970s and originally targeted yellowfin tuna, but switched to albacore when yellowfin moved out of Cape waters in 1980, a pattern that repeated itself in the middle of the first decade of the 21st century, before the yellowfin became abundant again around the Cape. Although tuna occur in mixed shoals, bigeye tuna and skipjack *Katsuwonus pelamis* are caught in low numbers in comparison to albacore.

The tuna pole-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 and sciaenid linefish stocks. The other two sectors that were created are traditional linefish and hake handline. Since the medium-term rights allocation in 2002, the tuna pole-fishery sector consists of 191 vessels of more than 10 m length, of which 136 are active. A maximum of 200 rights (200 vessels or 3 600 crew) was made available for this sector.

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

Pelagic shark

Due to concerns of high pelagic shark catches, the pelagic shark longline fishery was merged into the large pelagic longline fishery in March 2011. The Department has undertaken to terminate targeting of pelagic sharks due to the following reasons: (1) both blue and mako sharks are threatened species, as described by the 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 more susceptible to overfishing; and (4) concerns over ecosystem effects. Under current management, the bycatch limit has been set at 2 000 t dressed weight. Once this limit is reached, fishing in the large pelagic fishery would stop. The domestic pelagic longline fishery originally only targeted tuna and swordfish, although shark bycatch was also recorded. Foreign pelagic tuna-directed fisheries are mostly comprised of Japanese and Chinese vessels targeting offshore oceanic species such as mako and blue sharks, and carcharhinids such as silky shark *Carcharhinus falciformes*.

Research and monitoring

South Africa has an established onboard scientific observer programme to obtain length frequencies, biological samples, and fisheries information on target and bycatch species. The observer coverage is aimed at 20% for domestic vessels and 100% for foreign-flagged vessels. The contract for the observer programme for domestic vessels came to an end in March 2011. Currently, 100% coverage is achieved on foreign flag vessels but no coverage has been achieved on domestic vessels since March 2011.

The recent establishment of a large pelagic fishery represents an important milestone in the development of South African fisheries. However, research directed at the large pelagic species targeted by longline is in its infancy in South Africa and to date only four dedicated research trips have been undertaken since 2008.

The main focus in the past of research on large pelagic resources in South Africa has been on the life history and stock structure of swordfish in southern African waters. The observer programme was used extensively since 1998 to collect swordfish length frequencies and biological material for age and growth studies, sexing, maturity staging and dietary studies. Genetic studies have also been conducted to better understand the mixing dynamics of swordfish in the boundary region between the Atlantic and Indian oceans.

A pilot tagging programme for swordfish and bigeye and yellowfin tuna, using commercial longliners as a tagging platform, was conducted between 2004 and 2006 with approximately 300 large pelagic fish tagged. One swordfish was recaptured from this tagging programme just a few months later from the same vicinity where it was originally tagged. However, there have been too few recaptures to draw any meaningful conclusions about the movements of these fish.

South Africa's involvement in the South West Indian Ocean Fisheries Programme (SWIOFP) through Component 4 (Assessment and sustainable utilisation of large pelagic resources), has provided momentum to our research programme. The primary focus is to understand the distribution and movement of swordfish and bigeye and yellowfin tuna within the SWIO region, to which end 15 pop-up archival tags, (PATs) have been provided for deployment on these species, as well as hook monitors and time-depth records for deployment of an instrumented longline.

In 2009, two bigeye tunas were successfully tagged with PATs. The animals where found to move north, following the direction of the Benguela Current. In 2010, three yellowfin tuna were tagged with PATs. The three tags popped up and transmitted data earlier than they were programmed to, indicating that the animals had died prematurely and the tags had exceeded their depth limit of 1 200 m. The trends in the data are yet to be analysed in detail to understand the cause of these premature pop-ups. Three blue sharks were also tagged with PATs in 2010 and a further two blue sharks were tagged with Smart Position Only (SPOT) tags in 2011. The Department's research cruise in 2011 was a notable achievement during which 11 swordfish were successfully tagged using PAT tags in the SWIO region. Swordfish have proven to be very sensitive to handling on the line and South Africa is the first country to achieve PAT-tagging of swordfish in this region. Tags have been programmed for either 90 or 180 days and, although six swordfish have been reported to have likely died shortly after tagging, we await the success of the five remaining tags deployed.

The Department continues to collaborate with WWF, University of Washington Sea Grant, and Birdlife SA to assess the impact of longline fisheries on seabirds, turtles and sharks, and to investigate various mitigation and management measures. A National Plan of Action (NPOA) for seabirds was also published in 2008, which aimed to reduce seabird mortalities below 0.05 seabirds per 1 000 hooks. Good collaboration between the fishing industry, researchers and managers; continual refining of mitigation measures; the implementation of stringent management measures through permit conditions; and close monitoring has resulted in a decrease of seabird mortalities, currently almost at the goal identified in the NPOA for seabirds.

Rhodes University (Grahamstown) is also collaborating with the Department and has conducted research on the stock de-

lineation of yellowfin tuna in the boundary region between the Indian and Atlantic oceans by conducting genetic analysis and investigating movement patterns.

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.

A stock assessment for yellowfin tuna conducted by ICCAT in 2011 (using catch-and-effort data through 2010) indicated that the stock in the Atlantic Ocean was overfished and catches were about 10% higher during 2008–2010 than in 2007. ICCAT have recommended that no additional effort be exerted on the Atlantic yellowfin stock, as production models have indicated that increased catches will slow or reverse rebuilding of the stock. The high catches in the Indian Ocean in the period 2003–2006 (average catch of 464 000 t) may have led to a decline in the biomass of the Indian Ocean stock. A stock assessment conducted in 2009 revealed that this stock is currently fully exploited and may be entering an overfished state. The IOTC Scientific Committee recommended that the catches in the Indian Ocean do not exceed the current estimate of MSY of 300 000 t (catch of yellowfin tuna in 2009 was 288 100 t) and that improvements in the status of the stock are dependent on future recruitment reaching previous high levels

and the control of fishing pressures (catch and effort).

The last full southern Atlantic albacore stock assessment was conducted by ICCAT in 2011, using a broad range of methods on data up to 2009. The results of that stock assessment suggest that the stock is both overfished and experiencing overfishing. Consequently, the TAC was reduced to 24 000 t in the south Atlantic region. South Africa, together with Namibia, share a catch limit of 10 000 t that is not allowed to be exceeded. The Scientific Committee of the IOTC noted that the stock status should be monitored closely to assess the impact of recent increases in catch levels from 2005–2009.

Swordfish stock assessments were conducted by ICCAT and IOTC in 2009. These indicated that the stock in the Atlantic Ocean is not overexploited, with current catches (11 108 t in 2008) being well below the estimated MSY level (15 000 t). In contrast, the outlook for the swordfish stock in the Indian Ocean is more pessimistic, with large concerns regarding the high effort and catches made in the South-West Indian Ocean.

The latest stock assessment of bigeye tuna in the Atlantic Ocean was conducted in 2010, using catch data up to 2009, and indicated that the stock is optimally exploited. The total catch in 2009 increased to 86 011 t, higher than the targeted TAC of 85 000 t recommended by the ICCAT (Standing Committee on Research and Statistics) to promote stock growth.

The total catch of bigeye tuna in the Indian Ocean reached 40 700 t in 1999, but the average annual catch for the period 2005–2009 has been 114 600 t. The stock assessment in 2006 used four assessment models and the results showed that the stock was fully exploited. Current catches (2009) of bigeye tuna (102 200 t) are within the range of the estimated MSY levels of between 100 000 t and 115 000 t.

Southern bluefin stock status indicators were reviewed at the 16th meeting of the CCSBT Extended Scientific Committee in 2011. The indicators continue to support previous evidence that this tuna resource is still overexploited. The stock assessment also indicated that the spawning stock biomass (SSB) is at a very low fraction of its original biomass (4.6% of unfished levels) as well as below the levels that could produce maximum sustainable yield (15% of SSBMSY), and these results were consistent across all possible scenarios. The CCSBT set a global TAC of 11 810 t per year for 2007–2009. However, due to further evidence in decline of stocks of this resource, the global TAC was reduced to 9 449 t for 2010 and 2011. The CCSBT will consider further reduction of the global TAC for 2012 unless there is a demonstrable improvement in stock status indicators before then.

Stock assessments of pelagic sharks, conducted by ICCAT in 2008, were inconclusive due to widespread under-reporting of shark catch-and-effort data. Despite this result, there is international concern regarding the stock status of pelagic sharks due to the biology of these species and the current high fishing capacity worldwide. As a precautionary measure, RFMOs have called for the capping of effort on sharks and have requested that nursery grounds for these species be protected.

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West Coast rock lobster

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

Introduction

The West Coast rock lobster fishery is the most important rock lobster fishery in South Africa on account of its high market value (more than R260 million per annum) and its importance in providing employment for over 4 200 people from communities along the West Coast of South Africa. The West Coast rock lobster is a cold-water, temperate, spiny lobster species that occurs from Walvis Bay in Namibia to East London in South Africa. In South Africa, the commercial fishery operates between the Orange River mouth and Danger Point in waters up to 100 m in depth. This slow-growing species inhabits rocky areas and exhibits a seasonal inshore-offshore migration governed by its biology and environmental factors. Currently, 20% of the resource is harvested by hoop nets from 'bakkies' (dinghies) in the nearshore region up to one nautical mile offshore, and 80% by offshore trap vessels operating up to water depths of >100m. The resource in the nearshore region is also harvested by recreational fishers and the informal small-scale subsistence fishers that operate exclusively in the nearshore region during the summer.

The invasion of West Coast rock lobsters into the traditional abalone fishing zones east of Cape Hangklip marked the onset of the eastward shift in lobster distribution. Commercially viable quantities of lobster in this area resulted in the opening of three new lobster fishing zones. The fishery on the West Coast, which historically landed the bulk (60%) of the lobster catch, now lands only 40% of the total catch annually. This decline in catch has had a devastating effect on coastal communities with economic hardships experienced by most fishers on the West Coast. In the face of resource decline an 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 39). 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, overexploitation, 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 of (89 mm carapace length (CL) was introduced in 1933, which protected a large proportion of the slower-growing female component of the population, and a tail-mass production quota was imposed in 1946. However, catches declined sharply during the 1950s, particularly in the northern areas, in response to overfishing. A minimum legal size limit of 76 mm 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 again 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 40, 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 hoop-net fishers operating in the nearshore region.

Other management controls applied included protection of

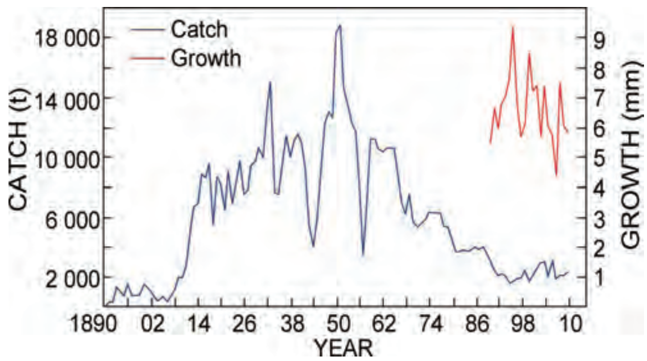

Figure 39: Historical catches of West Coast rock lobster 1890-2010, with the associated trend in growth indicated for the period post-1990

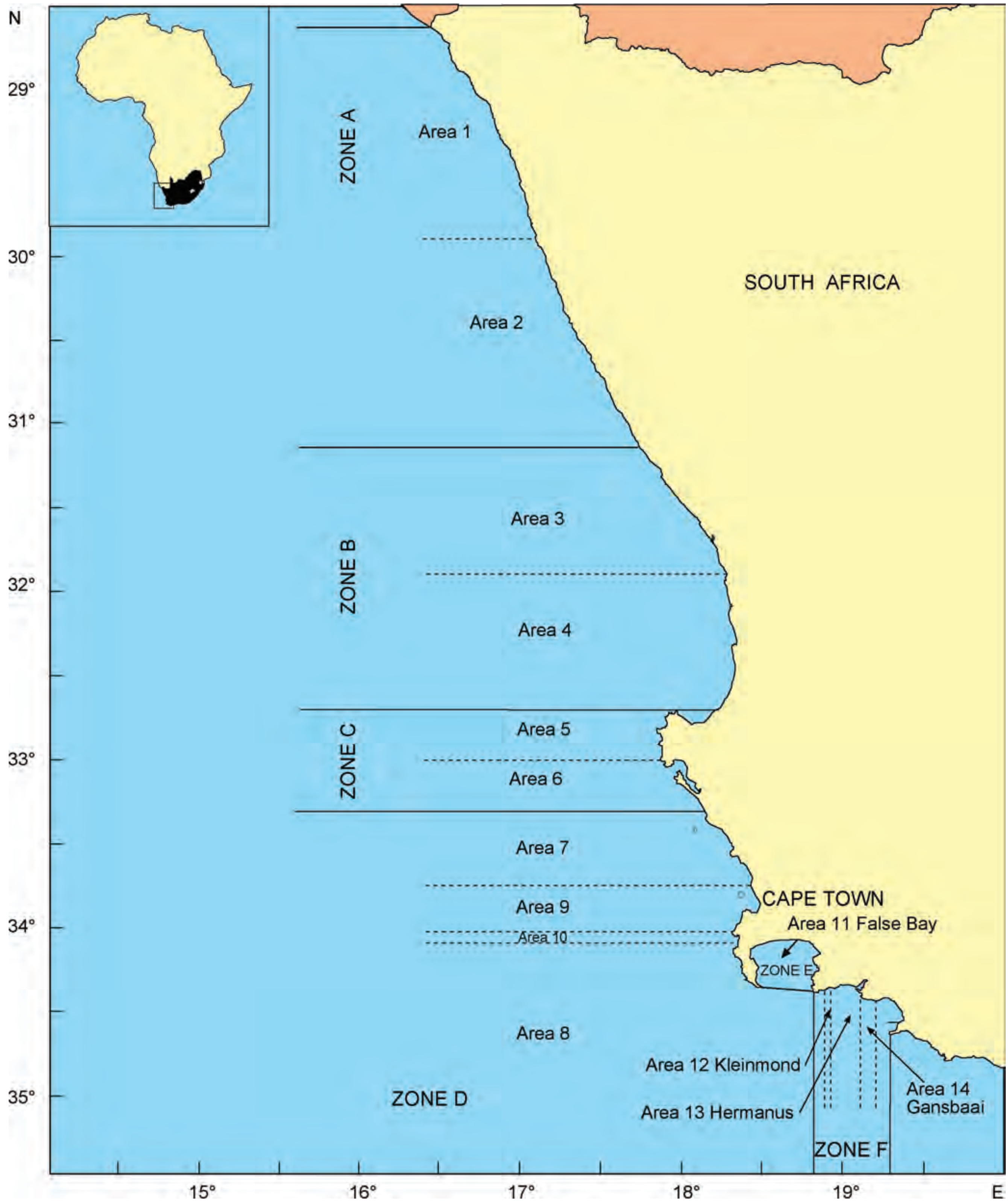

Figure 40: West Coast rock lobster fishing zones and areas. The five super-areas are A1–2 corresponding to Zone A, A3–4 to Zone B, A5–6 to Zone C, A7 being the northernmost Area within Zone D, and A8+ comprising Area 8 of Zone D in conjunction with Zone F

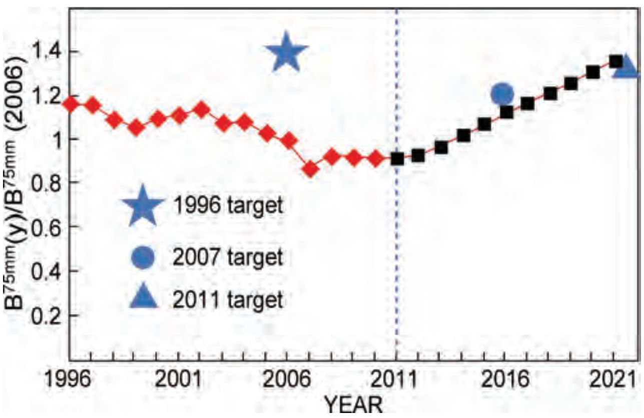

Figure 41: Biomass recovery targets for the 1996, 2007 and 2011 OMPs for West Coast rock lobster. The recovery targets are expressed as a proportion of the biomass estimated for 2006. The vertical line indicates the current position in time. Values to the right are predicted median estimates of resource recovery for the 35% recovery option

females with eggs (berried females) and soft-shelled lobsters, a closed winter season, and a daily bag limit for recreational fishers. Catches stabilised around 3 500 to 4 000 t until 1989 when the resource started to decline further. This continued decline in the resource during the 1990s and early 2000s was attributed to mass strandings of lobster and reduced growth caused by low oxygen events along the West Coast. During this period, the size limit was decreased from 89 to 75 mm 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 OMP developed in 1997 was to increase resource abundance to 20% above the 1996 levels 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 (Figure 41). This decline was due to recruitment failure and increased fishing pressure (increase in the number of nearshore right-holders) during 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. The OMP adopted in 2011 aims to rebuild the resource by 35% by 2021 (i.e. B^{75mm} (2021/2006) = 1.35) The predicted median estimates of resource recovery (Figure 41) illustrate that the predicted biomass levels reached in 2021 will still be slightly lower than the target recovery level set to be achieved by 2006.

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.

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 onboard commercial vessels to derive abundance indices of subadult, 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 FIMS data and analysis methods have been recently re-checked, and changes in weather conditions have been identified as a source of variation in 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 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 also under investigation, to formulate energy-growth-reproduction conversion factors for predicting future trends in growth and reproductive potential.

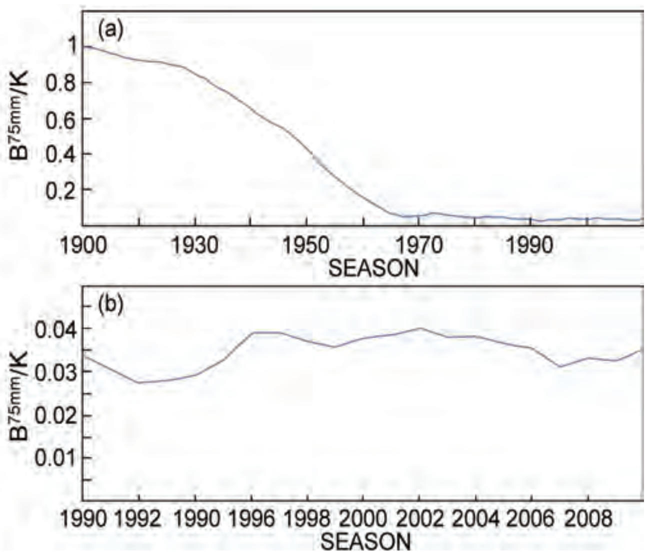

Figure 42: (a) Annual biomass of male rock lobsters in relation to pristine (B^{75mm}/K) values for the resource as a whole (i.e. summed over the five super-areas) 1900-2010; (b) values for 1990+ only.

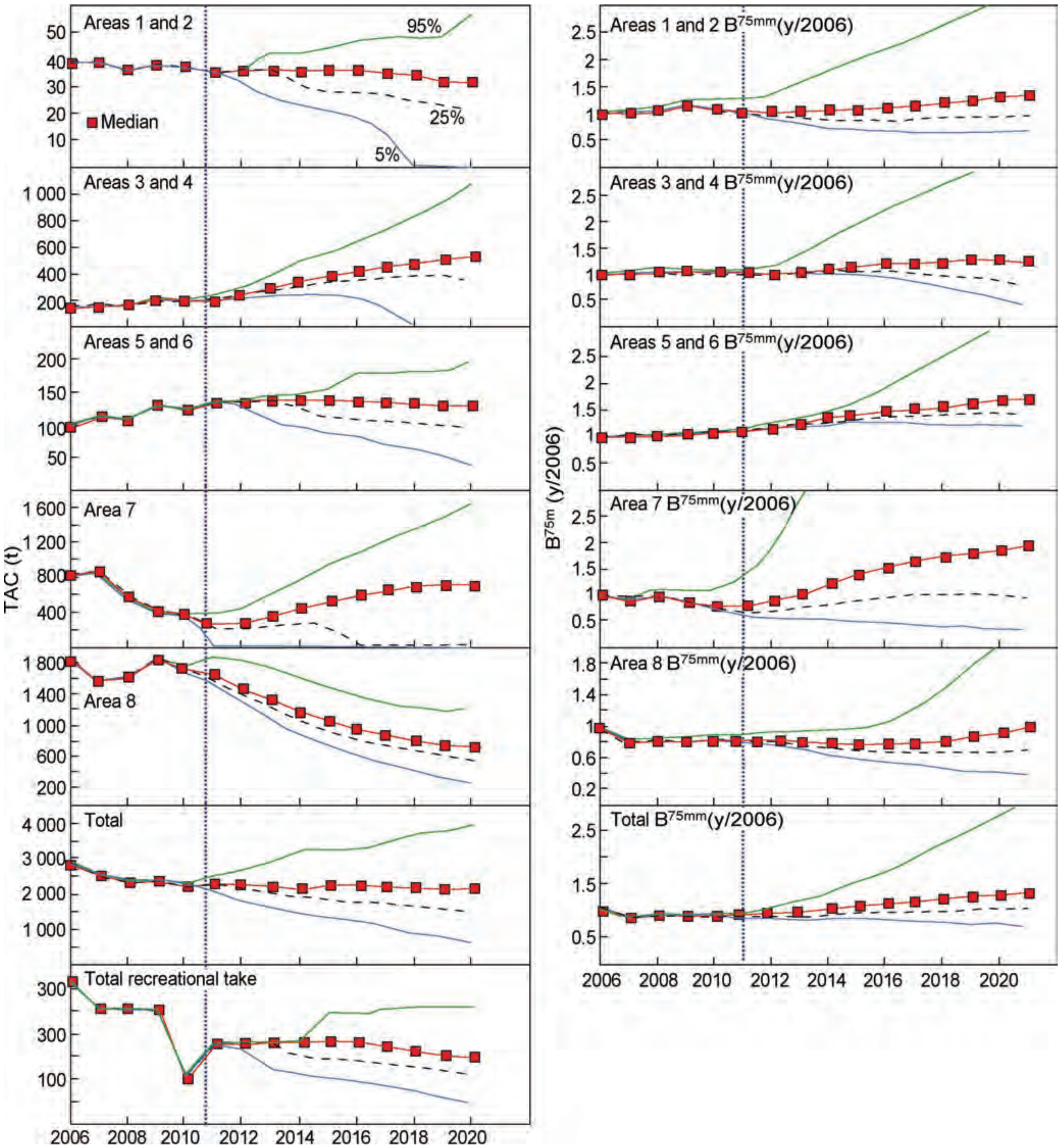

Figure 43: Total global TAC and B^{75mm}(y/2006) trajectories including a 35% recovery target. The median, 5th, 25th and 95th percentiles are shown. Global recreational allocations are also shown

Current Status

The biomass of male West Coast rock lobster above the 75 mm CL minimum size limit is currently at 3.5% of pristine levels (B^{75mm}/K =0.035) (Figure 42). The OMP adopted in 2011 is empirically based, which means that it uses data collected from the fishery directly for calculating the TAC. No population model is fitted to input data as for previous OMPs. As in the past, four indices are used as input data to the OMP in order to set the TAC: trap CPUE, hoop-net CPUE, FIMS and somatic growth. Recent trends in these indices are given in Table 12.

In 2010 hoop-net CPUE decreased in Super Areas 1+2 and 3+4 but increased in Areas 5+6 and 8+, whereas trap CPUE increased in Areas 7 and 8+. FIMS CPUE declined in Areas 5+6, 7 and 8+ but increased sharply in Areas 3+4, indicating the possible start of a recovery following the walk-out events of the 1990s. Growth rates in Areas 1+2, 3+4, 5+6, and 8+ were lower in 2010 than in 2009, whereas Area 7 was

Table 12: Input data for the 2011 OMP TAC calculations for Super Areas 1-8+

Year	Trap CPUE	Hoop-net CPUE	FIMS CPUE	Somatic Growth of 70mm male lobster (mm y^{-1})
		Super Areas 1+2		
2005	–	1.353	–	2.708
2006	–	1.281	–	2.804
2007	–	1.387	–	3.791
2008	–	1.135	–	3.530
2009	–	1.556	–	7.132
2010	–	1.041	–	3.582
		Super Areas 3+4		
2005	–	0.512	1.712	3.368
2006	–	0.410	0.239	3.231
2007	–	0.830	0.267	2.410
2008	–	1.356	1.548	4.134
2009	–	1.436	0.009	3.515
2010	–	1.331	3.863	3.252
		Super Areas 5+6		
2005	–	0.854	0.241	4.055
2006	–	0.949	0.119	3.918
2007	–	1.198	1/267	3.097
2008	–	1.477	0.756	4.821
2009	–	1.245	0.706	4.202
2010	–	1.513	0.662	3.939
		Super Area 7		
2005	0.624	–	15.79	3.281
2006	0.767	–	13.96	3.088
2007	0.465	–	21.88	3.291
2008	0.375	–	9.665	4.493
2009	0.592	–	5.088	2.981
2010	0.950	–	3.487	3.412
		Super Area 8+		
2005	0.938	1.073	62.71	2.649
2006	0.820	0.960	79.18	2.512
2007	0.739	0.839	106.65	1.691
2008	0.831	0.885	101.43	3.415
2009	0.835	1.023	101.19	2.796
2010	1.003	1.121	93.10	2.533

the only area to show an increase in somatic growth rate in 2010.The resource indices calculated in the OMP using the data in Table 12 are presented in Table 13. The critical values presented in Table 13 are the values below which an Exceptional Circumstances rule in the OMP would be invoked. This rule ensures that immediate and substantial reductions in TAC can be invoked to ensure sustainable utilisation in the event of very poor resource performance.

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.

Table 13: The resource indices for each super-area calculated using the data in Tables 12 and the critical values below which the Exceptional Circumstances (EC) rule would be invoked

Super-area	Gear-combined index of abundance	Critical value below which EC would be declared
1+2	0.95	0.7
3+4	1.917	0.85
5+6	1.421	0.7
7	0.885	0.8
8+	0.753	0.7

However, over recent years there are indications of some decrease with catches in 2010 estimated at 107 t. This is in line with the intended decrease in recreational catch brought about by a severe reduction in recreational season length. A thorough analysis has been conducted on the catch returns (details of catches made) received from fishers fishing under the Interim Relief provisions over the last few years. The estimated catch of the Interim Relief sector in 2010 was about 270 t.

The biomass of lobsters above the legal minimum size is currently at 3.5% of pristine levels (Figure 42). If the recovery target of 35% is met, the resource biomass will increase to 4.8% of pristine by 2021. The anticipated biomass recovery levels at a super-area level and the predicted global TACs are presented in Figure 43. The median (average) expected results as well as 5th, 25th and 95th percentiles are also shown in this figure. It must be noted in Figure 43 that even with this 35% recovery target, there is a 25% chance that the resource overall will decline, and even greater chance of such declines in some of the super areas. Every effort to reduce illegal harvesting, including substantially improved compliance with permit conditions for reporting of catches, should be instituted to ensure that sound resource management and stock rebuilding are not compromised.

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White mussels and small invertebrates

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

Introduction

White mussels of the species *Donax serra* occur from northern Namibia to the Eastern Cape of South Africa. Abundance is highest along the West Coast on account of higher plankton production there compared with the rest of the South African coast. As a result, the existing commercial harvest is restricted to the West Coast, whereas recreational harvest spans the entire distribution range. The mussels are harvested along sandy beaches in the intertidal zone and the commercial harvest of white mussels is solely for bait.

The common octopus *Octopus vulgaris* occurs along the entire South African coastline. It is found in intertidal rock pools to depths over 200 m and inhabits various substrata including shell, gravel, sand and reef. A pilot study on the biology and fishery potential of this species paved the way for a five-year experimental fishery which commenced in September 2004 and culminated at the end of September 2009.

Since then, exemptions to continue experimental fishing were granted to vessels that were still active in the fishery, and in October 2011 DAFF published an invitation for interested parties to submit an expression of interest to undertake exploratory fishing for *Octopus vulgaris*. The exploratory fishery is due to commence in 2012 once new permits are allocated.

The distributions of the whelk *Bullia laevissima* and three-spotted swimming crab *Ovalipes trimaculatus* range from Namibia to the Wild Coast. A small-scale experimental hoop-net fishery was established in 1989 along the West Coast, employing a fishing method similar to that of the rock lobster fishery but on sand. The original target species was three-spotted swimming crab. However, catch rates of whelks were higher, which gave rise to the current exploratory fishery targeting whelks with three-spotted swimming crabs as a bycatch.

The sea-squirt red bait *Pyura stolonifera* is distributed along the entire South African coastline in intertidal rock pools and shallow subtidal areas. An exploratory fishery for red bait is based on its removal as an antifouling operation, which is a necessity for most marine aquaculture operations, and for port pilings, etc. The red bait removed during this process is sold as a means of cost recovery and in turn creates employment opportunities.

History and management

Management of the commercial fishery for white mussels is currently effort-controlled and, at present, the TAE is considered the most effective regulatory tool for this sector. The recreational sector is controlled by a daily bag limit of 50 mussels per person. For both sectors, a minimum legal size of 35 mm applies. The fishery for white mussels started in the late 1960s as part of the general commercial bait fishery and stopped 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. Surveys conducted in the 1990s showed that commercial catches amounted to <1% of the standing biomass in the relevant areas, and the resource was considered under-exploited. In the decades preceding the 1990s, catches declined continuously (Figure 44). In 2001, four-year commercial harvesting rights were awarded in this sector followed by a new term of two-year rights in 2006. Since 2007, the commercial sector has been managed by means of a TAE of seven right-holders (eight 'pickers'including

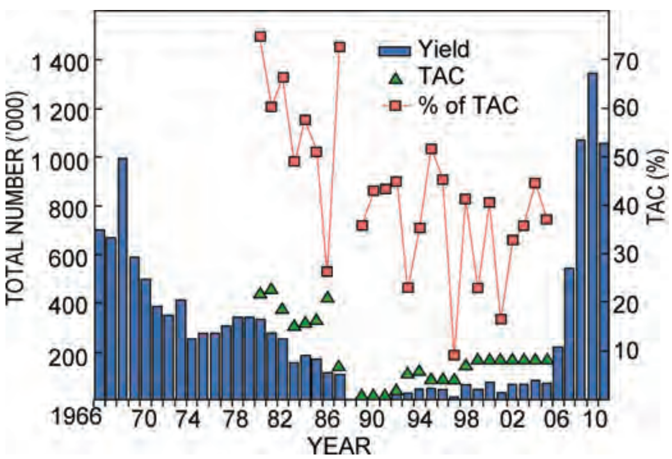

Figure 44: TAC, yield (total number), and percentage of TAC caught, of white mussels harvested commercially per annum, 1966–2010

Table 14: Survey data for white mussels by study site

Site	Year	Number per 1-m transect	Above minimum legal size (%)	Beach length (km)
Brittania Bay	1982	4 272	93.9	2.0
Brittania Bay	1989	3 092	97.0	1.0
Paternoster	1982	1 986	80.1	2.0
Paternoster	1989	150	80.0	0.7
Elands Bay	1989	1 320	77.6	2.5
Dwarskersbos	1988	2 884	60.3	8.0
Dwarskersbos	1989	2 959	54.1	22

the right holder) each harvesting within only one of seven commercial fishing areas along the West Coast. Each right holder was limited to a monthly catch of 2 000 mussels. However, due to unreliable data from the fishery, under-reporting and difficulties with catch monitoring, catch limits are 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 improving the quality of catch-and-effort data for use in future resource assessments.

A pilot study of octopus paved the way for a five-year experimental pot-fishery, which ran from October 2004 until September 2009. Eight areas were defined between Saldanha Bay and East London, with two permits allocated per area. Long-line fishing was employed with unbaited pots deployed at different depths between 10 and 50 m on suitable bottom types (coarse/sandy/shelly). Pot type, number and soak times were prescribed, and there has been approximately 100% observer coverage for this sector.

The experimental fishery did not yield sufficient information and a further exploratory fishery period for octopus will be undertaken from 2012. This new exploratory fishery will also use pots attached to long lines, but will not be as prescriptive in terms of specific requirements (such as standardising pot types and line deployments at specific depths) as was designed for the earlier experimental fishery.

A small-scale 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. Whelks, in particular, are still considered to be an excellent candidate for export markets. The experimental fishery ended

in 1993 due to processing and marketing challenges, and a severe red tide that depleted catch rates. In May 2008, an exploratory fishing permit was granted targeting the whelks and three-spotted swimming crabs (an expected bycatch). Fishing grounds are between west of Seal Island (False Bay) and Cape Town Harbour and a maximum of 100 baited hoop-nets may be utilised. This fishery is limited to weekdays only and no overnight setting of hoop-nets is allowed. Only one permit holder commenced fishing in May 2009.

In June 2009 a single permit was issued for the removal of red bait as an antifouling operation on submerged man-made structures, and another was issued in 2010. Whole organisms are removed from the structures but only the inner flesh is sold as bait, whereas the hard outer casing is disposed of. The total allocated amount is 7 t and this may only be harvested by hand using knives and gaffs. The harvesting area is limited to the marine aquaculture area within Saldanha Bay and the Portnet structures in the Port of Saldanha, and collection of washed-up red bait is permitted on the beaches immediately bordering the port.

Research and monitoring

In the early 1990s, research on white mussels was confined to a few *ad hoc* area-specific stock assessment surveys carried out in response to requests for commercial permits. Fishery-independent stock assessment surveys have been conducted since September 2007 and data are being collected in order to provide a true reflection of the abundance of the white mussel resource on an area-by-area basis (Table 14). Catch monitors have been deployed since 2009 at each of the sites of commercial white mussel harvesting and commercial and recreational catch data are regularly recorded.

The octopus experimental fishery had a strong start at its beginning in 2005, with 12 activated permits and 66 trips undertaken. Unfortunately, this declined rapidly thereafter, with no fishing effort being recorded in 2008. In 2009 only three permits were activated. As a consequence, the experiment has not yet provided the information necessary to assess the status of the octopus resource and to determine the viability of a potential commercial fishery for this species. In order to gain this information, a new exploratory fishery will be initiated in 2012.

A permit for the whelk and three-spotted swimming crab fishery was issued in May 2008 and subsequently in mid-2009. Information collected from the fishery includes the animals' mass, length and breadth, and the total mass of the catch, whilst the animals are still alive. These data are used to monitor changes in the catch throughout the year.

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 and there is no harvesting of the naturally occurring stocks.

Current status

Although research on white mussels, in the form of fishery-independent surveys, has been conducted by the Branch: Fisheries Management since 2003, 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 three years (to between about 1 350 000 mussels in 2009 and 1 060 000 in 2008 and 2010 respectively, Figure 44). It must be noted that the largest component of the overall catch of white mussels is by the recreational sector, but these catches are not monitored routinely. There are also information gaps on the level of exploitation by subsistence 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 at 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.

Insufficient data were collected during the experimental fishery for octopus to answer the key questions regarding the status of the resource, and for the possible further development of this fishery. However, the preliminary studies of octopus biology and population dynamics indicated that this resource appears to be underexploited. The planned exploratory fishery should assist in providing the information necessary to assess the viability of a commercial octopus fishery.

The stock status for neither the whelk nor three-spotted swimming crab resources has yet been determined. The exploratory fishery currently underway should assist in providing the information required to assess the long-term viability of a commercial fishery on these resources.

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