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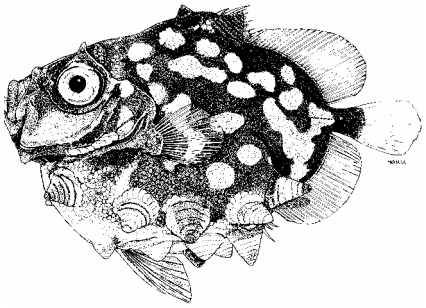
MANAGEMENT OF DEMERSAL FISHERIES RESOURCES OF THE SOUTHERN INDIAN OCEAN



Cover photographs courtesy of Mr Hannes du Preez, Pioneer Fishing, Heerengracht, South Africa.
Juvenile of *Oreosoma atlanticum* (Oreosomatidae). This fish was caught at 39° 15' S, 45° 00' E, late in 2005 at around 650 m while mid-water trawling for alfonsinos. This genus is remarkable for the large conical tubercles that cover the dorsal surface of the younger fish.

Illustration by Ms Emanuela D'Antoni, Marine Resources Service, FAO Fisheries Department.

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MANAGEMENT OF DEMERSAL FISHERIES RESOURCES OF THE SOUTHERN INDIAN OCEAN

Report of the fourth and fifth Ad Hoc Meetings on Potential Management Initiatives of Deepwater Fisheries Operators in the Southern Indian Ocean (Kameeldrift East, South Africa, 12–19 February 2006 and Albion, Petite Rivière, Mauritius, 26–28 April 2006) including specification of benthic protected areas and a 2006 programme of fisheries research.

compiled by
Ross Shotton
FAO Fisheries Department

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2006

PREFACE

Negotiations for what was to be called the Southern Indian Ocean Fisheries Agreement have been undertaken during five Intergovernmental Consultations on the Establishment of a Southwest Indian Ocean Fisheries Commission. These were held as follows:

i. Albion (Mauritius), 24–27 January 2000 (FAO 2000a)
ii. Antananarivo (Madagascar), 11–12 July 2000 (FAO 2000b)
iii. Saint-Denis (Réunion), 6–9 February 2001 (FAO 2001a)
iv. Antananarivo (Madagascar), 25–28 September 2001 (FAO 2002a)
v. Nairobi (Kenya), 27–30 January 2004 (FAO 2004) and
i. Mahé (Seychelles), 13–16 July 2004 (FAO 2005).

During a special session of the Intergovernmental Consultation held in St Denis, Réunion, in 2001, it was agreed that a meeting be held to advance the technical activities that would be needed to support effective management of deepsea fishery resources in the southern Indian Ocean when the planned fishery agreement came into effect. A first such meeting was held in Swakopmund, Namibia, from 30 May to 1 June 2001, and was hosted by the Ministry of Fisheries and Marine Resources of Namibia, with the technical assistance of FAO. The results of that meeting are reported in FAO (2001b). It was agreed at the Swakopmund meeting that a following meeting would be held in Fremantle, Western Australia, hosted by Agriculture, Fisheries, Forestry – Australia. This meeting was subsequently held in Fremantle, Western Australia, in 2002 and the results of this meeting are reported in FAO (2002b).

Following these meetings, there was a general feeling that little more could be done at government levels until a fisheries agreement was ratified. But at the same time, there was concern that (a) time was passing, (b) there was no certainty as to when there would be an "Agreement" and (c) fishing operations were continuing with no leadership or direction being provided concerning securing of vital catch and effort information from the few vessels remaining in the fishery. Further, the remaining operators recognized that given the small size of the deepwater fishery, they themselves would have to play the major role not only in the collection of fishery and fish population data, but also in undertaking stock assessment activities. It was in this context that three of the four operators approached me while we were attending the twenty-fourth meeting of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) in November 2005 to ask if FAO could play a coordinating role to advance management concerns and preparation of future management actions for when the Fisheries Agreement was finally ratified.

As a consequence of that request, a first meeting was held in Kameeldrift East, South Africa, from 12 to 19 February 2006. A follow-up meeting was then held in Albion, Mauritius, from 26 to 28 April 2006. This Circular reports on these two meetings. An important result of these meetings was the decision to declare eleven areas in the southern Indian Ocean as benthic protected areas (see Appendix VIII), a special class of marine protected areas, that would be observed by the fishing companies who participated in the meetings that this circular documents.

Many individuals, personally and through their employees have contributed material to this Circular. First among these should be mentioned Graham Patchell, Resources Manager, Sealord Group, Nelson, New Zealand. He has been responsible, through his employer, for the collection and making available all of the benthic swathe-maps used in the report and most of the echograms showing characteristic fish aggregations. These figures provide enormous insights into the bottom structures of the protected areas and all those interested in these areas must be most grateful to the Sealord Group for undertaking this work. Fabio Carocci, Marine Resources Service (FIRM), has kindly prepared bathymetric illustrations for each of the proposed benthic protected areas.

Bathymetric and oceanographic features were extracted from the General Bathymetric Chart of the Oceans (GEBCO Digital Atlas published by the British Oceanographic Data Centre on behalf of the Intergovernmental Oceanographic Commission (IOC) and the International Hydrographic Organization (IHO) in 2003) while background shaded relief were derived from the GeoMapApp, an integrated mapping application developed at Lamont-Doherty Earth Observatory containing predicted topography compilation of the ocean from satellite altimetry and ship depth soundings (Smith and Sandwell, 1997).

R. Shotton
Senior Fishery Resources Officer
Fishery Management and Conservation Division
FAO Fisheries Department

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ABSTRACT

The fourth and fifth Ad Hoc Meetings on Management of Demersal Fisheries Resources of the Southern Indian Ocean, were held in Kameeldrift East, South Africa, from 12 to 19 February 2006, and Albion, Petite Rivière, Mauritius, 25–28 April 2006. The meetings (a) reviewed options for specification of benthic protected areas (BPAs) in the southern Indian Ocean and (b) outlined a programme of commercially-executed fisheries stock assessment activities to be undertaken during the winter fishing season in the southern Indian Ocean. These included a programme of data collection and commercial-vessel acoustic resource assessment programmes.

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1. INTRODUCTION

This Circular documents the information presented, discussions and decisions made at two ad hoc meetings that were held to address existing and future problems of management of deepwater fisheries resources of the southern Indian Ocean. The foundations for these meeting were three previous meetings that had been held to address the same anticipated problems but whose emphasis had been from a governmental perspective. The first of these was held in Swakopmund, Namibia, 30 May–1 June 2001 (FAO 2001). The second meeting was held in Fremantle, Western Australia, Australia from 22 to 25 May 2002 (FAO 2002). A brief third ad hoc meeting was held during the Fourth Consultation on the Establishment of a Southwest Indian Ocean Fisheries Commission held at Berjaya Mahe Beach, Seychelles, 13–16 July 2004. No report was produced from this last meeting.

These three meetings were primarily attended by government representatives. In November 2005, while attending the twenty-fourth meeting of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), three of the four remaining operators in the deepwater fishery of the southern Indian Ocean expressed their concern in regard to the delays over the implementation of a fisheries agreement and their worries that while time passed, important resource management issues were remaining unaddressed. In particular they felt there was a need to advance discussions on resource management issues and even better to initiate actions if agreement could be reached on what was to be done. They requested the assistance of FAO to facilitate and chair a meeting to address these issues.

The first of these meetings was held in Kameeldrift East, South Africa (22–25 May 2006) and was attended by company representatives from four countries, one of whom was a vessel skipper, managers of commercial fishing companies from four countries, two representatives of fishing companies and an officer from the Fisheries Department of the Food and Agriculture Organization of the United Nations (Appendix III). The second of these meetings was held at the Fisheries Research Centre,[1] Albion, Mauritius from 25 to 28 April 2006. The second meeting was to follow up on initiatives that had been raised at the first meeting in Kameeldrift East in February. This meeting was attended by four company fisheries officers, one skipper, one fisheries scientist, two officers from the Albion Fisheries Research Centre, Mauritius, and an officer from FAO.

There were two particularly important outcomes of these meetings. The first was the decision of the operators to form an association of industry operators who were undertaking deepwater fishing in the southern Indian Ocean. The objective of the Association was to promote the prosecution of responsible fisheries and to support effective fisheries management of the species exploited by its members.

Following the decision of the industry representatives to associate, it was agreed to observe a number of high-seas marine protected areas (Section 4). This resulted in the creation of what are believed to be the first open-ocean high-seas marine protected areas. Their purpose is the protection and conservation of benthic fauna. In this context, this action is consistent with the view expressed by Kimball (2006) that efforts "do not require a new legal instrument *as a first step*". This action is consistent with the FAO Code of Conduct for Responsible Fisheries and it should be apparent that the actions represent a serious commitment to implement a modern and effective regime for the management of fisheries and of the sensitive ecosystem affected in the southern Indian Ocean. This action shows a commitment that goes beyond only rhetoric.

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[1] The kindness of the Ministry of Agro-Industries and Fisheries, Mauritius, in making available the facilities of the Fisheries Research Centre at Petite Rivière for the purpose of this meeting is gratefully noted by the meetings' participants.

The agendas for the two meetings are given in Appendixes I and II and a list of participants is given in Appendix III.

2. OBJECTIVES AND ANTICIPATED WORK OF THE MEETINGS

It was agreed that the meeting should address the technical and scientific issues pertaining to the future management of deeper water fishery resources of the southern Indian Ocean in the area that had been identified as the basis for a future possible regional fisheries agreement. While it was noted that no commission, convention, or other means existed by which fishery management decisions or actions could at the present be undertaken, it was agreed that the basis for the meeting was the common view that when such a fisheries management body was formed, it would need a factual basis on which to make management decisions. The goal of the Ad Hoc Technical Meeting was to satisfy this requirement. As such, the meeting recognized that any conclusions it reached would not create any formal obligation for action on the part of any state or enterprise. However, participants were unanimous in agreeing that future effective fisheries management in the proposed commission area would require cooperation and goodwill in the provision of fisheries data, respect for the requirements of confidentiality for such information and cooperation in its analysis and reporting of the results.

3. SEABED AND OCEANOGRAPHIC CHARACTERISTICS OF THE AGREEMENT AREA

3.1 Physical oceanography of the agreement area

The South West Indian Ridge is a slowly spreading ridge system separating the African, Australian and Antarctic tectonic plates and has a unique geological structure. The seabed in this area rises from depths of 6 000 m and many of the ridges and seamounts of this chain are characterized by massive slips and faults that make bottom trawling difficult, if not impossible, at least with existing technology. As a result, only limited areas can currently be, or have historically been, fished by bottom trawls.

Longhurst (1998) does a useful service in partitioning the Indian Ocean into a number of pelagic biomes[2] that inform us of the relevant oceanographic environments that would be expected in the areas of the Southern Indian Ocean Deepwater Fishers' Association (SIODFA) benthic protected areas. In the southern Indian Ocean, the biomes of relevance are:

i. the Indian South Subtropical Province and
ii. the Eastern Africa Coastal Province including the
    - Agulhas Current and
    - Agulhas Retroflection.

These biomes mainly cover the southwest part and the east-central and southeastern part of the Indian Ocean. Not unsurprisingly, Longhurst's material focuses on current and water masses that can easily be observed from the surface: what is happening in deepwater waters has been far less measured or monitored.

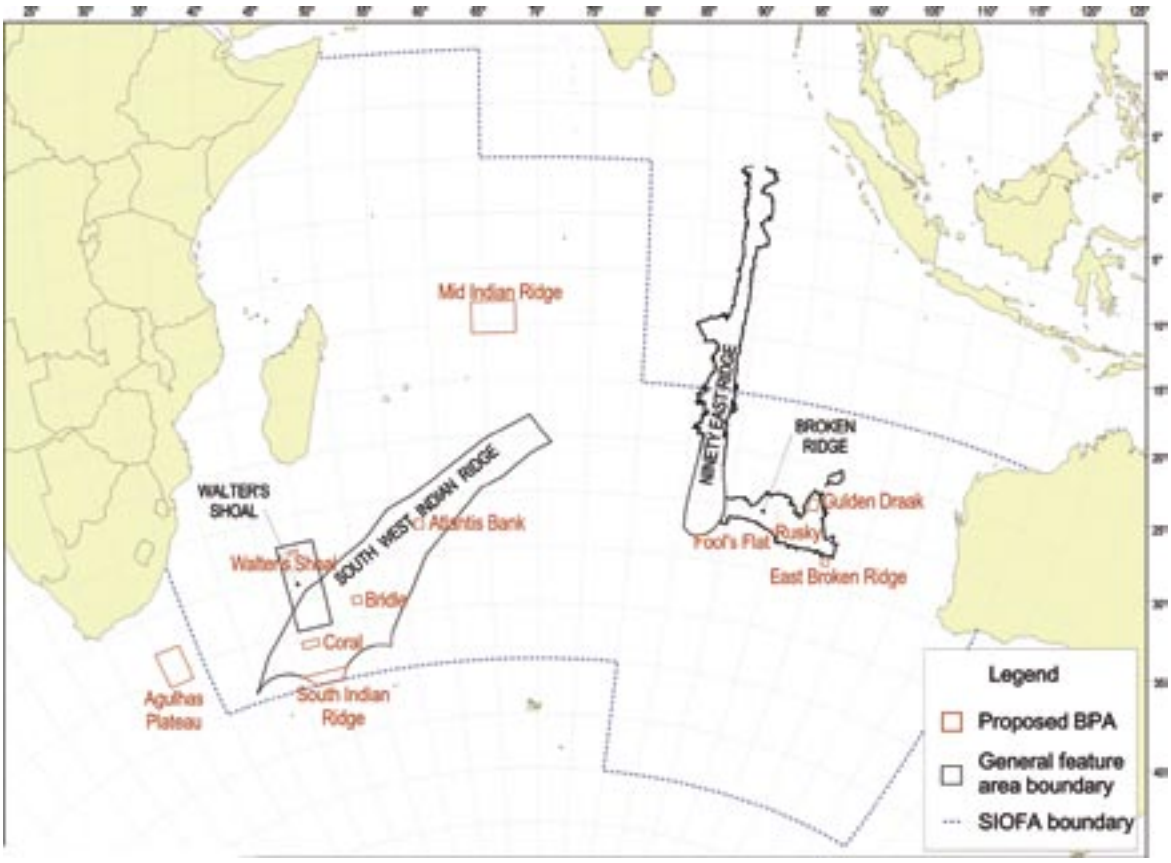
The locations of the benthic protected areas (BPAs) can be grouped into five main areas:

i. the Agulhas Plateau to the extreme south-east Indian Ocean
ii. the South West Indian ridge in the southeastern quadrant of the Indian Ocean
iii. Walter's Shoal – on the southerly extension of the Madagascan Ridge
iv. the mid-Indian Ridge in the centre of the Indian Ocean and on
v. Broken Ridge in the southeastern Indian Ocean.

[2] Ecologically, defined as a large naturally-occurring community of flora and fauna occupying a major habitat.

FIGURE 1

Southern Indian Ocean showing the boundaries of the zone of competence of the *Southern Indian Ocean Fisheries Agreement* and the benthic protected areas observed by the Southern Indian Ocean Deepwater Fishers' Association (SIODFA)



Map compilation: 23 August 2006; Lambert Equal Area Azimuthal

This has left the Ninety East Ridge upon which no BPAs have been sited. The reason for this is that there are no bottom fisheries on this massive feature – when trawl fishing is undertaken it is exclusively by mid-water trawling.

In the west of the Agreement area, oceanographic research (e.g. Lutjeharms and van Ballegooyen 1984, Peterson and Stramma 1991) and biological oceanography (Dower and Lucas 1993, McMurray *et al*. 1993) has been done by South African scientists. However, in the east, most work, by Australians, has focused on the Leuwin Current, inshore of the West Australian Current, which is the water mass that flows over the area of interest here. Even for waters of the Leuwin Current, the most important work seems to remain that done in the early 1960s and reported upon by Tranter and Rochford in a number of papers in the mid-1970s. This work examined a number of sample collections taken along the 110 °E meridian between 9°30'E and 32 °S, which at its closest to the Gulden Draak BPA is still 1 450 nautical miles to the east.[3]

[3] An as yet unseen publication, *The Agulhas Current* (330 pp), edited by J. Lutjeharms, has recently been published by Springer. The book describes the circulation of the South Indian Ocean, the sources of the Agulhas Current, the Current proper, its retroflection, Agulhas rings, the Agulhas Return Current and their influence on the adjacent shelves and the coastline. It deals with the influence of this current system on local weather and climate and identifies those areas and regions where little is known and more information is crucial for oceanographic prediction in the region.

Indian South Subtropical Province

This biome extends from the hydrochemical front at 10–15 °S to the Sub-tropical Convergence at ≈ 30 °S. The Eastern margin is the Australian coastal boundary at the outer edge of the Leuwin Current, and to the west the coastal boundaries of the Eastern Africa Coastal Province. Longhurst notes that there is little organized knowledge of this subtropical Indian Ocean gyre. Circulation is variable in response to monsoonal influences and during the boreal summer, the southeast trades crosses the equator northwards with the intertropical convergence zone (ITCZ). Anticyclonic wind stress extends from around 10–15 °S to the southern limb of the gyre. This is strongest during the austral summer and autumn and reaches a maximum around 30 °S. During the boreal winter, the ITCZ lies south of the equator and winds and wind-driven currents are weaker and more variable. The central thermocline trough shoals and becomes divided into a series of separate basins separated by the shallower ridges.

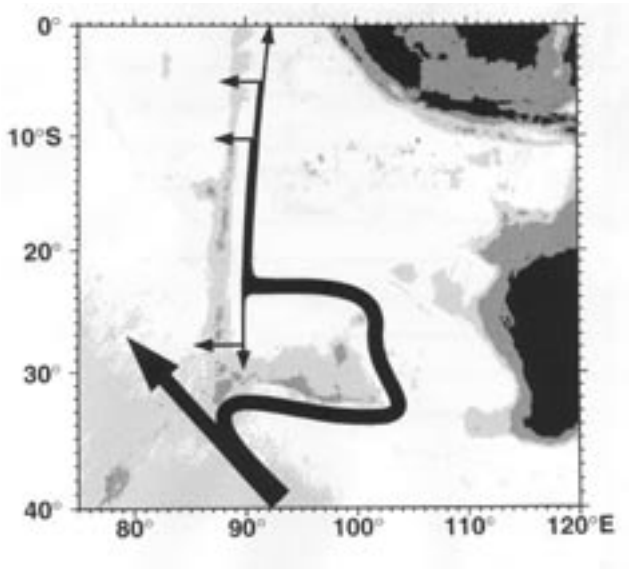
Longhurst places the Subtropical Convergence Zone in a separate system and notes that the return eastward flow of the poleward limb of the subtropical gyre occurs along the SCZ at about 40 °S. The core of this flow is the oceanic jet of the southern Indian Ocean Current, continuous from the Agulhas Return Current to the Western coast of Australia. Eddies and meanders progressively pass water into the interior of the gyre, and Longhurst puts the equatorward edge of its file of eddies and meanders at the limit to this biome. Across the entire province during the boreal winter, the thermocline is shallower in the west and deeper in the east and is driven by eastwards wind stress along the ICTZ. Polewards of 15–20 °S there is during the austral winter a trough between Madagascar and northwestern Australia around which flows an anticyclonic gyre.

A maximum of surface chlorophyll occurs during the austral winter (July–October); possibly driven by the mixed layer extending through the photic zone with associated nutrient entrainment. Coupling between herbivores and plankton appears to be closely linked. In synopsis, Longhurst notes there is moderate austral winter mixing when the pycnocline[4] lies briefly deeper than the photic zone. Primary production is driven by a deepening mixed layer with a broad summer–autumn peak. Peak chlorophyll biomass is brief and early.

Broken Ridge Plateau

Some information is available on the deepwater flow in this region. Warren and Johnson (2002) report that Circumpolar Deep Water from the South Australian Basin enters the Central Indian Basin by flowing north-westward passing to the southwest of the Broken Ridge Plateau (Figure 2). Water shallower than the sill depth of 3 500 – 4 000 m flows north-westward along the eastern flank of the Southeast Indian Ridge as a western boundary current to supply the upper

FIGURE 2
Water flow direction of the South Australian Basin into the Central Indian Basin



Source: Warren and Johnson 2002.

[4] A vertical density gradient (as determined by the vertical temperature and salinity gradients and equation of state) in some layer of a body of water, which is appreciably greater than the gradients above and below it; also a layer in which such a gradient occurs. The principal pycnoclines in the ocean are either seasonal, due to heating of the surface water in summer, freshwater inputs or permanent.

deeper water (>3 800 m) in the Central Basin. Water from above the deeper isobaths in the South Australian Basin enters eastwards along the Broken Ridge Plateau and proceeds northward as another boundary current, in the view of Warren and Johnston, probably to the northern limit of the East Indiaman Ridge where it turns westward to feed the deep western boundary current system of the West Australian Basin.

Eastern Africa Coastal Province

This province includes a coastal area that is of only peripheral interest here; but the relation of the coastal currents at their southern limit where they form the Agulhas Retroflection is of relevance. The greatest area of shelf is the Agulhas Bank, which lies between the Cape Peninsula (19 °S) and Port Elizabeth (26 °S).

There are several currents of relevance in the coastal region: (i) an eddying current flowing south through the Mozambique Channel; (ii) a rapid and direct southward flow along the east coast of Madagascar; (iii) the Agulhas Current, subtropical water that flows southward from Madagascar to the Cape Peninsula and (v); in the area south of South Africa, the Agulhas Retroflection. These currents together form the poleward western-most limb of the southern subtropical gyre of the Indian Ocean.

Agulhas Current

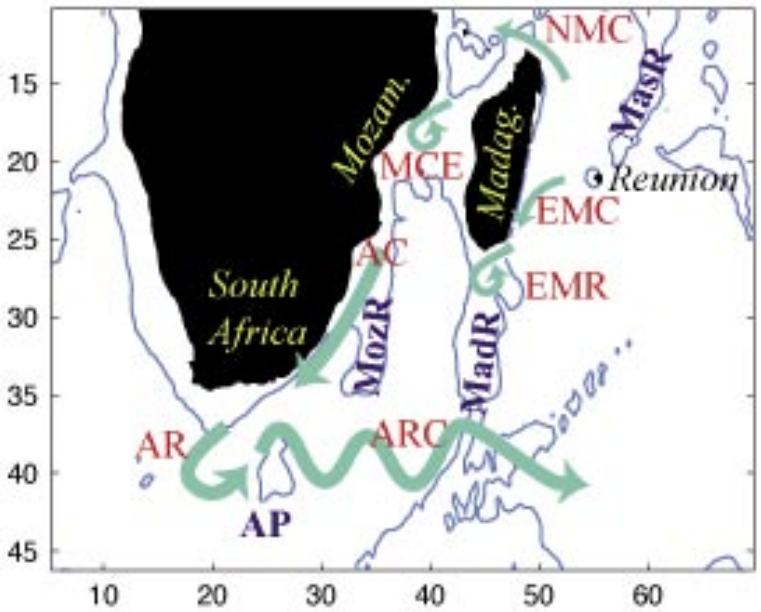
Quartly and Srokosz report that the Agulhas Current System (Figures 3 and 4) lies at a critical point on the global thermohaline circulation. It starts in the region of variable flow at the southern end of the Mozambique Channel around 25 °S and flows south to the southern extremity of South Africa; it is also fed by flows around the southern tip of Madagascar. Moving offshore, there is a meandering jet of maximum speed and further seaward, a zone of anticyclonic shear. As the Current progresses it becomes wider and border plumes and eddies also increase progressively. Shedding of eddies is particularly well studied in the Agulhas Retroflection Area south of South Africa (Figure 3).

Agulhas Retroflection

This persistent feature (Figures 3 and 4) occurs where the western boundary currents encounter the east-flowing circumpolar currents and its ecological effects are continuous with those of the Agulhas Current. The flow can show wide north–south meanders with strong thermal contrast (Quartly and Srokosz). Water from the Retroflection feeds into the easterly-flowing current around the circular core of the South Subtropical Convergence. The scale of the Retroflection is >300 km and the flow of the Agulhas Current reverses in this anticyclonic feature to flow eastwards along the 40 °S parallel as the southern Indian Ocean Current into the circumpolar

FIGURE 3

Map of SW Indian Ocean, showing land masses, subsea features and principal current systems



AC: Agulhas Current; **AP**: Agulhas Plateau; **AR**: Agulhas Retroflection; **EMC**: East Madagascar Current; **EMR**: East Madagascar Retroflection; **MCE**: Mozambique Channel Eddy; **NMC**: North Madagascar Current; **MozR**: Mozambique Ridge; **MadR**: Madagascar Ridge; **MasR**: Mascarene Ridge.

Source: Quartly and Srokosz.

FIGURE 4
Composite CZCS image of the Agulhas Retroflection region and southern Indian Ocean February 1983 (NASA)

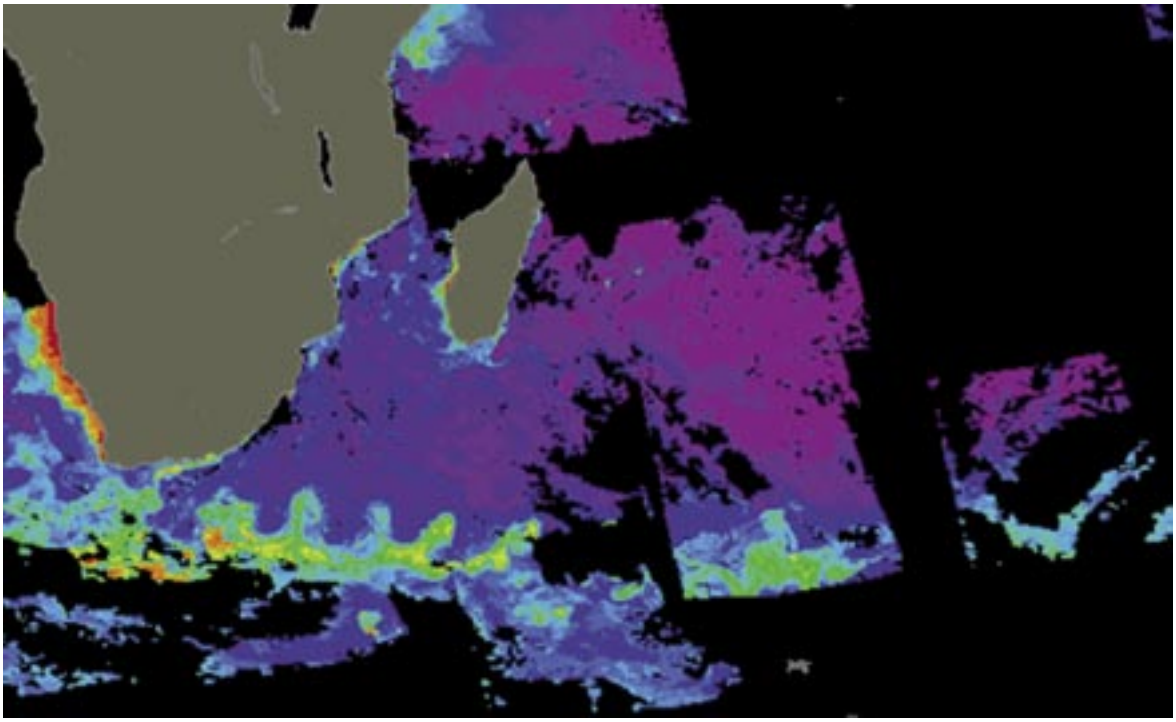


Figure 4 shows standing waves in the Agulhas Return Current induced by interaction with the Agulhas Plateau. The collision of the Agulhas Current with the Benguela Current and Antarctic Convergence Current produces the Agulhas Return Current. This merges with the Antarctic Convergence Current and then encounters the Agulhas Plateau approximately 1 500 m deep. The interaction of the currents with the plateau creates immense undulations in the current that are evident almost 2 000 km east of the Retroflection.

current system. This system often covers the Agulhas Plateau. Figure 5 shows the locations of the BPAs in relation to these oceanographic features

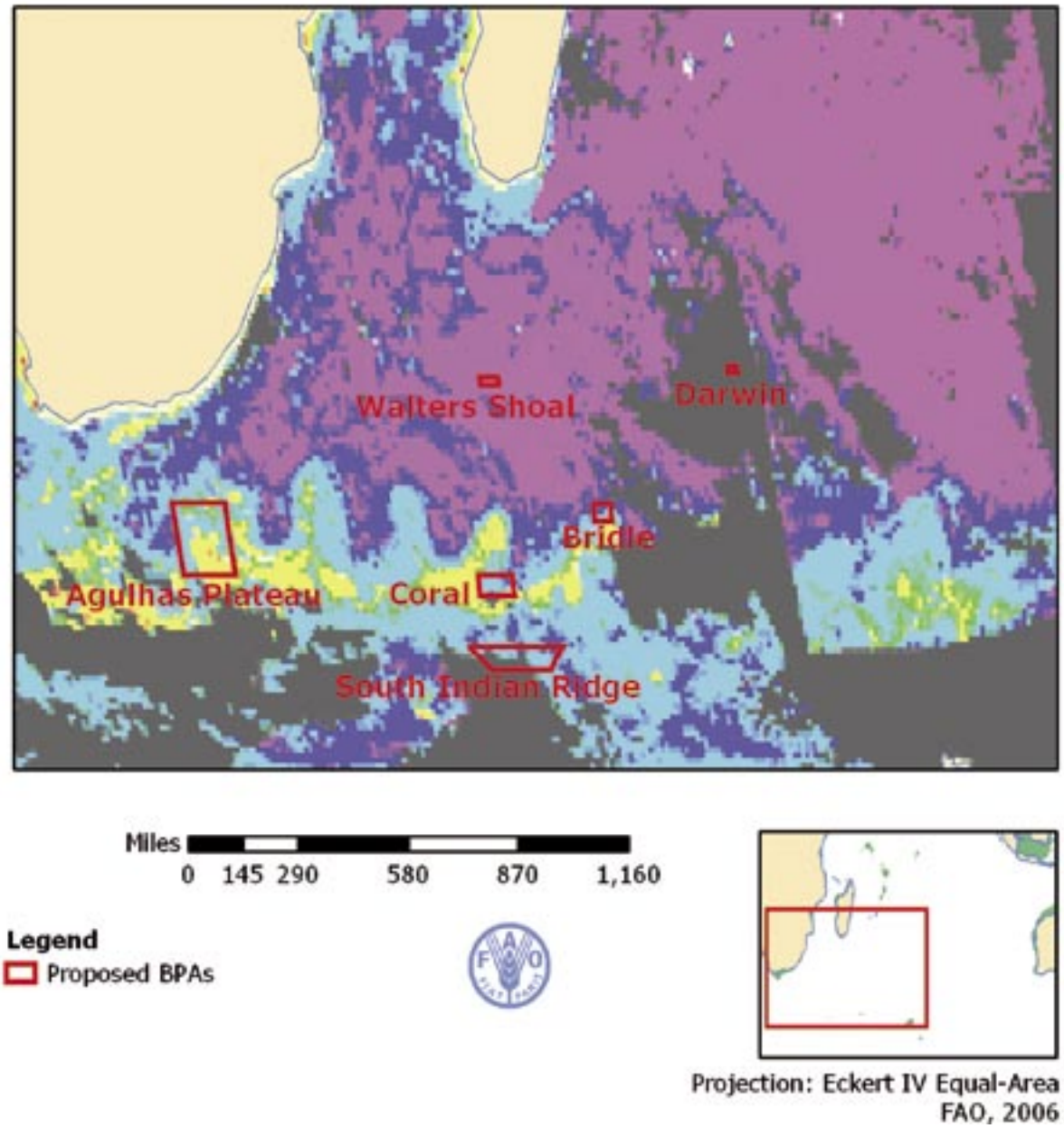
Topographically-driven upwelling occurs in the Agulhas Current downstream of the major coastal prominences at 25 ° and 34 °S. Chlorophyll blooms may be detected in these areas. On the Agulhas Bank, there is evidence of a typical temperate shelf-production cycle: in winter the mixed layer is deeper than the photic zone and production is light-limited. In summer the euphotic zone becomes thermally stratified and between the two seasons there is a spring diatom bloom. During the summer on the Agulhas Bank, shelf-edge upwelling may result in intrusion of cold bottom water onto the bank, resulting in episodic blooms of diatoms. Longhurst (1998) notes that phytoplankton growth in eddies shed in the Agulhas Retroflection are limited by convective instability and outside these zones, by light limitations.

3.2 Description of SWIO area, grounds fished, gear deployed and environment

Figure 2 of FAO (2002b) shows recommended data reporting sub-areas for the Indian Ocean that separate deep-sea ridges for fisheries landings reporting purposes. The potential fishing grounds in Area 3 extend southwest from the north easternmost point at about 35 °S 55 °E to the most southerly point at about 45 °S, 40 °E. The southernmost boundary is on the northern border of the CCAMLR zone, outside of Area 3; this area enters the South African exclusive economic zone (EEZ) around the Prince Edward Island complex.

Here, the areas targeted can be grouped into five grounds on the South West Indian Ocean (SWIO) and Madagascar Ridges. On the Madagascar Ridge effort has been directed on Walters Shoals as well as grounds extending northwards to southern Madagascar. Catches in this area have been

FIGURE 5
Retroflection region in the southern Indian Ocean showing location of the relevant benthic protected areas



reported as being more diverse than on the SWIO Ridge, with higher proportions of wreckfish (*Polyprion* spp.) and bluenose (*Hyperglyphae antarctica*).

It is reported (Japp MS) that the grounds fished in the SWIO are extremely difficult to trawl relative to known deepwater grounds elsewhere. New Zealand skippers are frequently used by fishing operators on the SWIO grounds and they have all reported difficulty in the trawling conditions. Typically established trawling lanes, as have been developed in orange roughy fisheries elsewhere, were non-existent on the SWIO grounds, which exacerbated skippers' problems. An example of a heavily fished area is the Melville Banks. Depths here vary considerably and logbook data suggests that the most frequently fished depth range was 750–1 000 m though trawling as deep as 1 500 m has been recorded. It should also be noted that grounds fished do not match the charted areas well and skippers often had to develop their own bathymetry charts through real-time 3-D mapping software. Discussions with owners and skippers also indicated that in the early phases of the fishery, many skippers did not have the necessary skills to fish the area and lost their gear – hence

why many vessels had such brief appearances. There are also indications that the grounds are not as typically steep as in many other known seamount fishing areas, but were generally flattish, hard and irregular, making predictable trawling conditions difficult.

A factor in all discussions by Japp with fishing operators, undertaken on behalf of FAO to better document this fishery, was the common experience of the existence of strong currents and variable bottom temperatures. Bottom currents were highly unpredictable and this was also associated with variability in bottom temperatures and well formed deep thermoclines: in some cases temperature inversions were reported. Several operators indicated that the prevailing currents are driven by the subsurface circumpolar circulation and that the key to the future of the fishery was identifying and predicting the variable bottom-water and temperature profiles. This might indicate that the eddies of the Aghulas Retroflection extend further than could be expected.

Species availability was also unpredictable and correlated with both current strength and temperature. Successful orange roughy catches could 'switch on and off' and were not necessarily correlated with poor fishing conditions. As in other areas of the Southern Hemisphere, aggregations of orange roughy occurred, but were also unpredictable in nature.

3.3 Collection of XBT[5] Data

Some collection of XBT data by commercial fishing vessels has been undertaken by vessels of the SIODFA (see Figures 15 and 19) and by exploratory and commercial fishing vessels from Ukraine as well as research vessels of YugNIRO in Kerch, Crimea, Ukraine. It was recognized that there would be benefits from a coordinated collation and reporting of this data beyond that reported by Romanov (2003) in terms of understanding the movement of deepwater fishes in the region. It was agreed that actions should be taken to bring this to pass.

4. SOUTHERN INDIAN OCEAN BENTHIC PROTECTED AREAS

4.1 Selection of areas

4.1.1 Introduction

It was a unanimous view at the first meeting in Kameeldrift East that it would be essential to avoid fishing activities in a representative selection of areas in the region of their operations for the purposes of scientific studies and conservation of deepwater marine biodiversity. However, it was clear that it would be impossible to reach agreement among the operators on what areas should be observed as some form of marine protected areas without consulting those best informed about the conditions occurring in the fishing area. For this reason, the FAO was asked to coordinate correspondence among the participants and to prepare a list of areas that could be discussed and evaluates at the second meeting, which was subsequently held in Mauritius.

It was the view of the operators that less than one percent of the region within the depth range of 500–1 600 m that would come under the *Southern Indian Ocean Fisheries Agreement*, had been bottom trawled, i.e. more than 99 percent of the southern Indian Ocean in this depth range would have been untouched by bottom trawling. And, because there had only been trawling on a small proportion of the South West Indian Ocean and the central southern Indian Ocean (including 90 ° East Ridge regions and Broken Ridge) it was highly unlikely that trawling would have had a major adverse effect on the general marine environment. However, there would have been localized effects on the hard substrate epifauna in some regions where trawling had occurred.

A number of areas were identified by different operators and operators' skippers as potential BPAs. In about a third of these cases, there was consensus that an area deserved protection. In about another third of the cases, the areas that were proposed were accepted, but after modification of their boundaries. And in about a third of the proposals, agreement was not possible. However,

[5] Expendable bathythermograph data.

agreement was reached at the Albion, Mauritius meeting on a similar number of new conservation areas that were considered to be superior in satisfying the requirements that had been identified as necessary.

It was agreed that the primary objective of the marine protected areas was to protect benthos and that the purpose of the "benthic" protected areas would not include specifically conservation of fishery resources. It was further recognized that although designed to protect benthos, not only bottom trawling but midwater trawling as well would need to be banned in the designated areas. This would be required as it is not possible with the information provided by vessel monitoring systems (VMSs) to determine whether a vessel is bottom trawling or midwater trawling. To the extent that fish populations are resident in the protected areas, then they would be conserved by the ban on fishing. However, it was the view of the Association's members that conservation of fishery resources should be done primarily through effective and responsible fisheries management.

There was also discussion on how most appropriately to describe the proposed protected areas. While it was recognized that the areas could be described as *marine protected areas*, it was noted that the primary objective was that these areas were being nominated to protect the benthic fauna, i.e. for conservation. For this reason, it was agreed that they would be referred to as *benthic protected areas* (BPAs). This terminology would also be consistent with that which had been proposed in New Zealand for similar areas, albeit within the New Zealand exclusive economic zone (EEZ).

4.1.2 Considerations in the selection of the benthic protected areas

It was recognized that there were two objectives in creating protected areas in the southern Indian Ocean Selection: (a) the protection of areas of particular benthic biodiversity to ensure that such areas were sustained in a state that was as close as possible to that existing before the start of trawl fishing operations in the area and (b), providing direction to others, within the fishing industry and in other economic sectors, that areas had been selected for protection. It is hoped that restrictions that the SIODFA have placed upon themselves would be adopted by other economic sectors though it was recognized that actions of the Association's members could not be imposed on others.

One issue that was considered in establishing the BPAs was the possibility of their becoming fully protected areas. In such a case, all mining and/or oil exploitation and many types of research work would be prevented in a fully protected area. If the BPAs listed here were to be converted into full MPAs, many parties would be involved in the discussions. Hence e.g., large sediment-covered areas between 1 000 and 1 400 m along Broken Ridge in particular, have not been proposed as BPAs as they may become areas for other extractive purposes and whose environmental concerns would be the concern and mandate of other sectors. So, instead of proposing protection of large areas where trawling is impossible, localized areas of known value and representative benthic biodiversity have been chosen for protection: here, no bottom or midwater trawling will be allowed by SIODFA members'vessels. Thus, little of the enormous abyssal plain has been included in the proposed BPAs.

SIODFA members have created large bathymetric databases of the entire Indian Ocean. Large areas have been swathe mapped using 11 kHz frequency sidescan sonar. Examples follow in subsequent sections. Sidescan sonar uses low frequency sound with an acoustic system that has multiple transducers to map seafloor habitat. The system used for this mapping had a wide footprint and covered large bottom areas: it not only provided accurate bathymetry, but could also distinguish between soft and hard sediments. Additional bathymetric databases have been built up from commercial vessel echo sounders using the Seaplot ™ and Piscatus ™ data logging systems.

Highly detailed bathymetric information is available for most of the fishable depths in the region and was used to determine inferred habitat and biodiversity information collected from operations

TABLE 1
Indian Ocean benthic protected areas – names and locations

SIODFA BENTHIC PROTECTED AREAS						
Area	**Coordinates**				**Area (km²)**	**Area features**
	Lat (S)	Long (E)	Lat (S)	Long (E)		
Gülden Draak	28° 00′	98° 00′	29° 00′	99° 00′	10 867	A massive mid-ocean seamount in pristine biological condition.
Rusky	31° 20′	94° 55′	31° 30′	95° 00′	147	A productive knoll located on extensive ridge; extensive black coral exists with the benthos in an almost pristine state.
Fools' Flat	31° 30′	94° 40′	31° 40′	95° 00′	585	A deep-sea bank with numerous canyons incising its slopes; strong upwelling currents sustain extensive coral beds; in pristine condition, this is a previously unmapped area of the seabed.
East Broken Ridge	32° 50′	100° 50′	33° 25′	101° 40′	5 037	A seamount rising to 1 000 m, biologically pristine; its benthos and topography previously undescribed.
Mid-Indian Ridge	13° 00′	64° 00′	15° 50′	68° 00′	135 688	An area of seamounts rising to 650 m; a tropical region in pristine biological condition.
Atlantis Bank	32° 00′	57° 00′	32° 50′	58° 00′	8 694	This seamount was formed from an ancient island; extensive research has been conducted on this BPA by a number of agencies; it is the location of a productive fishery
Bridle	38° 03′	49° 00′	38° 45′	50° 00′	6 788	An area of knolls and ridges in almost pristine condition; previously unmapped and undescribed.
Walters Shoal	33° 00′	43° 10′	33° 20′	44° 10′	3 443	This area, which rises from 4 000 to within 10 m of the surface provides a habitat for a variety of whale species; the area is characterized by high biodiversity
Coral	41° 00′	42° 00′	41° 40′	44° 00′	12 376	A spreading centre with seamounts and ridges with depths from 4 500 m to 180 m. Extensive coral beds, a near pristine area.
South Indian Ridge (North/ South)	44° 00′ 45° 00′ S	40.878° S 42.124° E	44 00′ 45° 00′ S	46.544° E 45.711° E	39 358	An area of seamounts adjacent to the CCAMLR region to the south; in pristine biological condition. This area is bounded to the east and west by the EEZs of South Africa and France.
Agulhas Plateau	38° 00′	25° 00′	41° 00′	28° 00′	85 828	Region of seamounts north of the proposed South African Antarctic MPA; contiguous with the South African EEZ to the west.
Total area					**309 051**	

TABLE 2
BPA feature summary

BPA feature	Physical characteristics				Known to have been trawled	Believed to be unfished[1]	Oceanograhic data exists	Biological data exists	USSR/ Ukrainian fishing data exists	Other fishing data exists
	Plateau	Canyons	Corals	Knoll or seamount						
Gülden Draak	✓	×				✓	✓?	✓	✓	
Rusky	×	×	✓	✓	✓		✓	✓	✓	
Fools' Flat	✓	×	✓		✓		✓	✓	✓	
East Broken Ridge	×	✓		✓		✓	✓	✓?	✓	
Mid-Indian Ridge	×			✓						
Atlantis Bank		×	✓	✓	✓		✓	✓	✓	
Bridle		×		✓	✓		✓	✓	✓	✓
Walters Shoal	✓	✓			✓		✓	✓	✓	
Coral		×	✓	✓	✓		✓?	✓	✓	✓
South Indian Ridge		×		✓		✓				
Agulhas Plateau	✓			✓		✓	✓	✓	✓	

[1] Refers to deepwater trawling.
Blank indicates that the situation is unknown; question marks indicate some uncertainty.

in the area eleven benthic protected areas were selected. These were chosen to represent a large diversity in the geological structures, sediment overlays, bottom types and benthic habitat types in the Indian Ocean. While many features have hard substrates, which are suitable for attachment by sponges, corals, tunicates and the like, many are covered with unstable sediments or are composed of muds or clays and are relatively barren of benthos.

4.1.3 Selection criteria

Geographical extent

Given the size of the Agreement's area, there was unanimity that the areas selected for protection should be spread over a wide area, both in terms of latitude and longitude.

Representation of seabed morphology – type of feature

In proposing candidate areas for protection it was noted that areas selected should include the following types of bottom features, in multiple occurrences where possible:

- seamounts
- spreading ridge structures
- canyons
- slope edges
- banks
- abyssal plain
- structural complexity of the seabed

Previous exposure to fishing activity

Proposed areas were considered from the perspective as to whether they had:

- been trawled extensively
- experienced limited trawling activity
- experienced very limited (minor) trawling activity
- no previous fishing activity

Existence of previous knowledge concerning the proposed area

Consideration was given as to whether:

- the area contained new seabed features that were only known to, and explored by, the Association's members;
- the area was already charted but where the Association's members had contributed to improved understanding of the physical and biological characteristics of the area; or
- the area, while known, was unexplored.

In the case of bathymetric data collected by the Association's members, this consisted of data collected by (a) specially-commissioned swathe mapping and (b), fishing vessel track-line data.

Existence and availability of biological data

In considering the existence of biological data consideration was given to the known availability of:

- catch composition data
- bycatch data from trawling, both ichthyofauna and benthic and pelagic invertebrates
- acoustic images of corals and benthic biota
- anecdotal observations and related information
- the existence of other sources of information

Table 1 lists the names, locations and features of the BPAs. Table 2 shows a summary of the features and known information for each of the BPAs.

4.1.4 Applicability of the protected areas

Consideration was given to the implications of the Association's decision to nominate and observe a suite of high-seas areas as biodiversity protected areas. It was recognized that, at present, the Law of the Sea Convention provides no satisfactory means of establishing areas on the highs seas whose fauna and biodiversity can be absolutely legally protected and so provide a foolproof legal basis to enforce compliance. It was recognized that decisions by those at the meetings would only apply to the Association's members and be self-imposed – there are no means of requiring others to comply with their decisions. Thus, for example, tuna purse seining or longlining, in the waters of the designated zones would be an issue for the appropriate regional management organization, in this case, the Indian Ocean Tuna Commission (IOTC). Of course a decision by the members of the IOTC to observe the BPAs would be welcome.

It was also recognized that there would be no benefit from asserting protection of biodiversity in areas beyond where their trawlers operate, e.g. by extending the boundaries of the no-trawling zones to large areas of adjacent abyssal areas simply to 'make the numbers look good'. It is for such reasons that large areas of sediment-covered bottom between 1 000–1 400 m along Broken Ridge have not been included in that BPA as they may be potential areas for other extractive purposes in the future. If at some time in the future oil or gas permits were to be issued for the areas that have been defined, or in adjacent areas, e.g. by the International Seabed Authority, obviously the SIODFOA would be in no position to insist on compliance with their decisions and it is uncertain if the Association would have standing to insist that it could provide input to regulatory decisions. On the other hand, there was consensus in hoping that other agencies would observe and support this initiative and not undermine its intent.

For these reasons, the participants at the two meetings agreed that adjacent areas of little or no potential interest to demersal fishing *should not be included* within proposed boundaries of the no take zones; rather their limits should be restricted to areas where there were (a) bottom features providing, or likely to provide, benthic habitat particular vulnerability to bottom trawling, (b) fauna, such as stands of deepwater corals were known to exist or (c), it was believed that the designated areas could be of particular scientific value.

4.1.5 Fishing operations considerations

Deepwater trawl fishing in the Agreement area consists of demersal fishing, i.e. when the trawl is close to, or on the bottom and midwater trawling. The general view was that about 60 percent of trawl shots by the Association's operators were midwater and about 40 percent were demersal, though this ratio varied between different operators depending on their fishing strategies, e.g. alfonsino are more commonly targeted with midwater trawling. Although the midwater trawls used in the Agreement area are rigged with "weak-link" footropes, i.e. sections of the trawl footrope designed to break if the trawl ground rope makes hard contact with the sea floor, there was unanimous agreement that to ensure that the benthos was assured of protection, ***all*** trawling – demersal and deepwater would be banned from the proposed protected areas.

Despite the primary focus on benthic conservation, it was noted that these areas would also serve a secondary fishery conservation/management function by providing a refuge from fishing activities for the species that occur in those areas. Several participants noted that the major midwater species that were targeted, i.e. alfonsino (*Beryx splendens*), boar fish (*Pseudopentaceros richardsoni*), blue-eyed whareou (*Hyperoglyphe antartica*) and cardinal fish (*Epigonus telescopus*) are mobile, if not highly mobile. Reliance on closures to fishing as an effective fisheries management tool would lead to failure; rather management of these resources will have to rely on accurate stock assessment sand setting of appropriate TACs. In the case of orange roughy and oreos, most of these catches are taken in relation to bottom features and preliminary observations indicate that there are numerous separate stocks, i.e. distinct breeding populations. In this case, there was agreement that use of commercial-vessel resource assessment, undertaken as an adjunct to fishing operations, is likely to be the only realistic means of resources management (see Section 12.2).

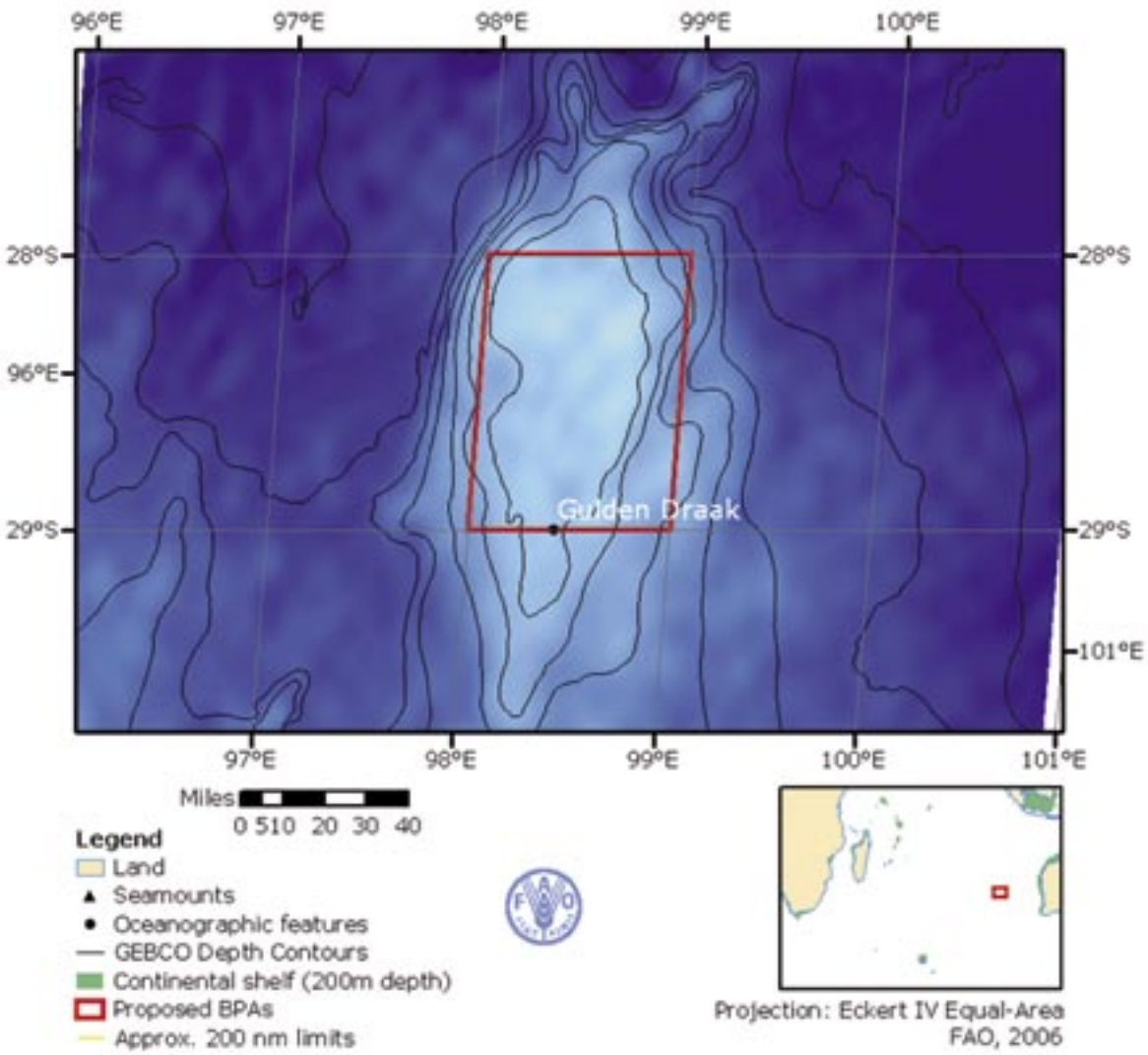
4.2 Gulden Draak[6]

Gulden Draak (Figure 6) is a large broken ridge and plateau area north of Broken Ridge and covers an area in excess of 10 000 km² in depths between 1 800 and 1 000 m; the feature runs in a north–south direction. The seamount rises from 4 000 to 1 100–1 000 m.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
28° 00′ S	98° 00′ E	101 – 300	0
		301 – 700	0
South-east		701 – 1 000	3.6
Lat	Long	1 001 – 1 500	9 290
29° 00′ S	99° 00′ E	>1500	1 573.4
		Total	10 867

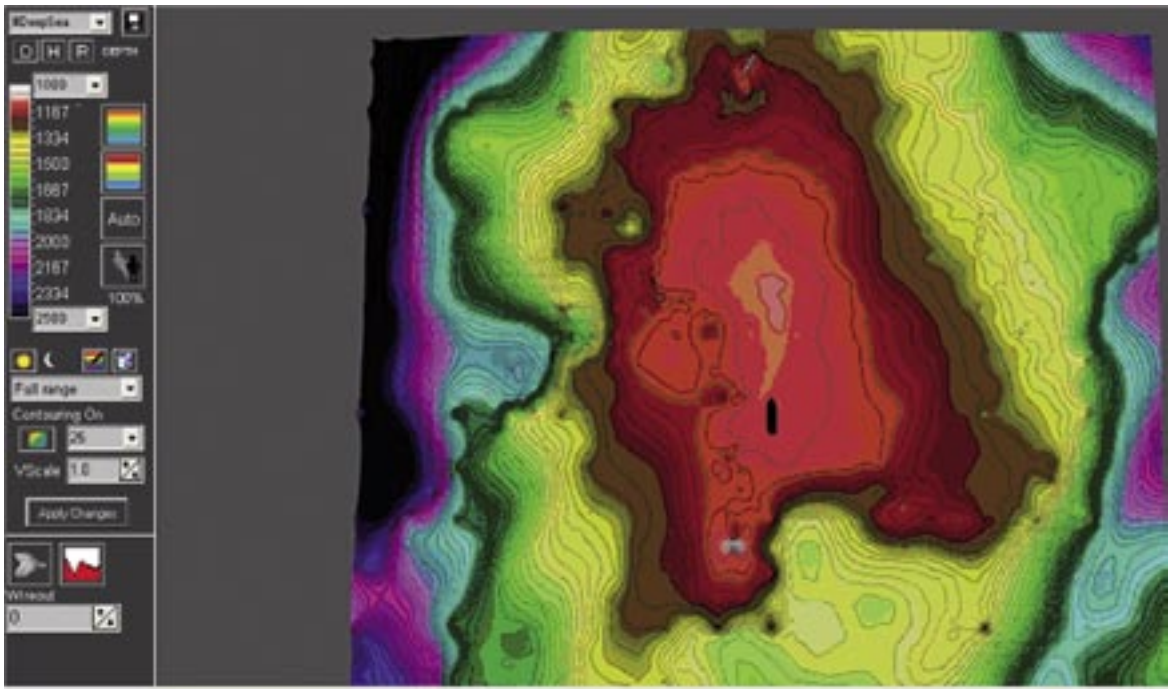
Because this region is widely separated from other fishing zones in the Indian Ocean it would have been only rarely visited by fishing vessels over the past decade. Despite this some information may be available from a range of fishing vessels that undertook occasional fishing there in the past, including the *F.Vs Will Watch*, *Nikko Maru*, *Southern Champion* and *Austral Leader*.

FIGURE 6
Gulden Draak benthic protected area



[6] The relation between the name of this Indian Ocean seafloor feature and the Belgian dark ale of the same name remains unknown.

FIGURE 7
Bathymetry of the Gulden Draak feature



Commercial fishes found in this area include several oreo species and the area is suitable for trawl fishing. Bottom water temperatures are low. Commercial log book information and acoustic records are available for this region and future work should be directed at documenting relevant fisheries information for this BPA. Despite this, it is believed that the majority of the benthic fauna in this area should be relatively pristine.

Some geological research has been done on the Broken Ridge area, e.g. that of Frey *et al.* (2000).

4.3 Rusky benthic protected area

This area has rocky extrusions and is characterized by extensive Cnidarian (black coral) coverage. Fishing on the Rusky benthic protected area is restricted to one or two tracks on the feature in the depth range 400–500 m. Hence, most of the feature should not have been affected by demersal trawling. It is reported that there has been past fishing by Soviet/Ukrainian vessels across the flats in this region, about the Broken Ridge area.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
31°20′ S	94°55′ E	101 – 300	0
		301 – 700	0.5
South-east		701 – 1 000	2.4
Lat	Long	1 001 – 1 500	143.4
31°30′ S	95°00′ E	>1500	0.3
		Total	146.6

4.4 Fools' Flat

This region (Figure 8) is found on the southern side of Broken Ridge Plateau, to the south of the Rusky BPA. This region was chosen because of the wide range of benthic habitats that it provides. The bank shoals to around 990 m; its southern side (the edge of Broken Ridge) drops down steeply to over 4 000 m. Figures 12 and 13 show two perspectives of this bottom feature. On the southern rim of the ridge are significant stands of unknown species of coral that have elevations of 20–30 m and can be seen with sidescan sonar (Figure 14). These, when they have been observed on vessel echo sounders, look like aggregations of fish (but they do not move) – hence the term "Fools' Flat". There appears to be strong upwelling over the south-west boundary and this no doubt has resulted in favourable conditions for the growth of the deepwater corals.

FIGURE 8
Rusky and Fools' Flat benthic protected areas

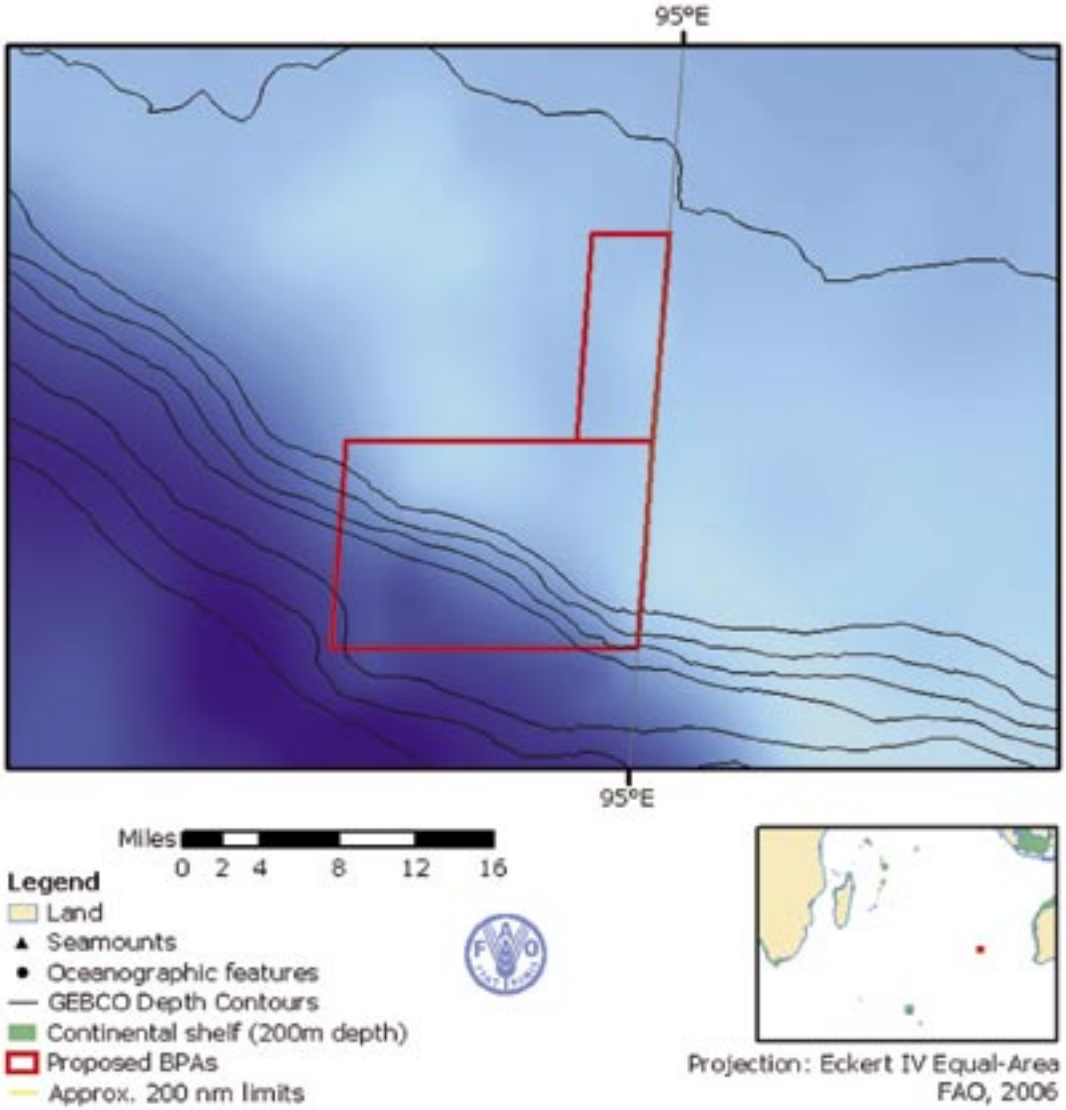


FIGURE 9
Bathymetry of the Rusky benthic protected area

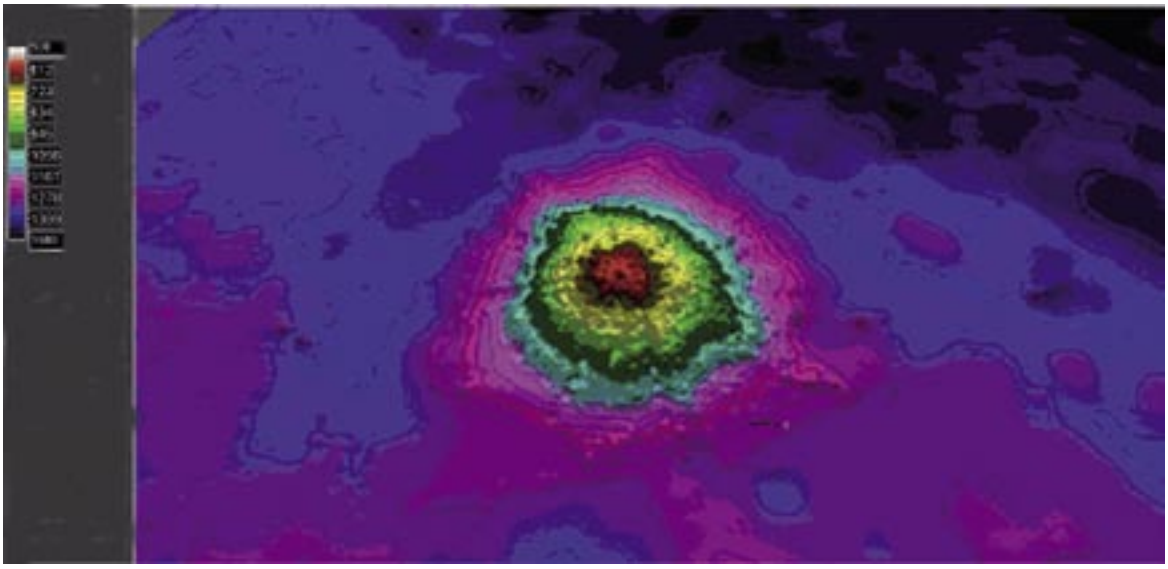


FIGURE 10
Swathe sidescan Image of Rusky Knoll

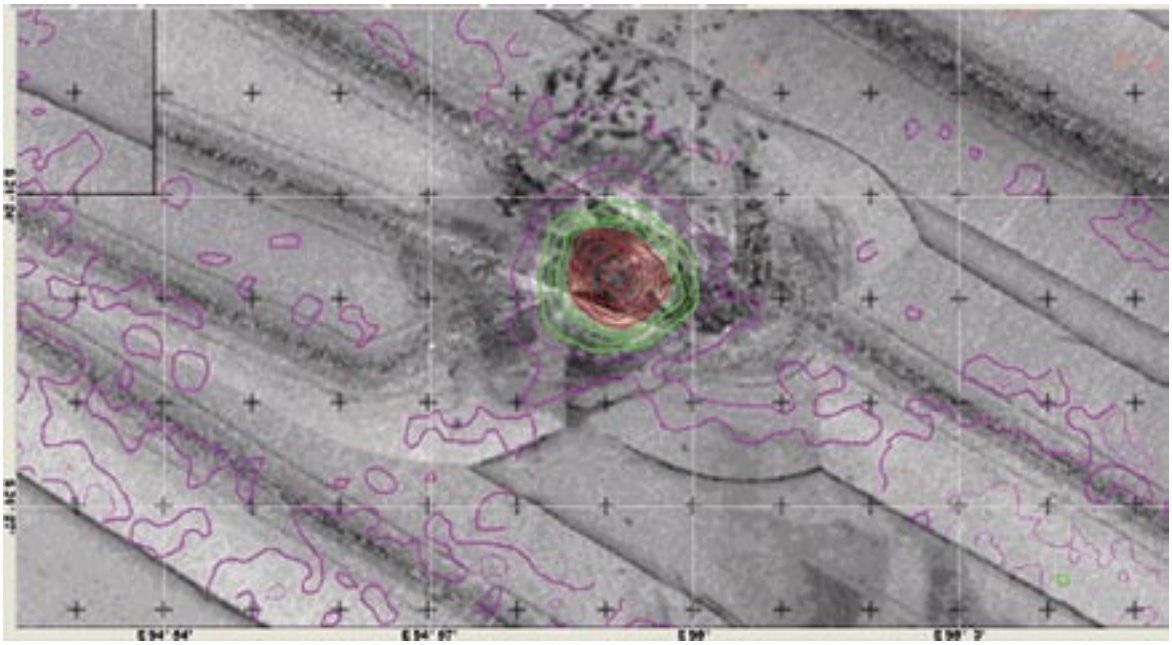
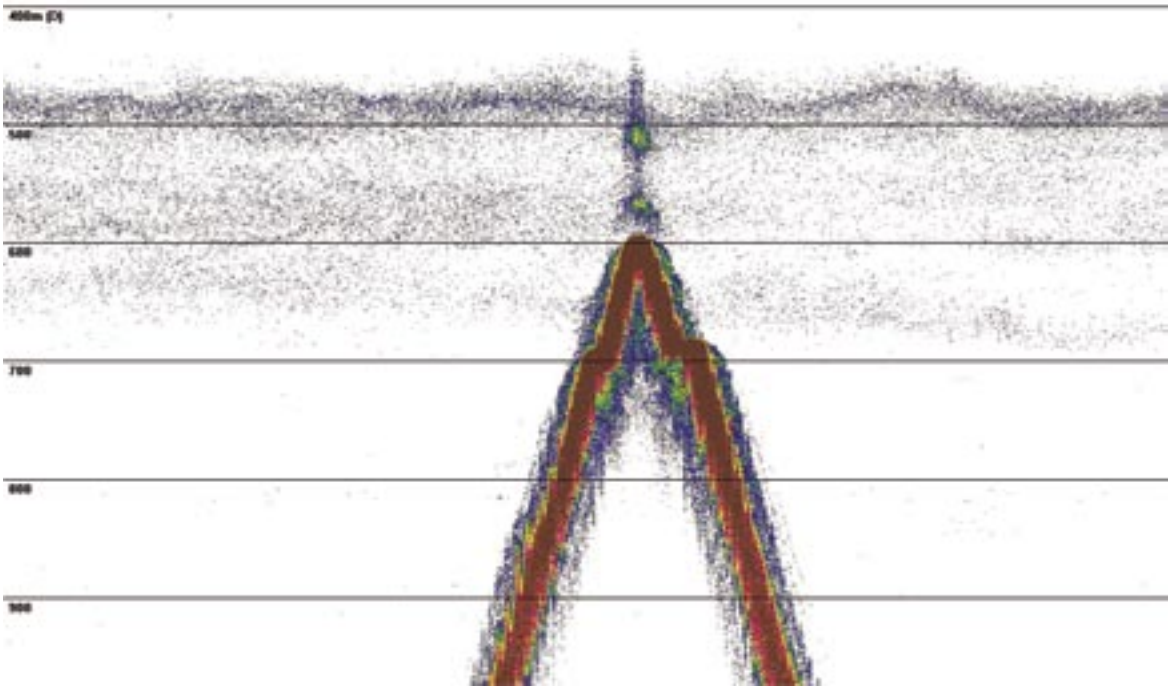


FIGURE 11
Echogram of small alfonsino (*Beryx slendens*) and boarfish (*Pseudopentaceros* spp.) schools on the top and the ledges around Rusky Knoll



Schools on the top and the ledges around Rusky knoll.

Source: G. Patchell, Sealord Group.

The only trawl tows undertaken here have been on the flat sedimented-bottom at around 1 000 m. At least two fishing vessels are believed to have data, collected in the past, and knowledge of the presence of fish fauna on this benthic protected area that will help in defining the ecology of this feature.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
31° 30′ S	94° 40′ E	101 – 300	0
		301 – 700	0
South-east		701 – 1 000	1.7
Lat	Long	1 001 – 1 500	299.7
31° 40′ S	95° 00′ E	>1500	283.9
		Total	585.3

FIGURE 12
Swathe sidescan image of Fools' Flat

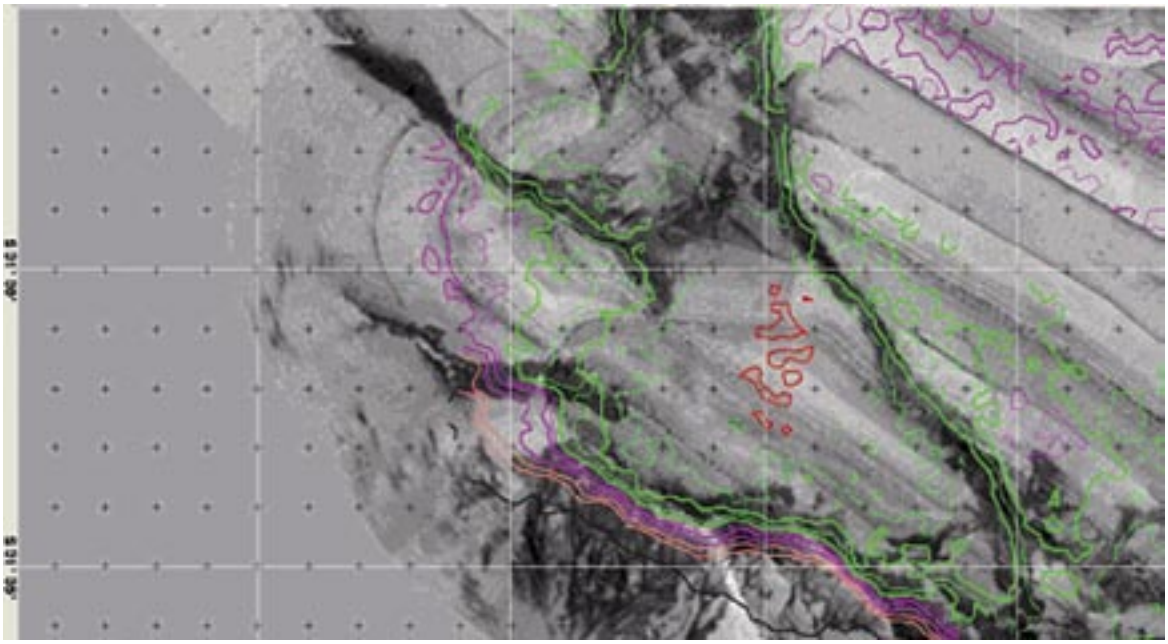


FIGURE 13
Bathymetry of Fools' Flat

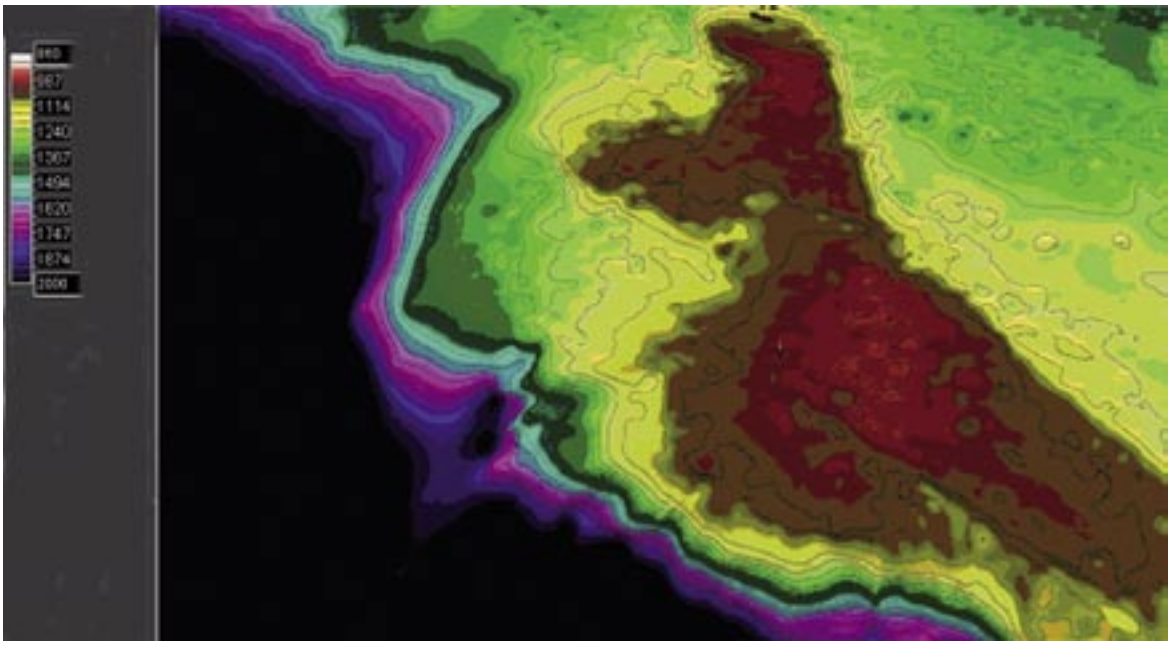


FIGURE 14
Sidescan image showing coral beds on Fools' Flat

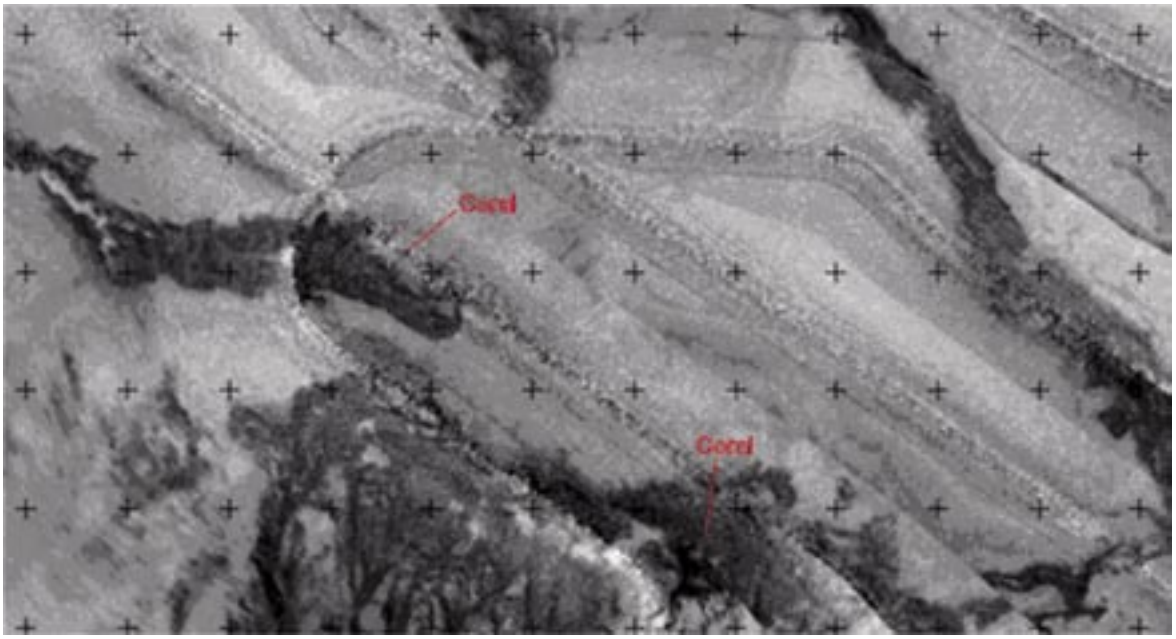
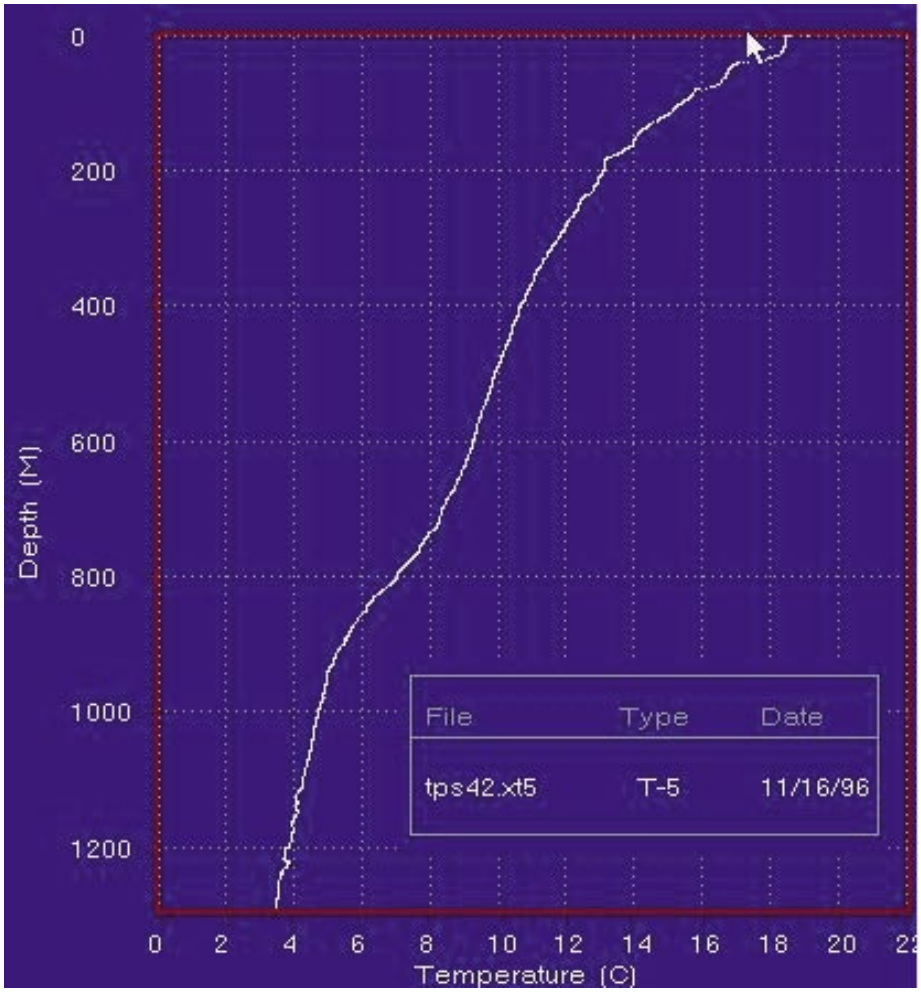


FIGURE 15
Bathythermograph profile, Fools' Flat, November 1996.
Zero to 1 250 m

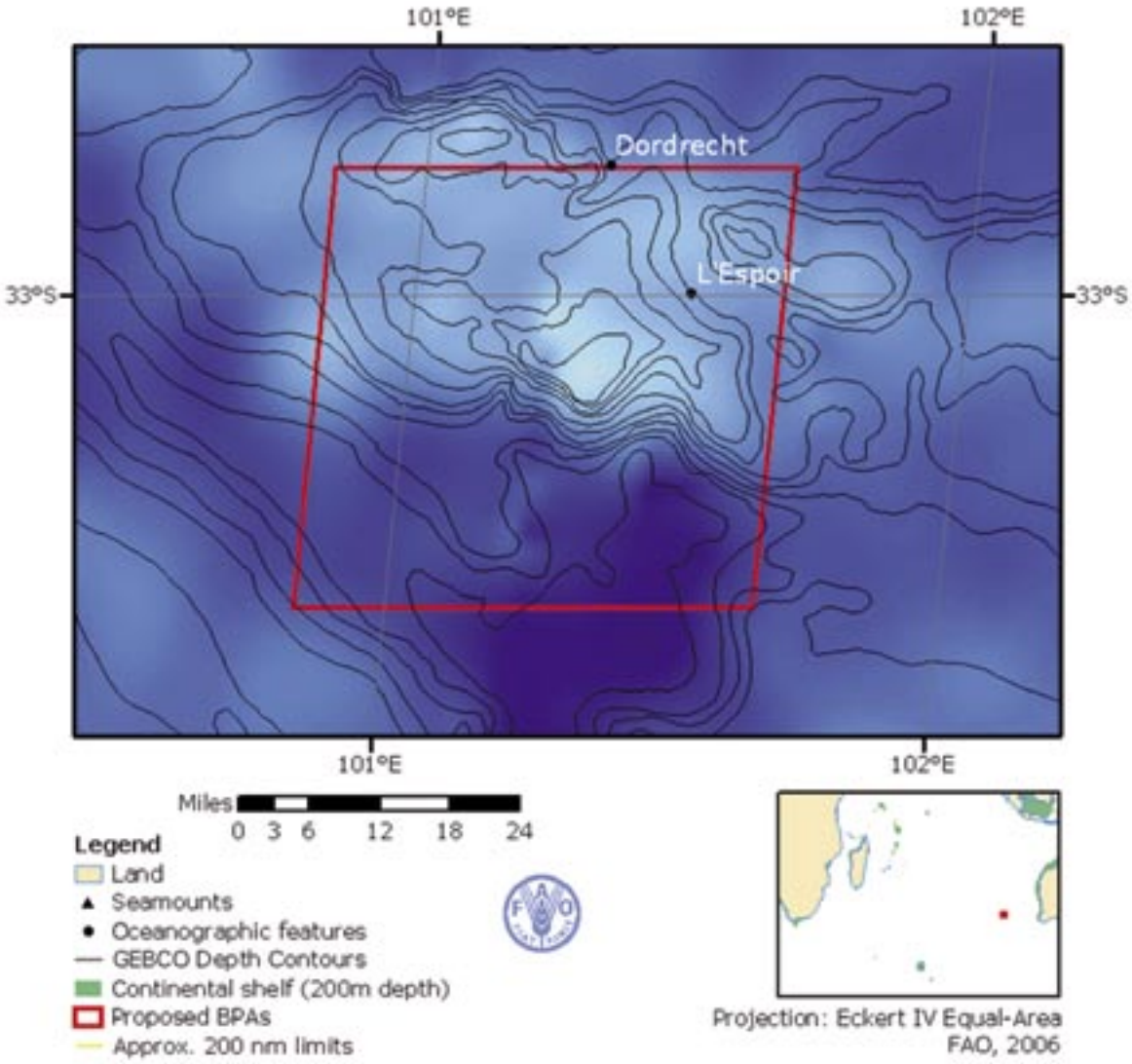


4.5 East Broken Ridge

This guyot[7] is located at the eastern end of Broken Ridge and is characterized by numerous slips and canyons extending down the sides (Figure 17). It rises from 3 000 m to a depth of 1 060 m (Figure 18). As far as is known it has not been previously described and has not been trawled. Exploration for fish aggregations has been undertaken, but only for one day. The seamount appears to have suitable environmental conditions for the deepwater species of fish that typically occur in the area (Figure 19). It is believed to be biologically pristine and its benthos and topography, which is highly fractured and, in the view of many skippers, makes demersal trawling impossible, is previously undescribed. There are some indications that this feature may have been above sea level at some time in the past.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
32° 50′ S	100° 50′ E	101 – 300	0
		301 – 700	0
South-east		701 – 1 000	0
Lat	Long	1 001 – 1 500	97.50
33° 25′ S	101° 40′ E	>1500	4 936.6
		Total	5 034.1

FIGURE 16
Bathymetry of East Broken Ridge benthic protected area



[7] A guyot is a flat topped seamount. Guyots show evidence of having been above the surface with gradual subsidence through stages from fringed reefed mountain, coral atoll, and finally a flat topped submerged mountain.

FIGURE 17
Swathe sidescan image of the Guyot east of Broken Ridge

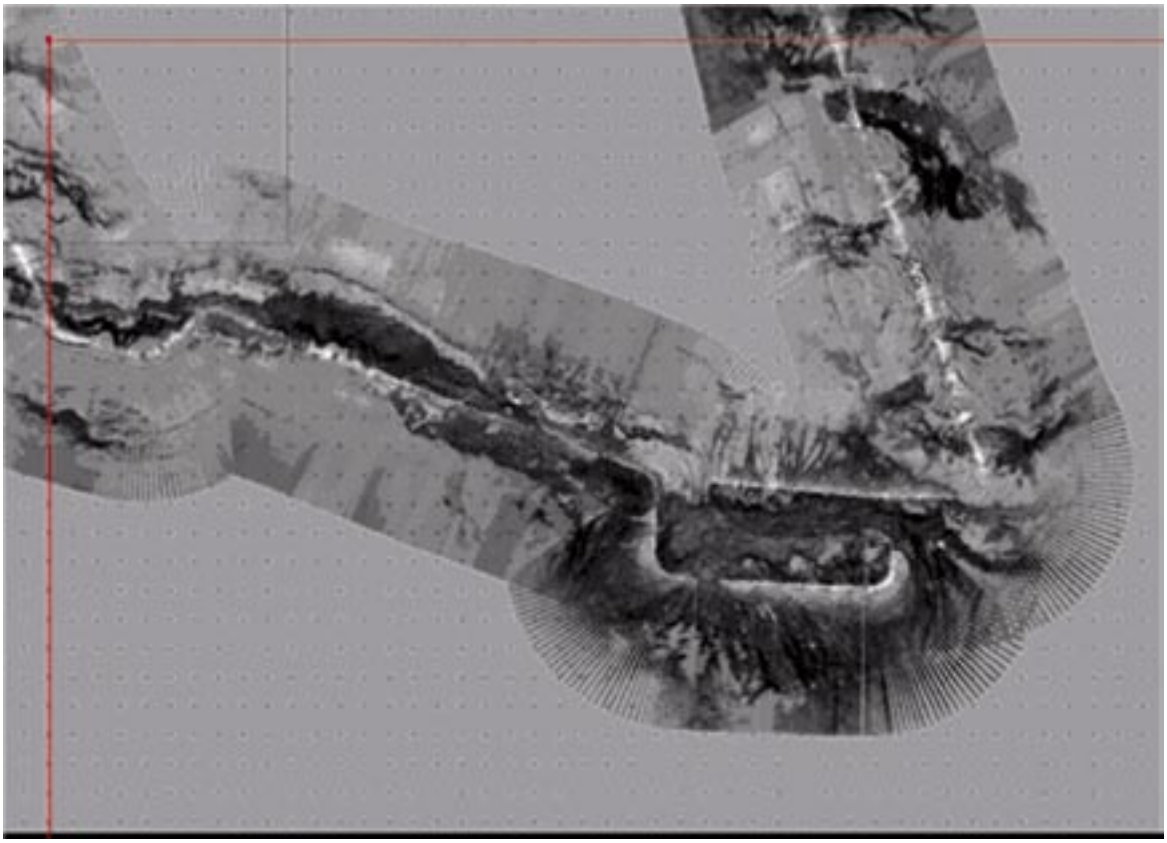


FIGURE 18
Bathymetry of seamount to the east of Broken Ridge (60-mile view)

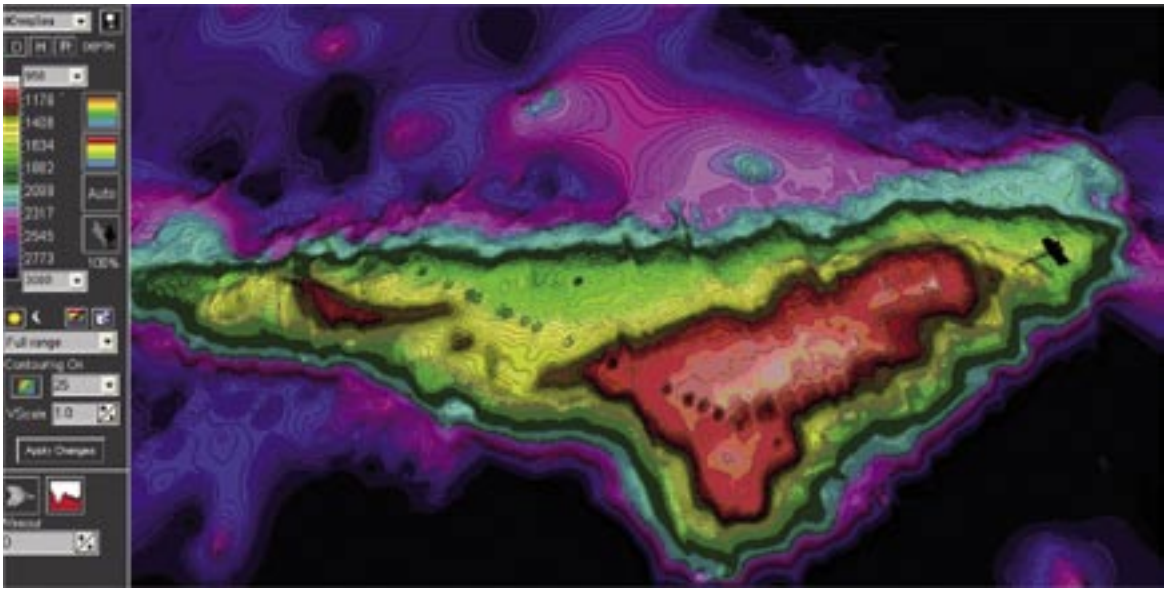
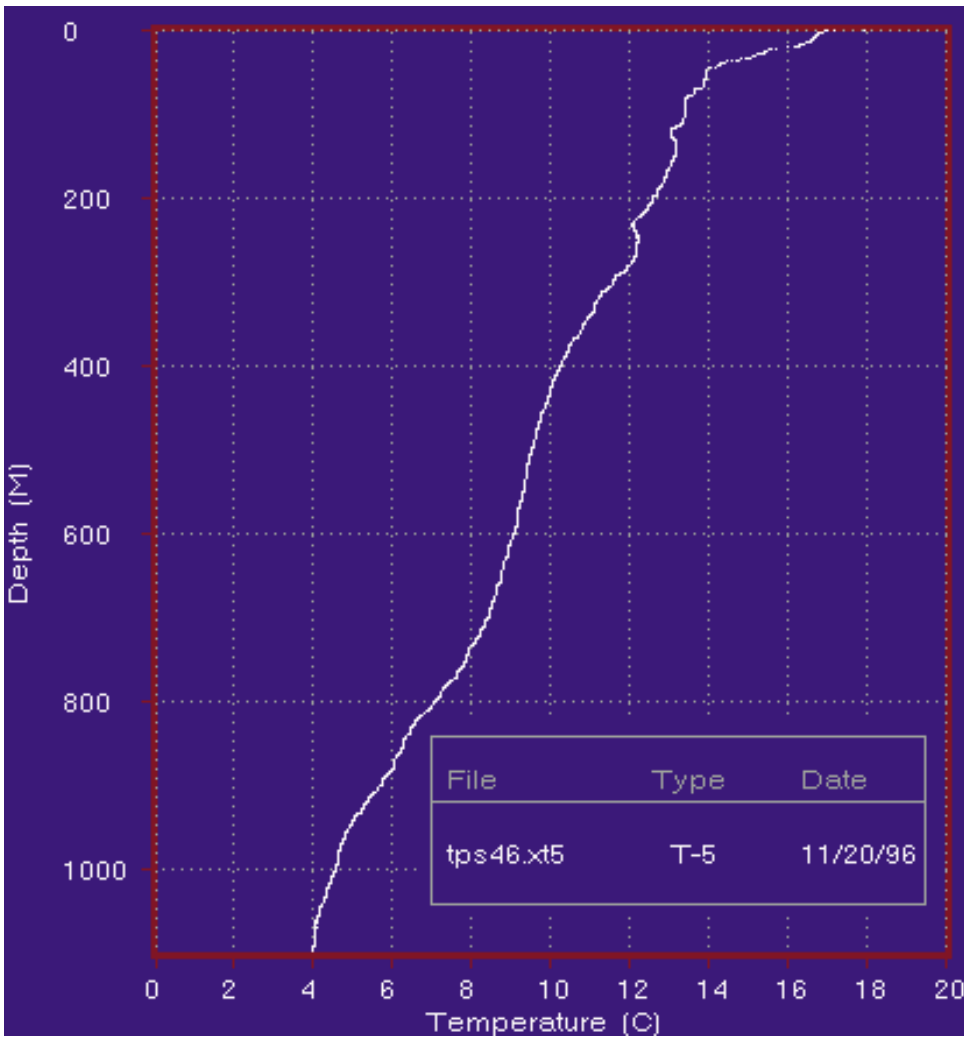


FIGURE 19
Temperature profile in spring near the Broken Ridge eastern seamount



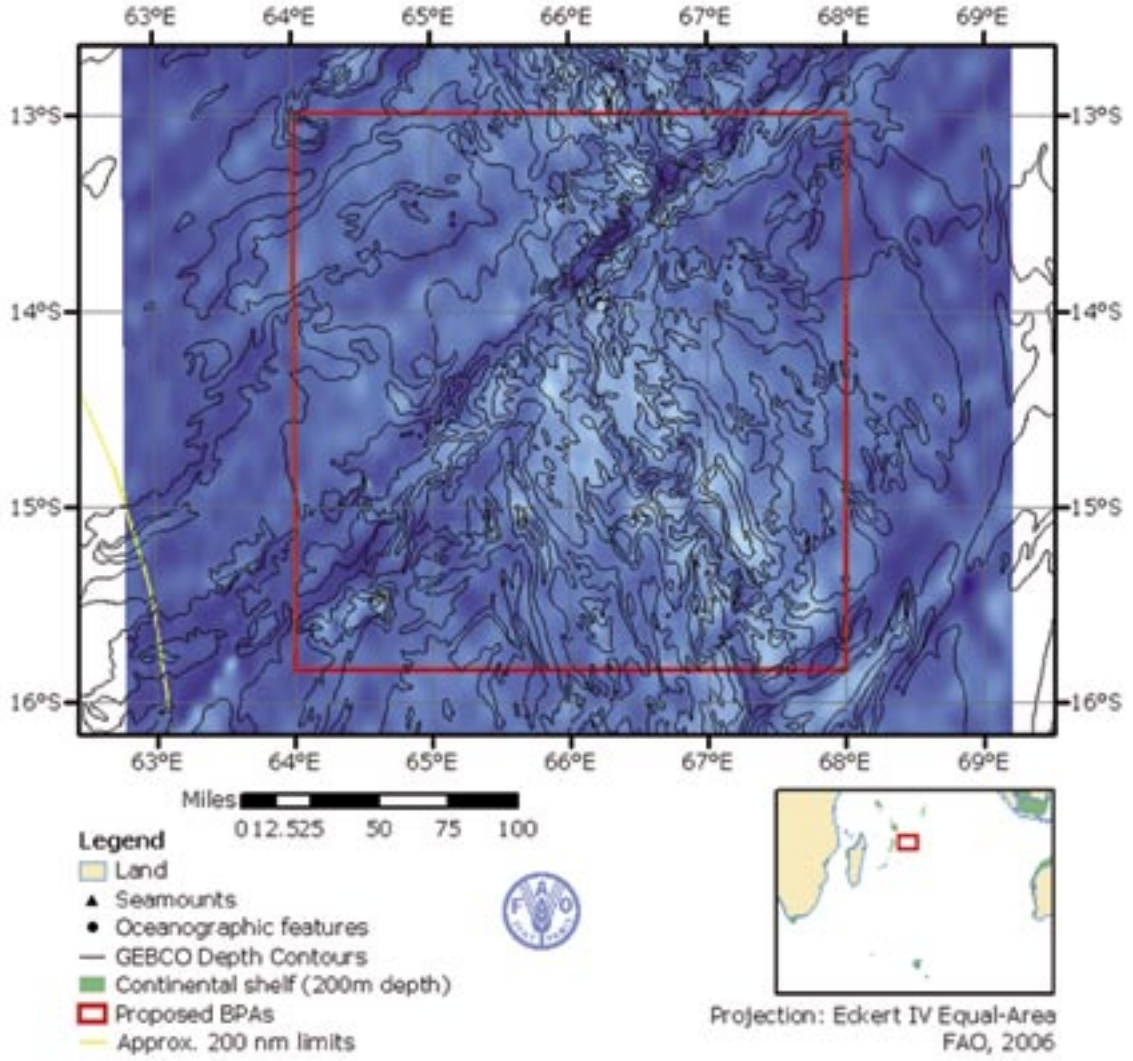
4.6 Mid-Indian Ridge

The mid-Indian Ridge lies to the northeast of Mauritius and has been described as part of a triple junction because the Australian, African and Indian tectonic plates meet in this area. A benthic protected area was defined here to provide a closed zone in the northern part of the 'southern' Indian Ocean. There are a number of seamounts on this ridge that provide trawling opportunities. This is an area of seamounts rising to 650 m in a tropical region. Most of the region is believed to be in pristine biological condition. Water conditions are described as 'warm'. Specific hills occur in the region of 15° 39' S, 64° 14'E.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
13° 00′ S	64° 00′ E	101 – 300	0
		301 – 700	0
South-east		701 – 1 000	0
Lat	Long	1 001 – 1 500	5.8
15° 50′ S	68° 00′ E	>1500	135 682.0
		Total	135 687.8

It was considered that this large BPA would provide an appropriate geographical complement in the Indian Ocean to the South African Prince Edward Island MPA, the Australian Heard and MacDonald Island World Heritage Area and possible future areas of conservation in the CCAMLR convention area.

FIGURE 20
Bathymetry of mid-Indian Ridge benthic protected area



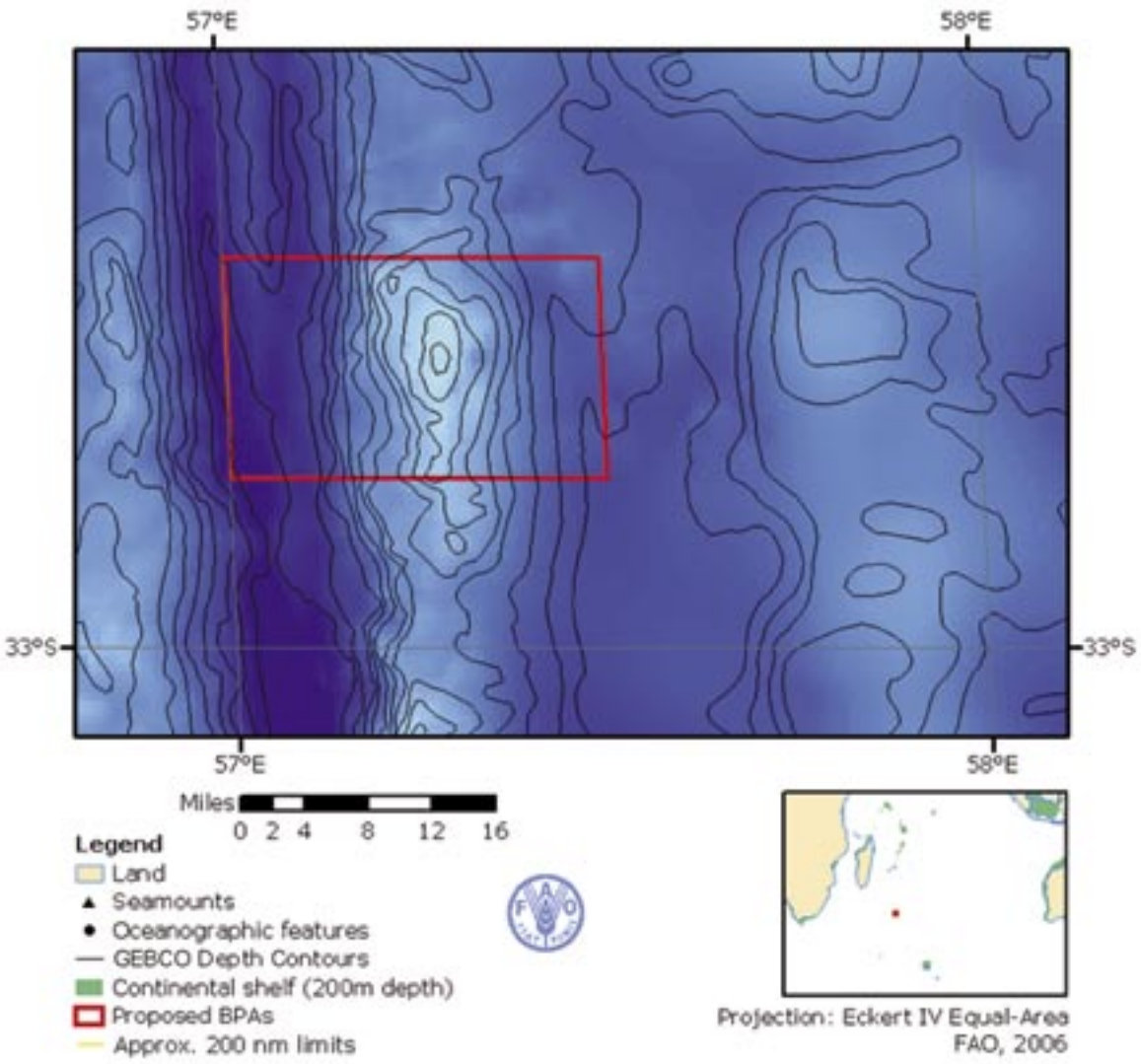
4.7 Atlantis Bank

Atlantis Bank is an oceanic core complex flanking the Atlantis II fracture zone on the Southwest Indian Ridge. Atlantis Bank is the first *tectonic* guyot ever studied. This guyot rises from 4 000 to 700 m and is on the Atlantis Fracture Zone of the Southwest Indian Ridge. It has a paleontological record and has been a drilling site within the Ocean Drilling Programme (ODP). It has been a major focus of research activity, including submersible dives and as such is the most intensively studied of the benthic protected areas that the SIODFA will observe. Baines *et al.* (2003) report on the mechanisms that have given rise to the 120 km long ridge of which Atlantis Bank is part. Figure 21 shows the bathymetry of this area.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
32° 00′ S	57° 00′ E	101 – 300	0
		301 – 700	1.4
South-east		701 – 1 000	36.0
Lat	Long	1 001 – 1 500	81.5
32° 50′ S	58° 00′ E	>1500	8 574.6
		Total	8 693.5

Atlantis Bank is a fossil island, with two fossil beaches and lagoons and a submerged headland. Precipitous ‘sea cliffs’ occur on either side of the feature and the bottom has areas of fossilized corals. These features are evident in Figure 22. About two-thirds of the bank is covered by limestone, with ripple marks, identical to those in the sand on modern beaches. However, these

FIGURE 21
Bathymetry of the Atlantis Bank



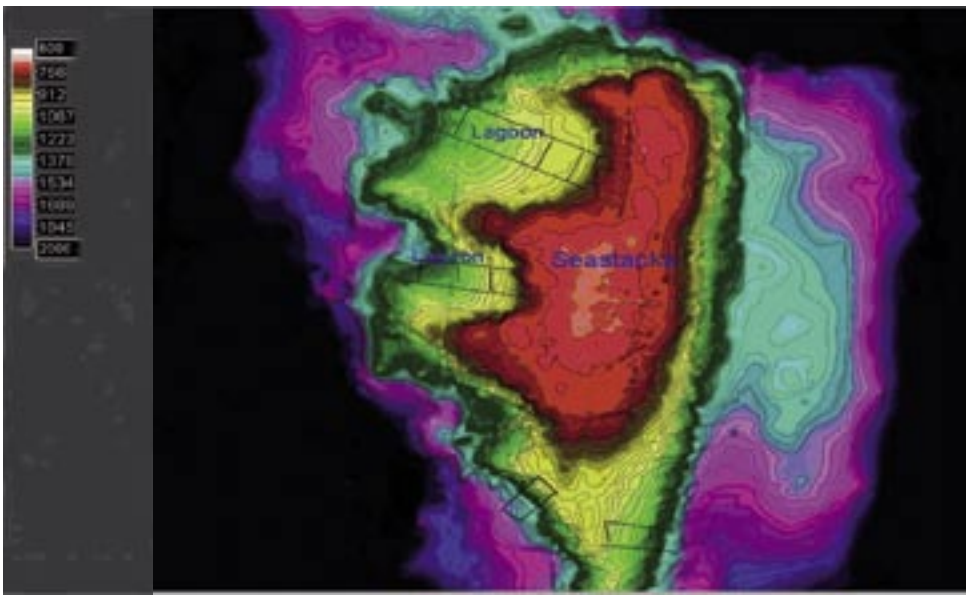
were 'frozen' or lithified as rock millions of years ago, on this island sank. There are little pot holes ground into gabbro rock, still partially filled with pebbles and sand, and headlands and fossil sea-stacks (isolated eroded remnants of the island) occur across the uppermost surface. This 'tectonic' island, which has an area of at least 25 km^2, has slowly subsided beneath the surface to a depth of 700 m and is considered to be remarkable for its modern biological community.[8]

Submersible dives have observed lobsters, crabs, sharks, sea fans, siphonophores, sponges, and other benthic species on this Bank. There have been a number of bottom trawl shots on this Bank, but with limited success because of the rugged nature of the bottom. There are many ancient seastacks, boulders, rock slides, and gravel beds that make it difficult to bottom trawl. Figure 22 shows the bathymetry and structure of the Bank with locations that have been trawled marked with black lines.

Jamstec (2000) has reported the results of observations on near-bottom and/or mesopelagic communities in depths from 750 to 5 365 m. Among other results he reported on the vertical stratification of crow shark (*Etmopterus pusillus*), Gilchrist's orange roughy (*Hoplostethus gilchristi*) and the bigeye dory (*Allocytus verrucosus*).

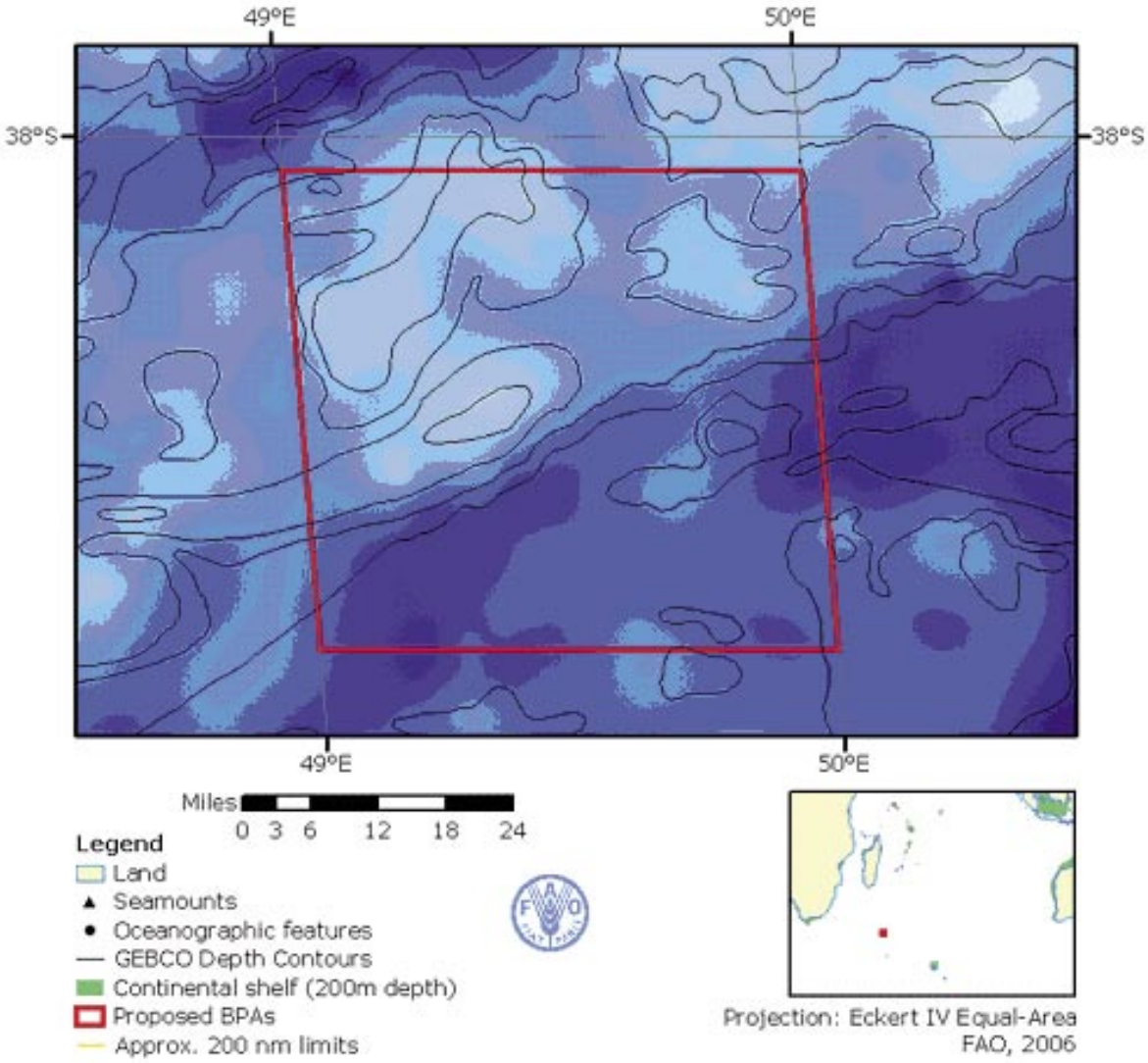
[8] See www.wshoi.edu/oceanus/viewArticle.do?id=2389&archives=true>

FIGURE 22
Detailed bathymetry of the Atlantis Bank



Bathymetry showing areas of submerged lagoons (north-west). Areas that have been fished are shown in the boxes to the west and south of the area.

FIGURE 23
Bathymetry of the Bridle benthic protected area



This bank has provided a significant mid-water trawl fishery for alfonsino and reportedly, catches of 1 000 tonnes have been taken; small catches of orange roughy have also been taken. There are areas that can be fished on Atlantis using bottom trawls and about 60 tows are known to have been made on this feature. Despite this, most of the sea floor appears to have been untouched by bottom trawling; indeed roughy 'marks' have been observed on unfishable areas. The Association decided to establish this bank as a benthic protected area, in part, because of the historical and scientific interest.

4.8 Bridle benthic protected area

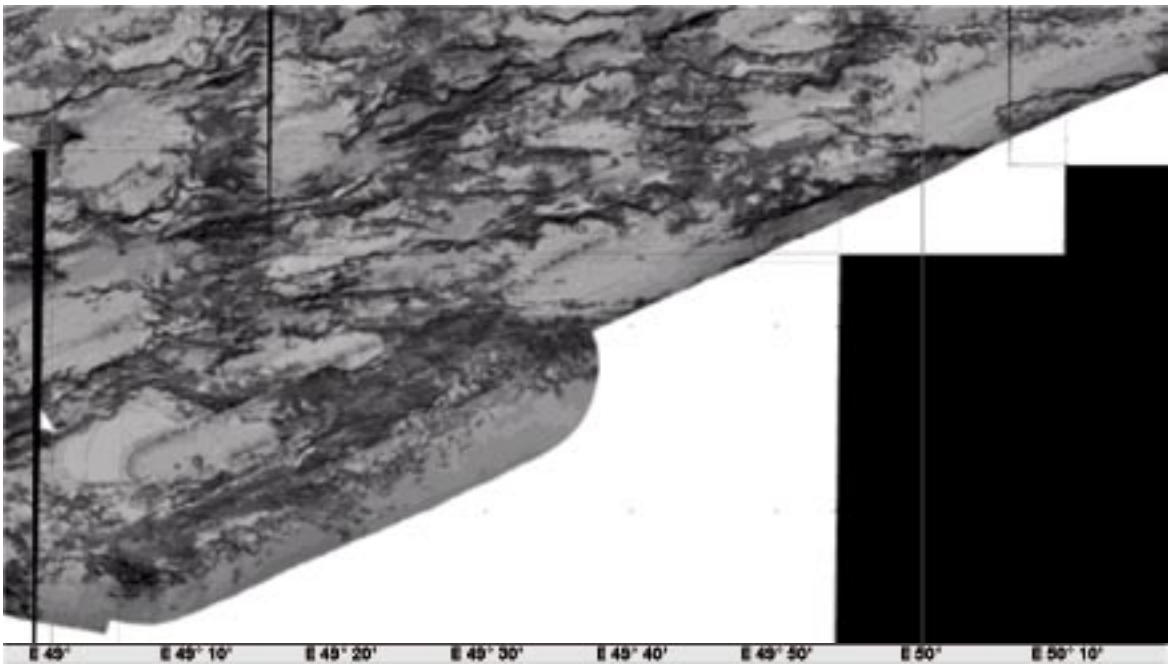
This region, in the central region of the Southwest Indian Ridge (Figure 23), contains a number of knolls and ridges between 900 and 1 500 m in depth and is surrounded by a substantial area of sediment in the depth range 1 500–2 500 m, shown as grey in the side-scan image (Figure 24). Most of these knolls have not been described before. There has been only limited trawl effort in the region with only small catches of orange roughy and oreo dories. There are five historically significant spawning stocks of orange roughy within 50 miles of this BPA.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
38° 03′ S	49° 00′ E	101 – 300	0
		301 – 700	0
South-east		701 – 1 000	0.2
Lat	Long	1 001 – 1 500	129.8
38° 45′ S	50° 00′ E	>1500	6 658.0
		Total	6 788.0

The benthic substrate is reported as characterized by many 'nasty' little ridges and an abundance of brain corals, especially further south. The area developed a reputation for breaking trawl bridles, the wires that connect the trawl doors to the net, and hence the name. There appears to be heavy sedimentation from surface productivity as in many parts of the BPA and the extent of sedimentation in the region highlights the productivity in the water column and potentially the benthos of this area. Figure 24 gives an image showing sedimentation on this bottom feature.

This region surrounding this BPA was heavily fished in the past with reports of 18 boats fishing some features in one day and up to 36 boats in this region during the fishing season in 2000.

FIGURE 24
Image showing sedimentation in the Bridle benthic protected area



Commercial estimates of past catches from this region are in the range of 5 000 – 10 000 tonnes. Some of the stocks may have been depleted to possibly 10–25 percent of the initial unfished biomass. But others are known to be well above this from acoustic surveys. The bathymetry of the benthic protected area is shown in Figure 25.

4.9 Walters Shoal

This benthic protected area is located near the southern end of the Madagascar Ridge. The region known as Walters Shoal covers a much larger area than the BPA and consists of a large number of knolls, seamounts and ridges with depths rising from 4 500 m to 180 m.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	87.6
33° 00′ S	43° 10′ E	101 – 300	104.4
		301 – 700	557.1
South-east		701 – 1 000	1 979.9
Lat	Long	1 001 – 1 500	672.9
33° 20′ S	44° 10′ E	>1500	41.5
		Total	3 443.4

There has been some fishing on the western side of this BPA in the past. Other operators are reported to fish for lobster on the shallow areas of the bank, which shoals to 10–12 m with areas of sandy bottom. It can exhibit breaking waves. It is also reported to be an area of importance for whale sightings. Bottom fishing has been reported in the shallow areas in the past.

FIGURE 25
Swathe map of the Bridle benthic protected area

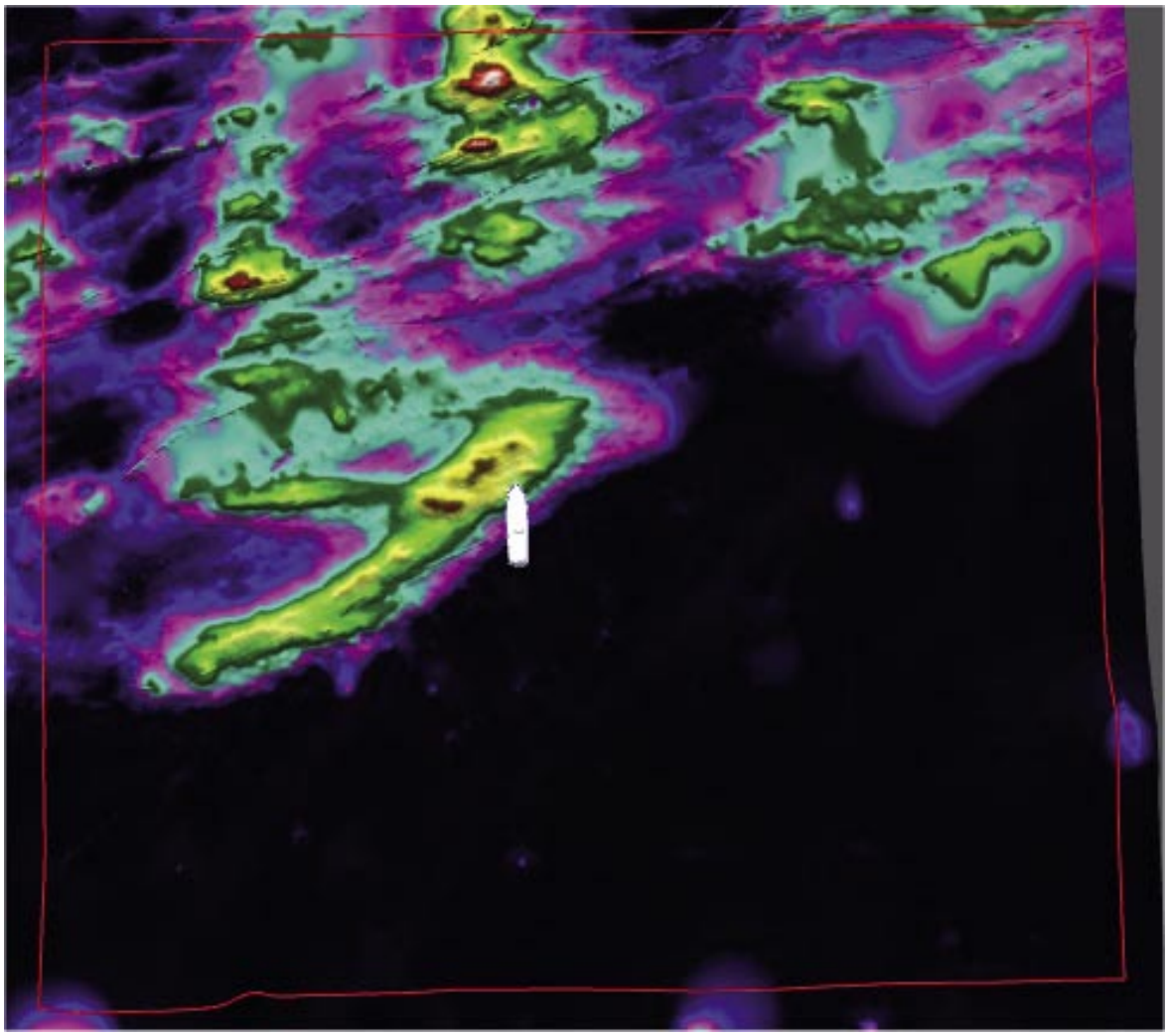


FIGURE 26
Walters Shoal benthic protected area

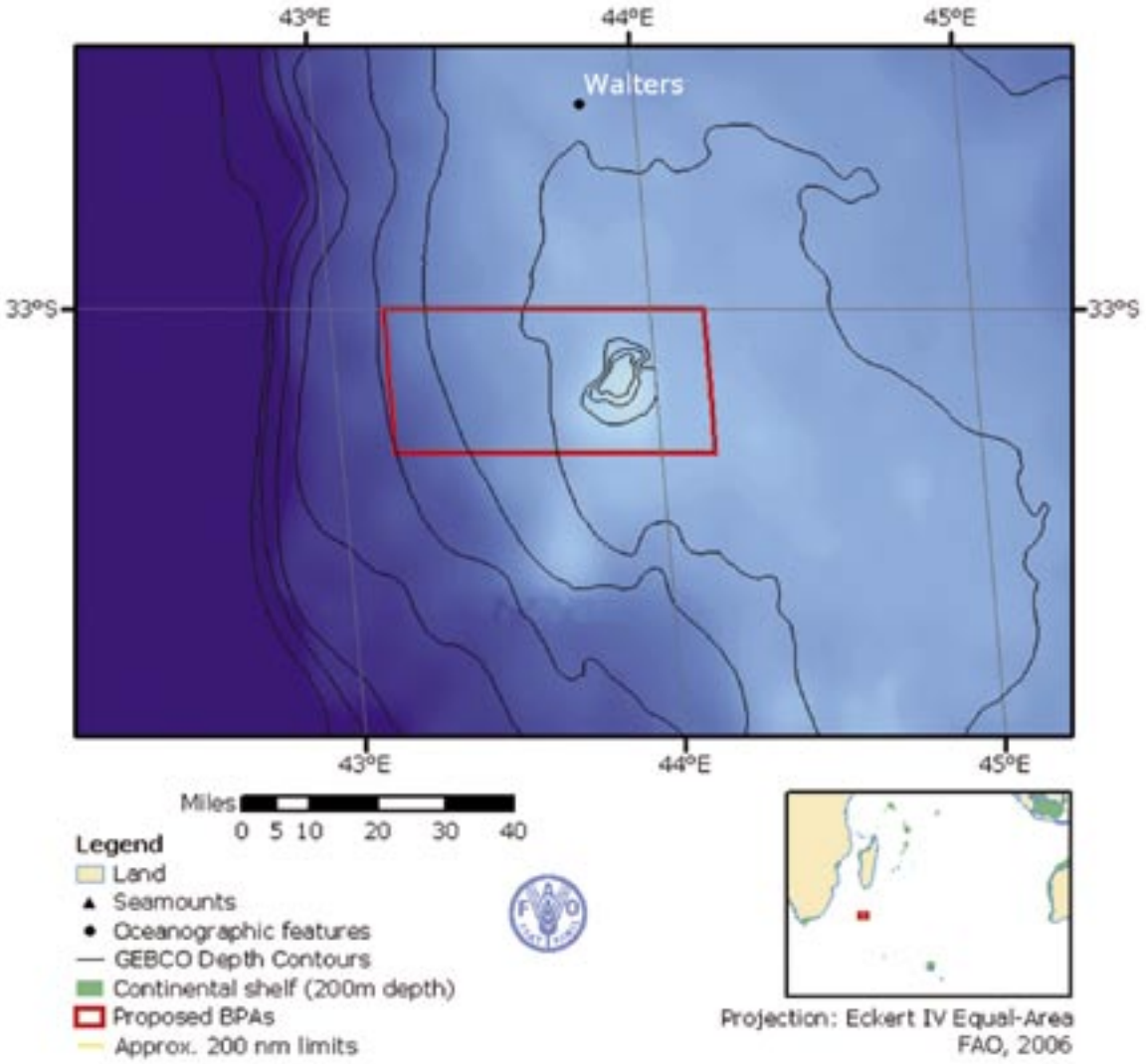


FIGURE 27
Bathymetry of Walters Shoal benthic protected area

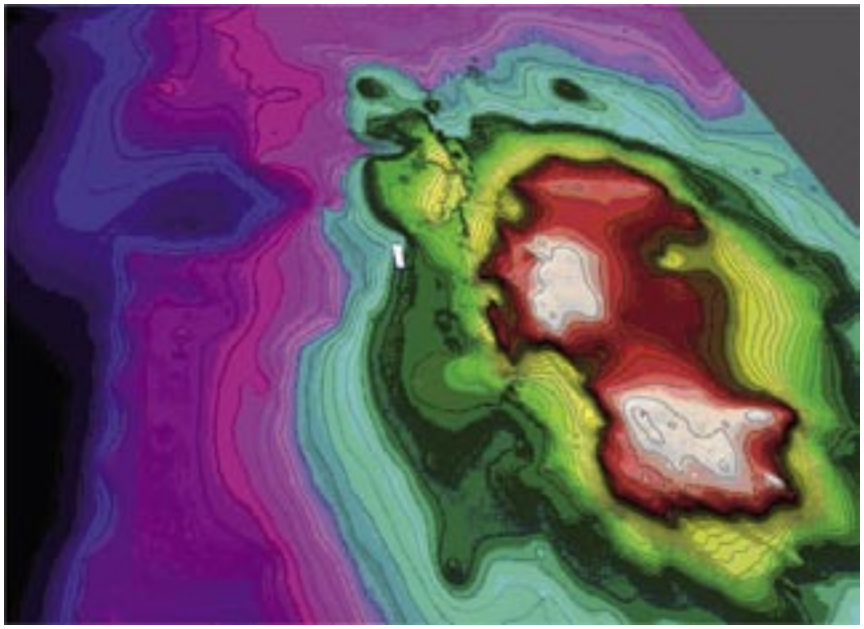


FIGURE 28
Coral benthic protected area

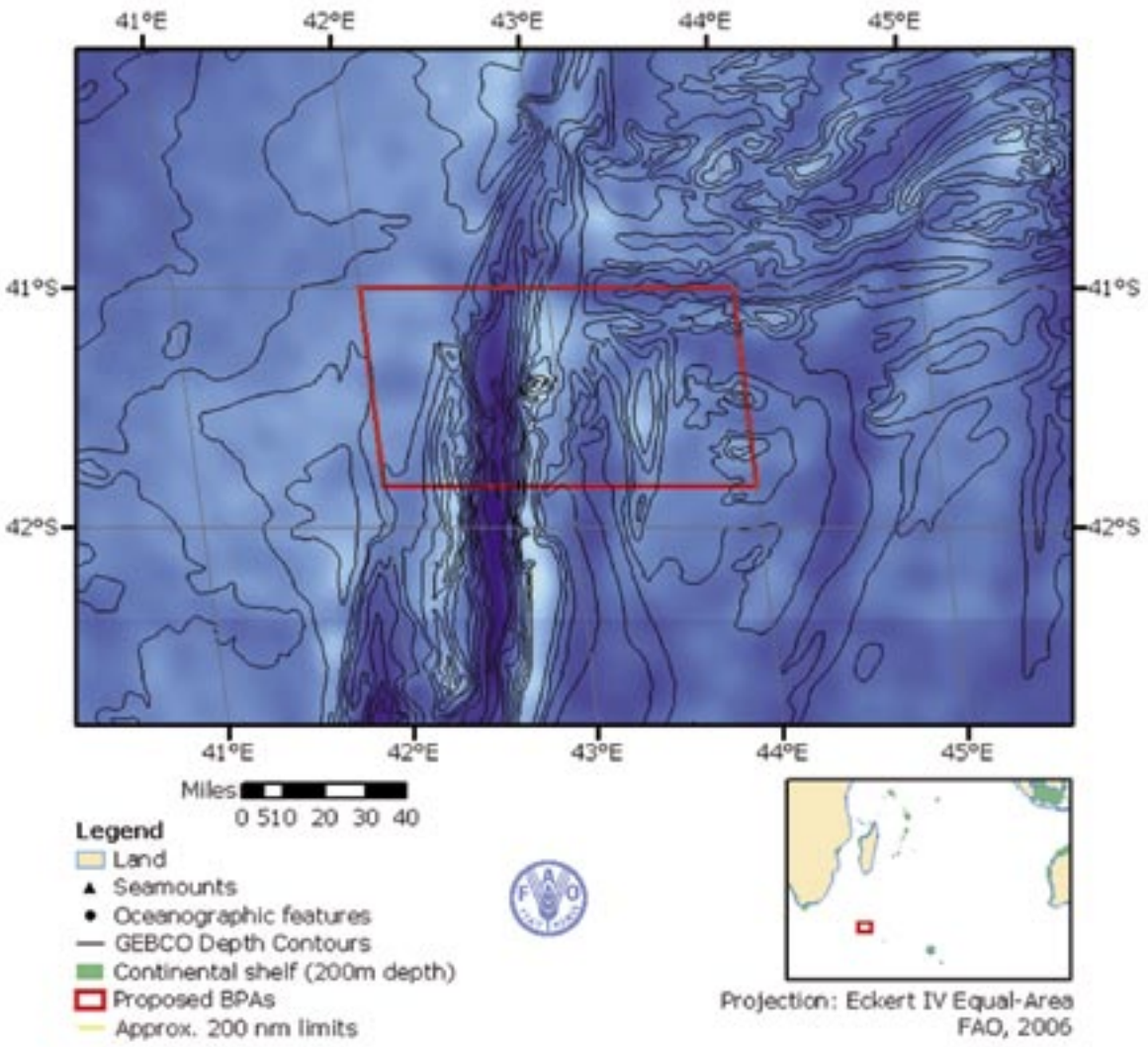
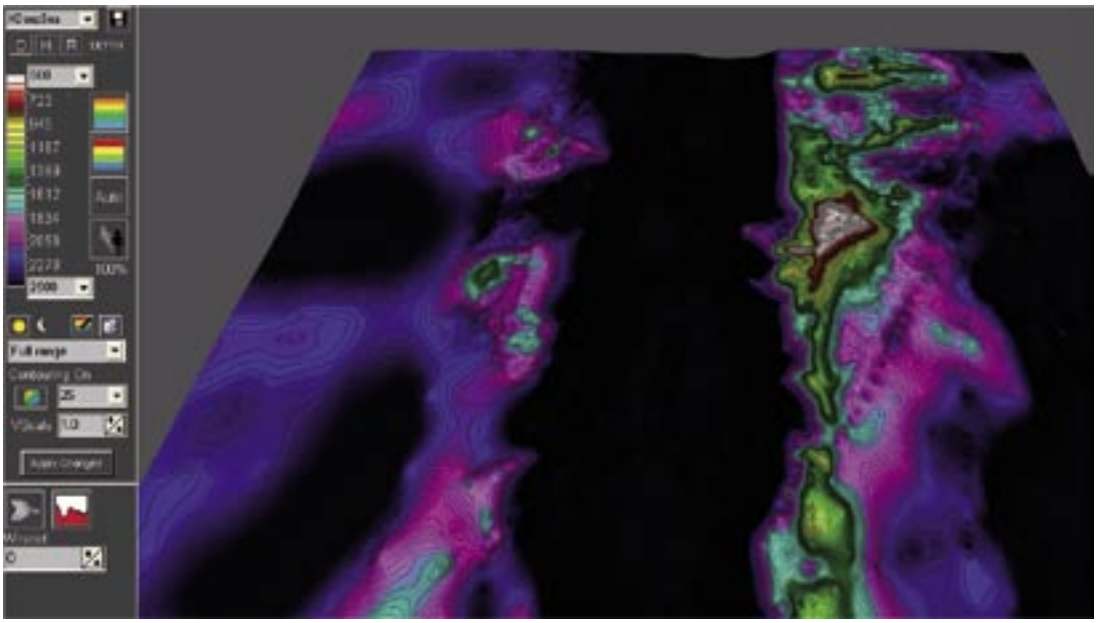


FIGURE 29
Bathymetry of the Coral benthic protected area



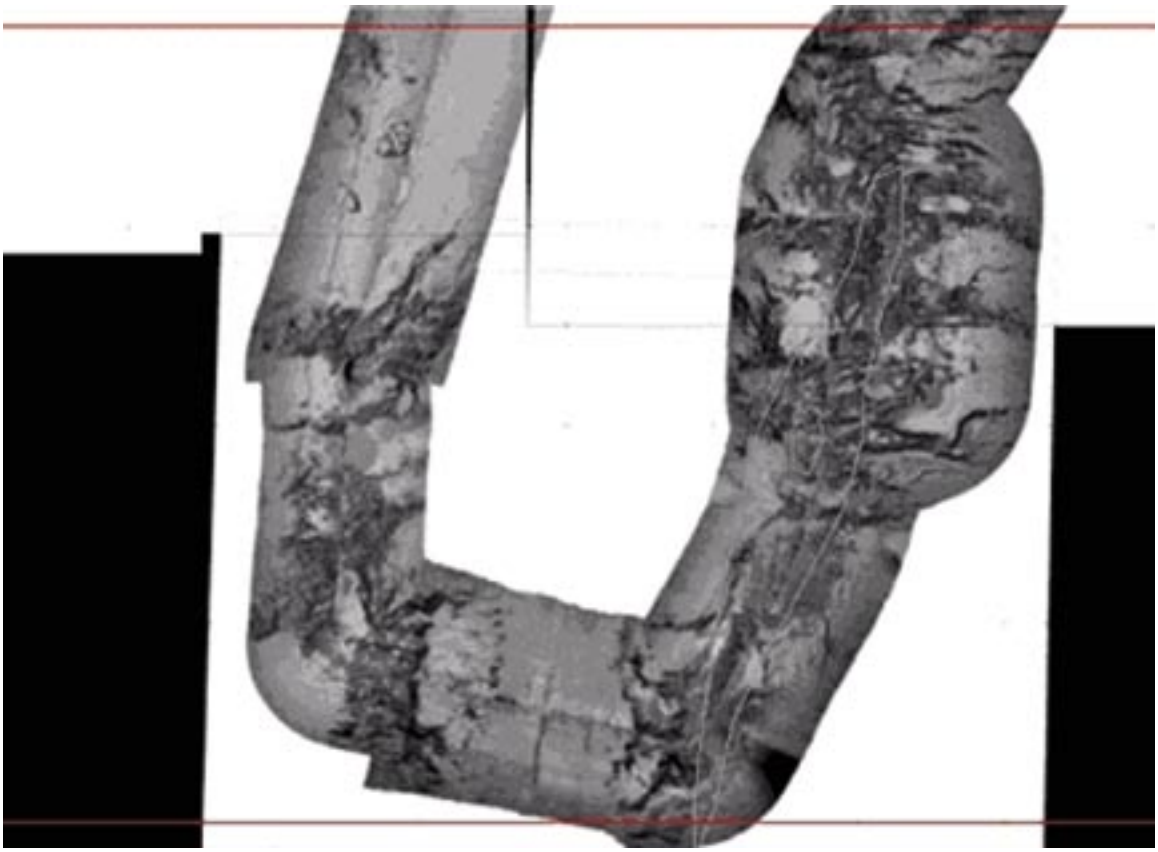
Some benthic and water-column faunal collections have been reported in this area, e.g. Parin, Nesis, Sagaidachny and Shcherbachev (1993) and Detinova and Sagaidachny (1994) based on work undertaken in the 1980s by three vessels that surveyed from Walters Shoal north to Socotra Is., and that of Ledoyer (1994) and Geinrikh (1995).

4.10 Coral benthic protected area

This benthic feature is characterized by the extensive presence of deepwater coral on one of the seamounts (and hence the name) which rises to within 160 m of the surface on the eastern side of a spreading centre, and which extends to 6 000 m depth at its maximum. Figure 28 shows the bathymetry of this area and Figure 29 a swathe sidescan of the same area. The main seamount is shown in Figure 30.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
41° 00′ S	42° 00′ E	101 – 300	8.0
		301 – 700	33.5
South-east		701 – 1 000	49.7
Lat	Long	1 001 – 1 500	510.1
41° 40′ S	44° 00′ E	>1500	11 774.6
		Total	12 375.9

FIGURE 30
Swathe sidescan image of the Coral benthic protected area



4.11 Southern Indian Ridge

This is an area of seamounts (Figure 31) adjacent to the CCAMLR region and is believed to be in pristine biological condition. The region abuts the CCAMLR-managed zone to the south and lies between the South African EEZ around Prince Edward and Marion Islands to the west and the French EEZ surrounding Crozet Island to the east. The estimated points of contact with the EEZ areas are: 44 °S,

Coordinates		Areas at depth	
Northwest		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
NW corner: 44° 00′S	40.878 ° E	101 – 300	
SW corner: 45° 00′ S	42.124 ° E		0
		301 – 700	
South-east		701 – 1 000	
Lat	Long	1 001 – 1 500	
NE corner: 44° 00′ S	46.544 ° E	>1500	
SE corner: 45° 00′ S	45.711 ° E		
		Total	39 702.3

FIGURE 31
Bathymetry of the Coral seamount

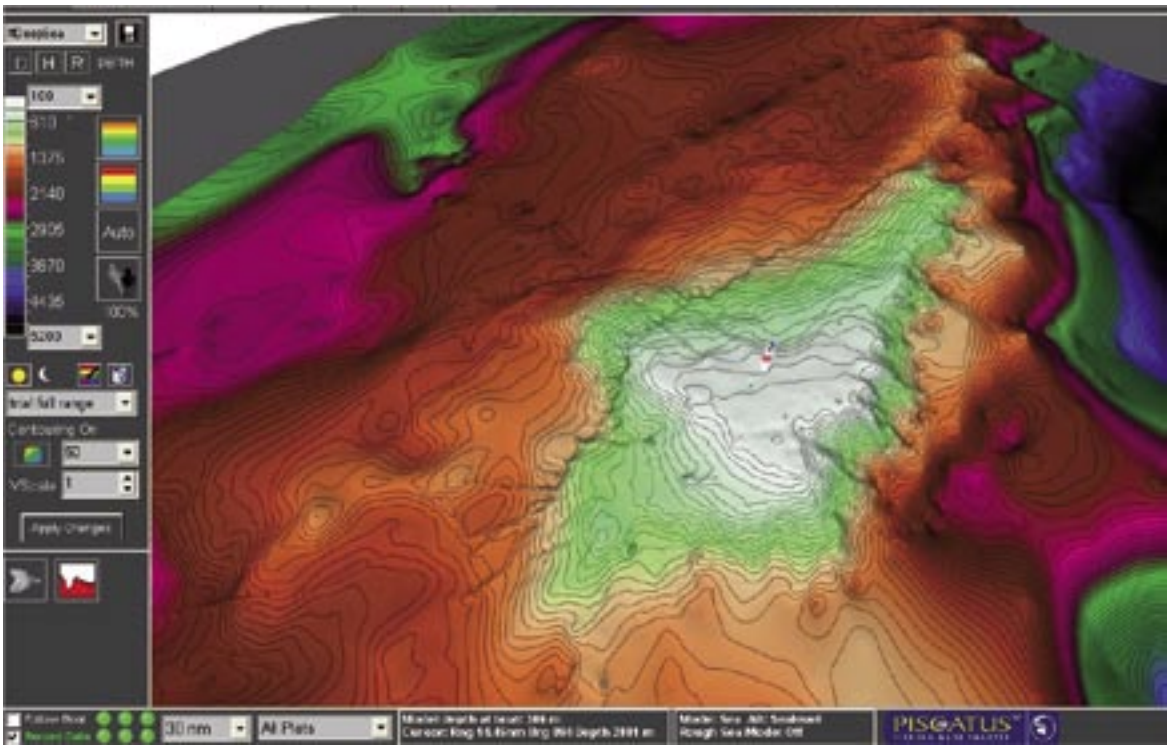
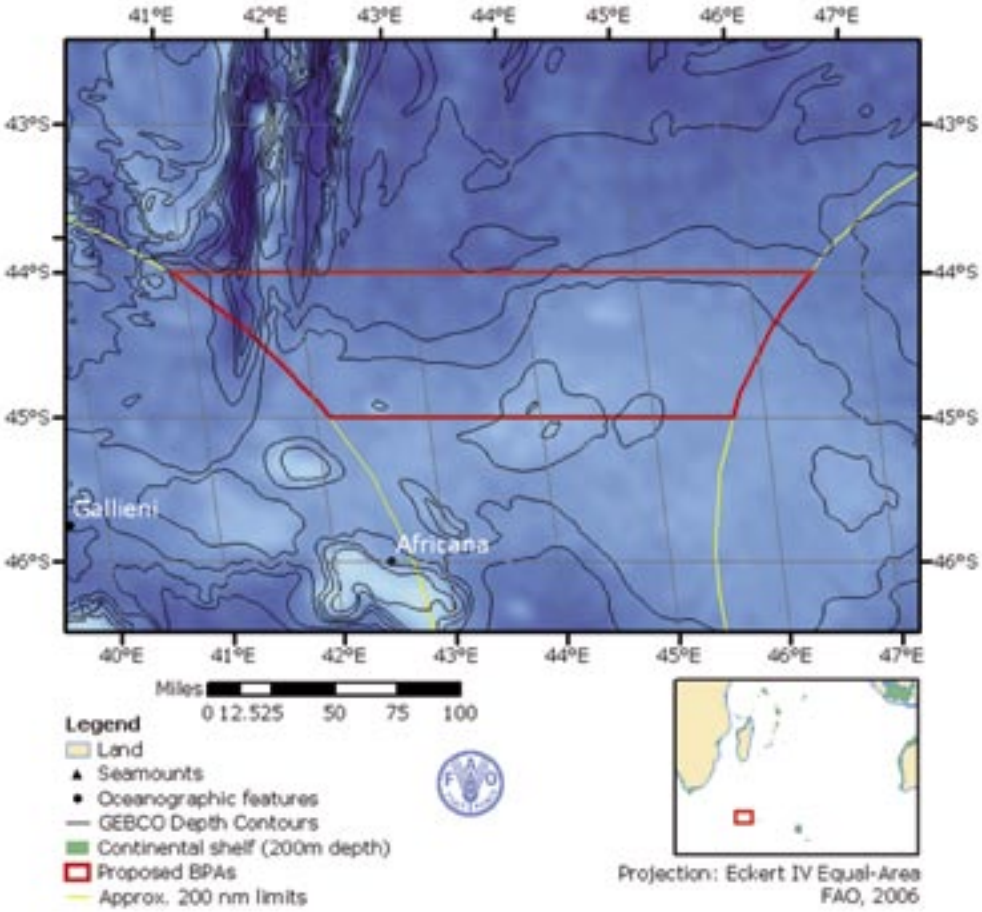


FIGURE 32
Bathymetry of the southern Indian Ridge benthic protected area



40.878 °E; 44 °S; 46.544 °E; 45 °S, 42.124 °E; 45 °S, 45.711°E. Most of this area is believed to be in pristine condition – there having been little bottom trawling, probably of less than 5 percent of the fishable area.

Bottom water is reported to be cold, ≈ 1 °C and it is reported that Patagonian toothfish (*Dissostichus eleginoides*) may be available to trawl in this benthic protected area.

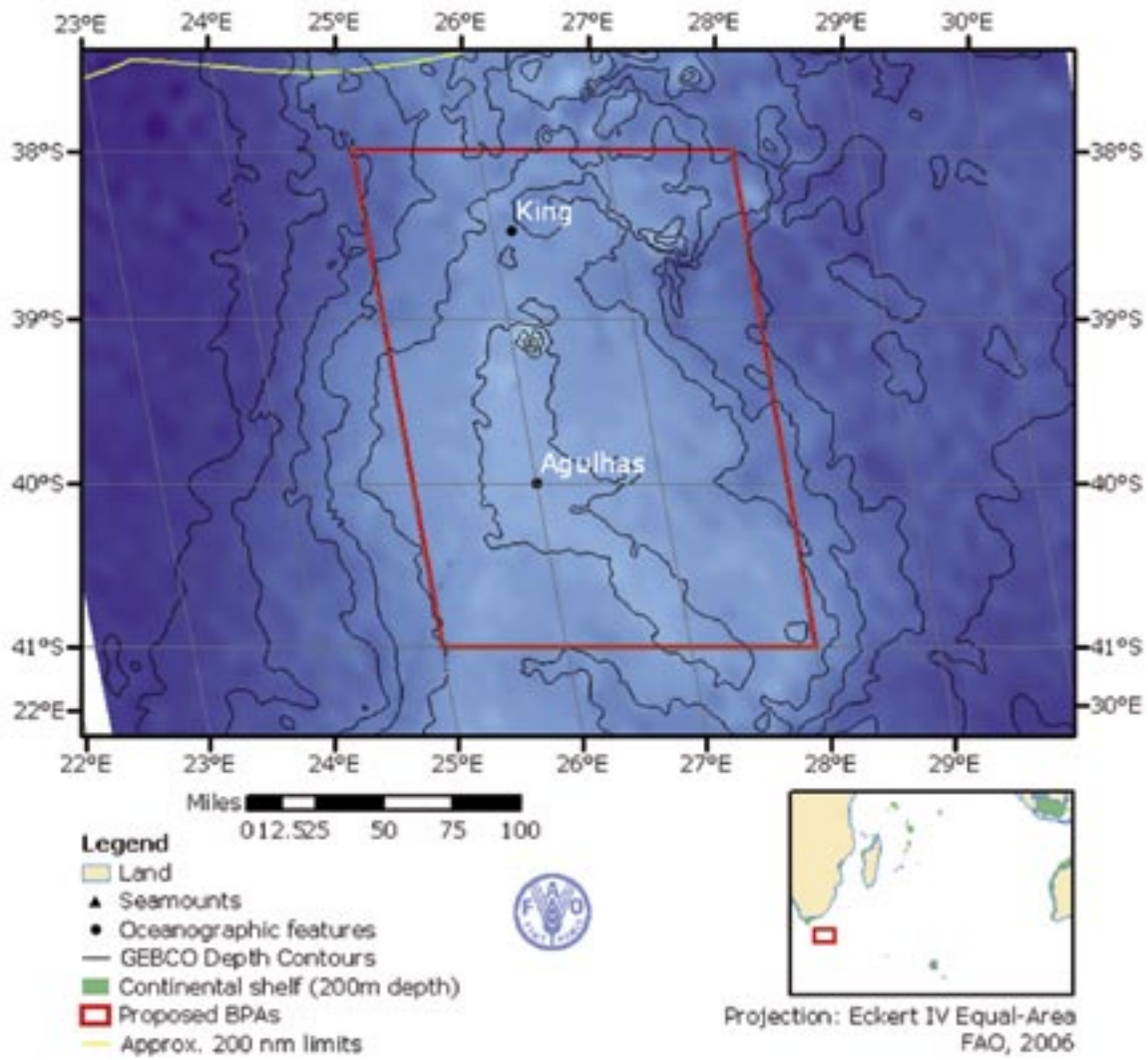
4.12 Agulhas Plateau

This is a region of seamounts (Figure 33) north of the proposed South African Antarctic MPA and lies to the west, outside of the *Southern Indian Ocean Fisheries Agreement* area. This area has been the site of geophysical studies, e.g. those reported by Barrett 1977.

Skippers report that there are abundant coral stands within this remote benthic protected area, which is several days steaming distance from other fishing grounds in the area.

Coordinates		Areas at depth	
North-west		Depth (m)	Area (km²)
Lat	Long	≤ 100	0
38° 00′ S	25° 00′ E	101 – 300	0
		301 – 700	0
South-east		701 – 1 000	8.0
Lat	Long	1 001 – 1 500	53.6
41° 00′ S	28° 00′ E	>1500	85 766.2
		Total	85 827.8

FIGURE 33
Bathymetry of the Agulhas Plateau benthic protected area



5. EFFECTS ON THE SEA FLOOR OF AIMED DEEPWATER TRAWLING

5.1 Notes on trawling practices

The modalities of deepwater, aimed, bottom trawling appear to be poorly understood outside of the deepwater fishing industry. The method of fishing involves a net landing on the bottom and moving down a slope as it is allowed to sink by slowly releasing the trawl warp. Generally, the total time the trawl is on the bottom is counted in minutes, rarely more than 10–15 minutes and possibly as few as 1–5 minutes. This type of fishing is totally different to the flat-bottom trawling carried out in much of the Northern hemisphere, notably in places such as the North Sea or the northeast Atlantic Grand Banks.

In the entire Indian Ocean region, the vessels from SIODFA now carry out about 2 000 bottom-trawl tows a year. Over recent years the vessels have reduced the use of steel bobbin rigs for ground gear, replacing them with rubber systems. SIODFA vessels will not use ground ropes strung with steel bobbins in the future.

5.2 Certification of skippers

Given the highly skilled nature of aimed trawling in association with deepwater features, the potential benefits a programme to certify competence in deepwater trawling were discussed. One major benefit would be to ensure that no one could take command of a deepwater fishing vessel unless it was clear that they had the competence to manoeuvre trawls on deepwater features without coming fast. It was the common experience that skippers always had at least 12 months experience deepwater fishing as a junior officer before having the opportunity to take command of a vessel operating in deepwater. Usually, this period of experience was much greater as first officers (i.e. 1st mate) were required to gain suitable experience at lower ranks.

Other components of a possible deepwater skipper certification programme that were discussed were:

i. demonstrated competence in interpreting bottom echograms to ensure that gear was not set on corals or similar sensitive benthic fauna and
ii. the ability to undertake commercial-vessel 'snapshot' fish stock assessment surveys during the execution of commercial trawling operations.[9]

It was agreed that the skippers themselves would be the most competent and able to offer suggestions for the development of a Code of Practice for Deepwater Trawl Fishing and in this context, the concept of holding skippers meetings was given a qualified endorsement.

5.3 Management of benthic protected areas

The Associations' operators recognize that reliable confirmation of their vessels' position by polling of vessel monitoring systems (VMS) data or transmission of VMS information will be essential for demonstrating compliance with closure of the proposed BPAs to their fishing activities. However there still must be freedom of movement through the areas that are closed to trawling as some of them occur on normal transit paths to other fishing grounds and steaming around them would incur substantial additional costs through lost fishing time and wasted fuel.

Organizations with a mandate for such activities will be encouraged to undertake marine research in the eleven BPAs and FAO and SIODFA will endeavour, as circumstances permit, to facilitate such work.

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[9] Vessel owners have a particular motivation to ensure this is avoided as the coral damages the catch, considerably reducing its value. Coral may also cause considerable damage to the gear – Ed.

6. MONITORING OF VESSEL ACTIVITY

All vessels operated by members of SIODFA maintain continuous vessel monitoring systems (VMS) operated under the following conditions:

Vessel	Flag	Comment
Bel Ocean II	Mauritius	VMS operated in compliance with Mauritian requirements; vessel polling available at all times.
Nikko Maru	Namibia	VMS operated under the terms of the Namibia requirements for vessels fishing on the high seas.
Southern Champion	Australia	Continuous VMS operated under terms of Australian requirements to fish in the Heard/MacDonald toothfish fishery
Will Watch	Cook Islands	Vessel equipped with two VMS to ensure uninterrupted polling capability by flag state

Much discussion centred on how best to use existing technology to monitor vessel movements and so demonstrate compliance in observing the no-trawling zones. While all of the vessels have the capacity to report using vessel monitoring systems (VMSs), the requirements for reporting varies depending on the flag state. For example, Australian-flagged vessels are required to report positions on a quasi-continuous manner to the Australian authorities. Vessels flagged to the Cook Islands are required to be able to be polled as to their position on an as-required basis. A similar requirement was reported as being in effect for vessels flagged to Mauritius. The Cook Islands-flagged vessel carries two such systems so as to be able to always ensure compliance with this requirement.

The operators expressed strong faith in the vessel monitoring system operated by the CCAMLR, not least because three of the SIODFA also fished in the CCAMLR zone and were familiar with the procedures, requirements, security and success of the CCAMLR procedures. There was agreement that control through the CCAMLR system would be acceptable to the Association's members given the experience with, and confidence in, the CCAMLR system. It was agreed that an informal approach be made to the Secretariat of CCAMLR to determine if such an arrangement would be possible and feasible.

7. COLLECTION OF BIOLOGICAL MATERIAL FOR RESOURCE MANAGEMENT PURPOSES

7.1 Present scientific data collection

It was noted that much biological material, especially orange roughy otoliths had been collected, especially by Austral Fisheries Pty Ltd, and that this material had been given to the Bureau of Rural Sciences in Canberra. This task had been facilitated in the past because of the practice of their vessel carrying marine observers, something that Australian regulations required them to do if their vessels were to fish in the adjacent Heard and MacDonald Is area. Both areas were commonly fished during the same trip by this company's vessels. It was agreed that an important future task for SIODFA and a Scientific Committee of the future southern Indian Ocean Agreement would be to identify and document what biological material existed and develop a programme for its analysis.

Given the uncertainty as to when the Agreement would enter into force, the imminent start of the 2006 winter fishing season and the importance of starting collection of biological samples as soon as possible, it was agreed that a programme for the collection of biological measurements should be started immediately on the Association's vessels. Sealord Group noted that they had an extremely positive experience in having the Factory Manager be responsible for the collection of biological samples. These people had experience in process engineering and were familiar with the needs for random sampling and proper procedures, such as accurate labelling of material that had been collected. Their procedure is given in full in Appendix IV.

It was proposed that a 500 kg sample be taken from each trawl, appropriately randomized, from every tow that caught more than 5 tonnes. As an interim measure, each Association member would be responsible for storing their own material (otoliths, etc.) in a secure manner. The meeting noted the fish aging services provided by:

- the Central Aging Facility, Marine and Freshwater Resources Institute, Queenscliff, Victoria, Australia
- NIWA, Fisheries Data Management Service, Wellington, New Zealand and
- Universidad Nacional Arturo Prat and Universidad de la Santísima Concepción, Chile.

Species priority
It was agreed that priority should be given to collection of otoliths from orange roughy and that the needs for otolith collection from other species, most likely alfonsino, would be reviewed in the near future.

7.2 Determination of landed weights
It was noted that while recorded catch weights for individual tows may not be highly accurate because of the difficult of separating product on a tow basis as it was processed, the daily product was always carefully recorded and should be accurate. Thus, this measure should be sufficient unless the vessel fished more than one feature in a day.

Action required
It was agreed that each industry member should document the conversion factors that are appropriate for the nature of processing each vessel undertakes. This may require a small working group to address this issue, but it was agreed that the technical problems that would be involved are not great.

7.3 Use of commercial packing grade information
It was noted that all operators carefully maintain records on the size composition of catch when packing, as revenues were price-sensitive. It was agreed that historical information on packing grades would be made available in appropriate circumstances to enable the size distribution of past catches to be inferred using an appropriate interpolation algorithm.

7.4 Identification on small-area stocks
It was noted that the southern Indian Ocean orange roughy fisheries probably target a moderately large number of separate spawning stocks. Relating past catches to local area stocks, while of great benefit and most important would be difficult, not least because of the resources that would be required to achieve such a task. However, if this can be done, it would facilitate attempts at estimating past unfished biomasses in the future possible management areas. It was agreed that assessment would be done on some form of spatial basis but how to do so remains for future discussion. As a working approach it was agreed that assessments should start at a large scale and proceed to smaller scales as was possible.

The view in the case of alfonsinos was that this species was relatively mobile and the appropriate basis to undertake assessments would be on a fairly large scale.

7.5 Availability of historic data
It was noted that many important fishing countries in the southern Indian Ocean had not, or were unable to, report to FAO past landings on a detailed areal basis. Presumably, in some cases, this was because of national requirements governing confidentiality of data when so few vessels or companies had been operating that it would be possible for the results of any one particular vessel or company to be identified no matter how the data were aggregated. Some information had been reported in FAO (2001a) and FAO (2002b), but it was recognized that a concerted effort would

be necessary to track down the results of catch successes during the period 1999 to date. And, that this activity would need to happen in an appropriate, i.e. confidential context, if accurate data were to be forthcoming.

8. COMMERCIAL-VESSEL ACTIVITIES

8.1 Execution of commercial-vessel acoustic resource assessment programmes

The meetings discussed the need for direct surveys of fish aggregations using acoustic methods. There was agreement that it was unlikely that research, or other vessels, would become available specifically for this task because of the expense of doing so. This was because of the remote location of the fisheries: hence vessel steaming times to and form the fishing grounds would likely be on the order of several weeks. Further, at least for stocks associated with seamounts, the large number of locations where fish aggregations might be encountered would require lengthy surveys and could still result in resource estimates characterized by considerable imprecision and possible bias.

The meeting was in agreement that adoption of commercial-vessel executed acoustic resource surveys may be the only way of addressing this problem. This approach requires that vessels are equipped with the appropriate acoustic apparatus, here, Simrad EK60 acoustics systems. The Simrad EK60 is the commercial version of their scientific acoustic systems and offers nearly the same performance, and certainly sufficient functionality, for undertaking stock assessments.

It was agreed that to achieve an acceptable compromise between commercial fishing operations and good acoustic assessment activities, vessels would undertake local-area surveys when fishable aggregations of fish had been found. It was the view at the meetings that such surveys may provide the only way of undertaking surveys of the target resources.

It was acknowledged that because the surveys would be opportunistic, and would not be undertaken using a wide-area probabilistic design, estimates of precision would necessarily be based on interpretation of the internal structure of data variability using geostatistical (Kriging) methods and abundance calculations would provide, in the first instance, minimum biomass estimates. It was agreed that there would be major benefits in, e.g. the FAO, undertaking several workshops to investigate better the assumptions that are used in such methods of resources assessment and the risks should they fail to be true. However, reference was made to the considerable work that had already been undertaken in this regard. Doonan, Bull and Coombs (2003) have described survey approached for these situations and commercial vessels have undertaken acoustic resource surveys on St Hellen's Hill, a seamount off Tasmania, in Chile and Norway (ICES 2005, 2006).

A detailed operational protocol was developed at the meetings (Appendix V) drawing heavily on the experience of the Sealord Group in undertaking such commercial-vessel surveys and there was agreement that all companies would endeavour to implement this protocol in undertaking such acoustic surveys during this winter's fishery targeting orange roughy. Particular note was taken of the need for appropriate filtering of echo data from deepwater scattering layers.

The meetings discussed many of the operational issues – some of which resisted easy solution. For example, one question was what minimum catch should prompt the execution of a local-area acoustic survey? A first proposal in answering this was ≈ 20 t.

Data processing

It was noted that there were independent supplies of services and support available, based in Cape Town, South Africa and Australia who could assist members in data interpretation. It was noted that acoustic assessment is data intensive: large amounts of data are collected that require careful analysis. It was proposed that a working group meet in November or December 2006 to review acoustic data collected during the winter fishery in 2006. At that time the Fisheries

Agreement might be in force and it was hoped this might be done through a subsidiary body of the Agreement.

At the request of the compiler (R. Shotton) of this circular, a company with experience in undertaking acoustic surveys in the southern Indian Ocean, Fisheries Resource Surveys cc., Cape Town, was asked to provide some background information on this activity from their perspective – this is included in Appendix VI.

8.2 Estimation of resource biomass using data collected by industry vessels

It was recognized that, for reasons of cost, commercial vessels must be used to assess the widely-spread demersal fish stocks of the southern Indian Ocean. This has raised new challenges arising not only from the practical limitations and complications associated with using commercial vessels as survey platforms, but also with the techniques of data analysis, both in estimating resource abundance and determining the precision associated with these estimates. The first two days of the meeting in Kameeldrift East were devoted to addressing this problem and a technical account of the procedures that have been adopted by one of the operators is described in Appendix VII.

It is recognized that collating such survey information from the four vessels involved in the fishery will be time consuming and expensive. However, good progress was reported in extending these methods of industry-implemented fisheries research across the fleet. Preliminary plans were made for a subsequent meeting to analyze and report on the data that was being collected.

8.3 Proposal for a skippers' meeting

The meetings considered the possibility and benefits of having a meeting of skippers involved in the SIO demersal fisheries. While it was noted that many issues would be commercially sensitive, it was also recognized that all of the skippers knew each other well[10] and information exchange and cooperation occurred at this level that was often not recognized at higher levels with the companies there were involved. Further, many of the skippers had worked for several of the companies and much information was held in common.

There was general agreement that such a meeting could be effective in:

- identifying areas that should be protected, whatever the reason
- facilitating the collection of ecological and fisheries-related information of the kind that rarely leaves the bridge
- collaboration on the issue of gear design with the objective reducing effects of gear-bottom interactions
- review of search and fishing strategies and its implication for CPUE analyses
- documenting information of fish behaviour and its implication for resource management;
- identifying areas where courses for skippers and other officers would assist in the management process, e.g. in commercial-vessel acoustic surveys development of computer literacy and
- developing protocols for report "IUU" fishing operations.

8.4 Data collection officers

The issue of collection of data was discussed. The experience in the required use of marine observers was mixed. Such observers could be extremely expensive and their interest and motiviation in data collection was often mixed. The commonest view was that factory staff, e.g. the factory managers, were often extremely well placed to either collect the data required for management purposes, or ensuring that it was done following the appropriate protocols. These managers usually had tertary level education, not surprisingly given the responsibility of their position.

[10] Indeed most either came from Nelson, New Zealand or live there – even the two Icelandic skippers in the fishery!

9. CONSERVATION ISSUES

9.1 Bycatch

Discussions at the meetings reflected the views that had been reported in 2001 and 2002 (FAO 2001a, 2002b) that little bycatch was taken by these fisheries. While vessels could, at times, recover bottom invertebrates, skippers always attempted to avoid this because of damage (a) to the gear and (b), to the catch. Fish that was squeezed against hard materials, e.g. rocks or corals, were inevitably damaged and, being of lower quality, fetched a lower price.

9.2 Fish bycatch

It was noted that there was no high-grading of the catch and that all commercial species (the vast majority of the catch) were retained.[11] Fish discards were estimated at much less than 1 percent of the catch and characteristically of the order of 0.1 percent of the target species. When fishing depths were less than 500 m, it was noted that fish bycatch of species that would be discarded increased, usually when targeting alfonsinos. At times, small specimens (≈ 7.5 cm length) of Oreostomidae were encountered in midwater. However, these fish were recognizable by the characteristics of their echo trace and only inexperienced skippers were likely to set the gear on them. Likewise, small alfonsinos of around 100 g were occasionally encountered. Small specimens of orange roughy were never encountered – thus there appears to be no danger of fishing immature specimens of this species.

Bycatch of shark was extremely small – at best on the order of one or a few specimens among tonnes of targeted species. In this context, several operators reported observing long-line and bottom-gill netting vessels targeting sharks, especially in the Walters Bank area in 2003 when at least two vessels were seen fishing.

9.3 Interaction of the trawl gear with seabirds

It was noted that for whatever reason, the regions of fishing operations tended to have few seabirds, which were rarely seen north of 35 °S though the presence of white-chinned petrels (*Procellaria aequinoctialis*) has been reported in the area by Pandey, Khare and Sudhakar (2006). In the fishing area about 90 °E, no seabirds were seen. When seabirds were seen they were usually sooty shearwaters or Cape pigeons. With one exception, none present at the meeting could recall any interaction of seabirds with the trawl gear, either the trawl warps or the netsonde cable. Should such an event occur, it was required that a log-book note was made. The one exception noted that over a period of five years, three birds had fouled the trawl gear.

All operators noted that no discharge of offal was done when the vessel was fishing. One explanation for the absence of seabirds in association with the vessels was that there being so few vessels fishing in the area, birds had not learnt to follow fishing boats.

Mitigation measures with respect to seabird interactions in some of the flag and member countries were discussed. It was noted that in New Zealand, new legislation required vessels greater than 22 m to be equipped with means of seabird bycatch mitigation. One such measure is the "Brady Bird Bafflers", which consisted of cones on booms towed behind the vessel. Other methods included warp deflectors and Torri lines. The consensus was that a combination of Torri lines and warp deflectors was preferable, where such measures were necessary.

9.4 Marine mammals

None of the operators reported ever having seen any seals during fishing operations in the area, though at times, dolphins were seen, though 'rarely'. Pilot Whales (*Globicephala melaena*) were seen from time-to-time but there was never any interaction with vessels. Sperm (*Physeter macrocephalus*)

[11] This is common in fisheries that are not regulated by a TAC – Ed.

and humpback (*Megaptera novaeangliae*) whales were known to migrate through the fishing areas but no interaction with fishing operations had ever been observed. One exception to this was reported by the operator of the *Nikko Maru No. 1* when three humpback whales 'investigated' the ramp area of the ship and no fishing operation was possible until they swam off.

9.5 Corals

Corals were taken as bycatch in limited quantities in some areas while in other areas none were taken at all. Species encountered as bycatch were dead brain coral (*Maeandra* spp.), Black Coral (Family Antipathidae) and branch coral (*Pocillopora* spp., *Alveopora* spp.). In this context, it was noted that only a few seamounts were completely trawlable and for the majority of seamounts fishing was only possible in a few restricted areas. Characteristically, it would be possible to fish on about 5 percent of the area of any particular seamount. Corals were particularly found to occur along the top edges of bottom features with stark faces where they could be seen with the vessels' acoustic system. Their presence in these areas probably resulted from accentuated upwelling associated with the sharply rising sea floor and thus accentuated food supply for these filter feeders. Characteristically they were found in depths to 700–800 m.

Skippers avoided coral bycatch because of the physical damage that such bycatch did to the fish in the net, which considerably reduced its value, and that for some types of coral, if taken as bycatch, every fish would require individual cleaning. Corals also shredded the gear, causing delays for the repair of the nets. Unsurprisingly, every skipper avoided this type of bycatch.

It was recognized that the issue of coral bycatch was an extremely sensitive conservation and political issue, accentuated by some non-governmental organizations' use of material that shows rare, though still to be avoided, coral in trawl catches. It was noted that the Association's members had the knowledge to contribute to the mapping of areas where significant areas of corals occurred. It was agreed that this should be undertaken. Two skippers noted that in recent voyages of nearly 60 days, the coral bycatch had been in the vicinity of 20–30 kg. Austral Fisheries Pty Ltd. offered to make their observer data available to Association scientists to allow exact estimates of coral bycatch rates to be determined.

9.6 Effects of bottom interactions with trawl gear

While explicit data were not available at the meeting, the common estimate of the ratio of bottom to midwater trawls was in the range 50:50 to 40:60. However, it was noted that tows that were expected to be a 'bottom-trawl' might not touch the bottom, while mid-water trawls, at times, may make contact with the bottom, and this was one reason why in these cases, the gear was constructed with a weak link to ensure that it did not become fast on a 'bottom hook-up'. The maximum incline that a skipper would attempt to fish was usually no greater than 35°.

A single vessel could be estimated to do 1 100–1 250 tows a year during about five trips. At present it was estimated that the fleet of four vessels would be undertaking about 1 500–2 000 tows a year. The usual time of contact of a bottom trawl with the seabed was estimated to be 10 minutes, but could range between 1 and 15 minutes, at between 3.5 and 4 knots, though depending on the catch, it could be as short as two minutes, especially when the fishing was conducted down slopes of bottom features. In the western region of the Fisheries Agreement Area, bottom topography did not permit long (≈ 2 hour) tows.

One operator reported that his vessel was exclusively engaged in mid-water fishing in the Agreement area and a second operator noted that their vessel was currently only undertaking one campaign a year in the Agreement area. The linear ground rope lengths were in the range 20–25 m. At the moment, only about five percent of tows were estimated to be in previously unfished areas. Door-to-door spread was estimated to be about 75 m and the operators reported that skippers often tried to fish with the trawl doors off the bottom.

A common reaction of skippers was that bottom fouling was very much avoided: a lost trawl would cost close to $100 000 to replace with the added costs of lost fishing time in rigging the gear.

10. SUSTAINABILITY AND CATCH DOCUMENTATION SYSTEMS

It was noted that within 12–18 months the USA may require that all orange roughy they import be monitored by a catch documentation system (CDSs) similar to that existing for Patagonian toothfish. In this case it was agreed that it would be in the interests of all that the operations of the SIODFA be in a position to comply should such a requirement. Among the needs associated with such a scheme would be a functioning VMS system.

Reports were also noted that some major US grocery chains, e.g. Walmarts and SAMS could require demonstration that catches were coming from 'sustainable' sources within the next five years. In this context, considerable difficulties were foreseen in achieving some form of certification, e.g. from the Marine Stewardship Council, not least because those choosing not to observe the requirements would fish 'around' those that did.

It was noted that a central feature of CDSs was the ability to demonstrate a 'chain of custody' in relation to the catch and that VMS data were an implicit part of this process. This, the meeting emphasized, underlined the need for a strictly secure VMS recording system in which the operators could have complete faith that the proprietary information was kept absolutely confidential. It was also anticipated that should such confidentiality exist in the data handling, this process could be linked to complete electronic handling of catch data. Landings would still be verified by port officials when the catch was discharged, as already happens.

11. DATA AND DATA HANDLING

11.1 Data collection

The issue of data collection in the SIOFA area has been discussed in FAO (2001) and FAO (2002b) and management, or at least data reporting regions have been discussed and recommended by FAO (2002b). These areas formed the basis for the recommendations of the subsequent Meeting of Plenipotentiaries for the adoption of SIOFA held at the FAO Headquarters in Rome, 6–7 July 2006 (and which are given in Appendix VII). It was noted that the Association's operators were using a variety of data recording methods and that it was agreed that an urgent requirement was to ensure that either a common trawl success recording system was used, or more probably, a common data storage system devised with a structure into which the data of the different operators could be easily converted. It was noted that one of the operators was in the process of transferring an extensive paper-based data record into a computer format to facilitate subsequent analysis. Data for a further operator was available in Excel format but would need reformatting to facilitate analysis. It was noted that commercially valuable fish were generally restricted to one of eight species.

11.2 Databases and analysis of existing data

It was noted that the various operators were in possession of much catch and effort data including information on bycatch and fishing locations. This information would form a vital basis of future stock assessment activities. However, different operators were in very different positions in their ability to provide their data in a manner amenable to analysis. One operator only had trawl information available on hard copy, i.e. as the original daily log records. Another operator had much information available in spread sheet format and was agreeable to making this data available for analysis in appropriate circumstances. This operator also had national requirements that determined what data were collected and reported and the manner of doing this. This included tow-by-tow information.

It was agreed that tow-by-tow information should be kept for possible analysis that recorded the standard information:

- course
- start and finish times of the tow
- coordinates of the tow (start and finish)
- tow type (bottom/mid-water)
- gear details
- vertical and horizontal opening of the trawl
- wire out
- net type and code
- feature name and position
- target species
- sounder used
- catch by species and tow

The information that was believed to be relevant as a primary level of a resources analysis would be catch by feature, though further consideration to that given in FAO (2002b) was required in the definition of what constituted a feature. Further, appropriate protocols for sharing of data would be needed, consistent with conventional procedures for maintaining operators' confidentiality. However, this was not expected to be a problem and that analyses would be undertaken by areal assessments.

12. MANAGEMENT CONSIDERATIONS

12.1 Organization of an industry group

There was a consensus among participants that those present should form a formal association for a number of reasons.

i. There was a need to agree upon and develop industry-driven protocols for fishery research and stock assessment in the region.
ii. Management procedures that had been developed by individual companies needed a group assessment, ratification and collective adoption.
iii. Development of a common design for log books and trawl data bases would benefit from a collective approach.
iv. A single group would facilitate development of co-management practices with the anticipated, but not yet signed or ratified *Southern Indian Ocean Fisheries Agreement*.
v. Much information exists of relevance to conservation of biodiversity and fish habitat: such information needs to be summarized collectively to best provide a coherent synthesis of the ecosystem situation.

It was agreed that in view of the small size of the intended association, there was little justification for a fixed secretariat and a floating secretariat would be more appropriate. In the context of funding of such an association it was noted that Namibian-flagged vessels must pay for a high-seas fishing licence. In the case of New Zealand there were no direct registration costs for high seas fishing.

12.2 Resource management

It was accepted that resource management would probably involve definition of management areas that would have:

i. associated total allowable catches set by species possibly with
ii. timing constraints.

Because of possible bycatch of benthic invertebrates, monitoring of bycatch may be required, at least on a sample-survey basis.

12.3 Disincentives for responsible management

In general two resources types are targeted: (a) fairly mobile species or at least species with panmitic breeding populations for which larger management areas would be appropriate, e.g. that for alfonsinos in the areas of the 90° East, Indian Ridge, Walters Bank and Mozambique Ridge and Plateau and (b), those that targeted localized spawning populations (orange roughy in the areas of Walters Bank, the Mozambique Ridge and plateau and the main Indian Ridge) for which highly detailed, and thus commercially confidential information would be required. In this latter case, this situation emphasized the requirement for data handling and analysis methods in which participants could be sure that disclosure of information would not be used to their operational disadvantage. While the means of doing this had been well established for management of fisheries in national waters of a number of fisheries management regimes, it was noted that this still was not the case for most fisheries on the high seas. To address this issue will require development of appropriate protocols for direction of meetings addressing stock assessment and provision of management advice. At a minimum, it was the view of Association members that participation in resource review meetings would require that participants could contribute catch success data including locations and species information. Association members would also be required to undertake biological sampling and resource assessment activities as appropriate.

The major problem of future open entry into the fishery was discussed and the reality that this failure in international fisheries law was of grave consequence in ensuring the sustainability of the fisheries. It was agreed that entry to the Operators' Association must be open to all deepwater trawl operators that accepted the objectives of the association and abided by its rules of procedure.

There was good agreement that at the present level of fishing effort – four deepwater trawlers – the resources should be sustainable, though this would require appropriate resource assessment and analysis. The question was raised as to whether catch allocations by country would be possible, and though it was agreed that this possibility was of great interest and deserved further consideration, it was concluded that the usual system of TAC and competitive fishing, despite its well known deficiencies, would be the means adopted by the SIOFA for management of the resources.

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APPENDIX I

Agenda

Meeting of Southern Indian Ocean Fishing Operators on Management of SIO Demersal Fisheries Resources

Kameeldrift East, South Africa
13–17 February 2004

Science Subgroup Meeting

1. Confidentiality and access to data
2. Review of historical information
    - Catch by area/feature
    - Effort estimates
    - Stock structure – SWIR, Walters
    - Biological data summaries by species (ORH, BYX)

3. Stock status
    - Number of stocks, how many overfished.
4. Available assessment information
    - Acoustics
5. MPA's known areas of coral for potential closed areas.
6. Recommendations on catch levels that could be sustainable with current assessment information.
7. Work needed to progress assessments
8. Additional information to be collected in 2006.

Fishing Operators Meeting

1. **Meeting reporting**
   What will be reported and other concerns

2. **Review**
   i. History & status of the fishery
      - Catch histories
        By year, species and areas – what do we know? What is unknown?
      - Product types and conversion factors
        Is this a concern – i.e. do we have whole weight equivalents?
      - Review amounts and CPUEs
      - Estimates of fishing effort
        days at sea
        directed tows (number) – etc.?

   ii. Management Status
      – RFMO's
      – Review of status of the Southern Indian Ocean Fisheries Arrangement (SIOFA)
        Where are the negotiations at? Future possible outcomes of relevance
      – Fishing Companies [past, and present; other users]
      – Flag States
        Management implications of the SIOFA, the Indian Ocean Tuna Commission, CCAMLR or?

3. **Resource assessment**
   Existing data – document and comment on status of availability
   Assessment activities – document; evaluate and identify/propose future activities
   Review and document management areas
   Stock assessment – document what is possible with existing information
   i. Orange roughy
   ii. Oreos
   iii. Alfonsinos
   iv. other
   Break out information as it is available

4. **Resource management and management issues**
   - Sustainability of the stocks

   Say what we can say; need for prudence, caution; etc. Need for leadership.

   - Moving towards TACs / Quotas?

   Where can we go in this regard? Now and in the future?

   - Contribution of the Industry to 'Science' and Industry Responsibility

   information and data collection – voluntary use of marine observers – what data to collect and a system to coordinate, collaborate and synthesize

5. **Views on future management directions**
   i. Setting TACs / some other form of quota
   ii. Ongoing stock assessment by the industry
   Document what is being done; identify what should be done and see what progress can be made in achieving it.

   iii. Marine observers & a data collection programme
   What is being done; what should be done; moving towards such goals

6. **Governance issues**
   - Restricting entry
   - Floating some balloons?

7. **Conservation issues**
   i. Damage to sea mounts in the SIO – Review and Assessment
   ii. Bycatch – Review and Assessment
   At a minimum capture and record any documented information; document anecdotal information; identify what should be done in monitoring bycatch; see what progress can be made in achieving it.
   iii. Advocacy on behalf of the industry relating to these issues
   iv. Considerations of Marine Protected Areas
   - Proposals for banning of high seas trawling – UNGA (and elsewhere?)
     Industry accreditation of skippers fishing high seas seamounts? Other? Progress in modifying gear to minimize bottom impacts if they occur.
   - Proposals for High Seas Marine Reserve Areas (MRAs)
   - Other forms of Marine Protected Areas (MPAs)
     > seasonal closures?
     > other?

   Acknowledging the situation and progress

8. **Other items for consideration?**
   Another meeting? When & where?

APPENDIX II

Agenda

Ad Hoc Technical Meeting
Southern Indian Ocean Deepwater Fishing Operators Association
and Fisheries Department, FAO, Rome

Fisheries Research Centre, Albion, Mauritius
25– 28 April 2006

1. Opening of meeting

Review of Meeting Objectives; Context of Kameeldrift East Meeting of February 2006

2. Meeting reporting
What will be reported and other concerns

3. Review

iii. History and status of the fishery
- Catch histories
  By year, species and areas – what do we know? What is unknown?
- Product types and conversion factors
  Is this a concern – i.e. do we have whole weight equivalents?
- Review amounts and CPUEs
- Estimates of fishing effort
  days at sea
  directed tows (number) – etc.?

iv. Management status
- RFMO's
  Review of status of the Southern Indian Ocean Fisheries Arrangement (SIOFA)
  Where are the negotiations at? Future possible outcomes of relevance
- Fishing Companies [past, and present; other users]
- Flag States
- The issue of NGO's etc. – *defense & offence*
- *Who do we want to manage the SIOFA, the Indian Ocean Tuna Commission, or CCAMLR, or ???*

4. Resource assessment
Existing data – document and comment on status of availability
Assessment activities – document; evaluate and identify/propose future activities
Review and document management areas
Stock assessment – document what is possible with existing information

v. Orange roughy
vi. Oreos
vii. Alfonsinos
viii. other.

Break out information as it is available.

5. Resource management and management issues

- Sustainability of the stocks

Say what we can say; need for prudence, caution in determining harvesting regime.

- Moving towards TACs / Quotas?

Where can we go in this regard? Now and in the future?

- Contribution of the Industry to 'Science' and Industry Responsibility

information and data collection – voluntary use of marine observers – what data to collect and a system to coordinate, collaborate and synthesize

6. Views on future management directions

iv. Setting TACs / some other form of quota
v. Ongoing stock assessment by the industry
   - Document what is being done; identify what should be done and see what progress can be made in achieving it.

vi. Marine observers and a data collection programme
   What is being done? What should be done? Moving towards such goals

7. Governance issues

- Restricting entry
- Floating some balloons?

8. Conservation issues

v. Effects on sea mounts in the SIO – Review and Assessment
vi. Bycatch – Review and Assessment

At a minimum capture and record any documented information; document anecdotal information; identify what should be done in monitoring bycatch; see what progress can be | made in achieving it.

vii. Advocacy on behalf of the industry relating to these issues
viii. Considerations of Marine Protected Areas
   - Proposals for banning of high seas trawling – UNGA (and elsewhere?)
     Industry accreditation of skippers fishing high seas seamounts? Other? Progress in modifying gear, etc.
   - Proposals for High Seas Marine Reserve Areas (MRAs)
   - Other forms of Marine Protected Areas (MPAs)
   > seasonal closures?
   > other?

9. Other items for consideration?

- Another meeting? When & where?

APPENDIX III

List of participants at the two meetings
KE - Kameedrift East, South Africa A - Albion, Mauritius

	KE	A		KE	A
BARKAI, Amos Partner OLRAC Silvermine House, Steenberg Office Park Tokai Cape Town South Africa 7945 Tel.: 27 21 702 4111 Mob.: 27 82 808 2276 Fax: 27 21 702 4333 E-mail: amos@olrac.com	✓		**FOSSHEIM**, Jørgen Vessel Manager Blue Ocean II Ltd Box 1279, SE-251 Helsingborg, Sweden & Kongshajvej 107 9210 Aalborg SØ Denmark Tel.: 45 9832 2322 Fax: 45 9832 3583 Mob.: 45 40 58 46 93 E-mail: Jorgen.fossheim@blueocean.dk		✓
DU PREEZ, Johannes Chief Executive Officer TransNamibia Fishing Pty Ltd, Walvis Bay, Namibia PO Box 5067 1202 Standard Bank Centre Heerengracht Cape Town 8001 South Africa Tel.: 27 21 421 5368 Fax: 27 21 421 0001 E-mail: pionfish@iafrica.com		✓	**HADDON**, Malcolm Associate Professor Tasmanian Aquaculture and Fisheries Institute University of Tasmania Marina Research Crescent Nubeena Cres. Taroona, Tasmania 7053 Australia Tel.: 61 3 6227 7279 Mob.: 61 0409 941 891 Fax: 61 3 6227 8035 E-mail: Malcolm.haddon@utas.edu.au		✓
EXEL, Martin General Manager, Policy and Environ Austral Fisheries Pty Ltd. 14 Neil St Osbourne Park Perth Australia Tel.: 618 9202 2436 Mob.: 61 0413 595 532 Fax: 61 8 9443 7750 E-mail: mexel@newfish.com.au	✓		**MACGIBBON**, Dougal Captain Blue Ocean Fisheries 34 Stansell Ave Nelson, New Zealand Tel.: 64 3 548 5773 Mob.: 64 212 55 1918 E-mail: master.beloceanii@telarus.net mettles@extra.co.nz (ashore)	✓	✓
FLANNIGAN, Brian Flantrade Investements cc. Box 50132 Waterfront 50132 Cape Town South Africa Tel.: 27 21 421 3990 Fax: 27 21 421 3992 E-mail: albacore@iafrica.com	✓		**NIKLITSCHEK** , Edwin Associate Researcher Centre for Quantitative Marine Ecology Universidad Austral de Chile Portales 73, Coyhaique XI CP 5950000, region de Aysen, Chile Tel : +56 67 234467 Fax: +56 67 239377 E-mail: eniklits@uach.cl	✓	

PATCHELL, Graham Resource Manager Sealord Group P.O. Box 11 Nelson New Zealand Tel.: +64 3 548 3069 Fax: +64 3 546 7458 E-mail: gjp@sealord.co.nz	✓	✓	**TOCKER** , Ross Operations Manager Sealord Group P.O. Box 11 Vickerman St Nelson, New Zealand E-mail: rdt@sealord.co.nz	✓	✓
SOONDRON, Vishnu Acting Divisional Scientific Office Albion Fisheries Research Centre Albion Petite Rivière Mauritius Tel.: 230 - 2384829 Fax: 230 - 2384184 E-mail: fisheries@mail.gov.mu		✓	**VENTKATASAMI**, Anand Acting Principal Fisheries Officer Albion Fisheries Research Centre Ministry of Agro Industries & Fisheries Petite Rivière Mauritius Tel.: 238 4962 / 4829 Fax: 230 238 4184 E-mail: fisheries@mail.gov.mu fish@intnet.net		✓
SHOTTON, Ross Senior Fisheries Resources Officer Fishery Resources Service FAO Fisheries Department Viale delle Terme di Caracalla 00100 Rome, Italy Tel.: +39 06 5705 6481 Fax +39 06 5705 3020 E-mail: ross.shotton@fao.org	✓	✓			

APPENDIX IV

Instructions for the collection of biological samples from orange roughy in the southern Indian Ocean[1]
June 2006

CONTENTS

1. INTRODUCTION

Fish length and age data from this fishery are an important requirement for the stock assessment of orange roughy because there are numerous stocks of this species in the Indian Ocean that have markedly different size and/or age compositions. The expectation is that size distributions will change as a fish stock is fished down. This pattern has not been well documented for orange roughy stocks around the world and consequently there are substantial uncertainties regarding the length and age composition of the catches in many fisheries.

The purpose of this sampling programme is to facilitate collection of *representative* length data and biological samples from all fisheries for orange roughy in the Indian Ocean. Some of these stocks are likely to have been heavily fished during the period 1999-2001 while others should have been only lightly fished. Information, collected from catches throughout the year will greatly improve the current understanding of the population dynamics and biology of this species, not only for the Southern Indian ocean but potentially for orange roughy fisheries worldwide.

In the case of the Indian Ocean, the resulting information will be incorporated into stock assessments for the stocks where acoustic information is available to provide a biomass index and will also be used to implement fishery management decisions. Not all vessels operating in the fishery have government observers on board to undertake sampling. However, it has been shown in New Zealand that the commercial fleet has the potential to collect a large quantity of biological data from the catches of deepwater species at a reasonable cost.

The collection of biological data can be integrated into the normal operation of a commercial fishing vessel to maximize the coverage of sampling and to provide the assessment programme with the data that are needed to manage the Indian Ocean fishery in a sustainable manner. Industry sampling programmes, operational for orange roughy in the New Zealand ORH3B Exploratory

[1] This text is based on material produced by the Orange Roughy Management Company and SEAFIC, New Zealand who use these methods for providing direction to factory crew members for the collection of biological data on New Zealand vessels.

Fishery Areas, have proved that shipboard personnel can be relied on to consistently collect biological data to a high standard of accuracy.

The instructions for sampling in this manual have been developed on the basis of New Zealand standards of sampling so that there is a single consistent practice among Association vessels. *It is critical that these instructions are strictly followed.*

2. EXTENT OF SAMPLING PROGRAMME

Sampling of catches of orange roughy is required from every stock that is fished. There are at least 15 separate stocks along the South West Indian Ridge and Walters Shoal. The sampling details for each area are outlined below. It is important to collect information from every significant stock that is fished. Because there is general lack of detailed information on many stocks, samples should be collected each day. However, if sufficient crew are trained for sampling, it would be most useful to collect samples from as many trawls per day as possible.

It is not necessary to collect biological samples when government Scientific Observers are on board the vessel. These observers should collect sufficient samples to meet the requirements of the monitoring programme. However, the biological sampling regime they use should follow the one outlined below.

3. SAMPLING PROCEDURES

3.1 Selection of a trawl for sampling

Biological samples are to be collected from the catch taken from at least one trawl for each day of fishing. One of two options should be used:

i. randomly selecting a trawl for each day or
ii. sampling every trawl with a catch greater than 5000 kg.

The trawl catch to be sampled should be selected at random from the fishing undertaken on a given day. Selection is to be determined based on a random time of the day for the time the trawl is on deck (i.e. when it is completed). The first trawl retrieved after the random time for that day is to be chosen for biological sampling. However, if the catch from this trawl is too small for a good sample, i.e. the total catch of orange roughy is less than 500 kg then the catch from the next trawl with a total catch larger than 500 kg should be sampled.

3.2 Calculation of random time for trawls

Lists of random times for each day of fishing are provided in Table IV.1. For example, for a random time of 04:33 sample the catch from the next trawl landed on deck which has a total catch greater than 500 kg. Remember not to sample the catch from trawls with a catch of less than 500 kg.

For random times later than 2000, it is possible that the next trawl will not be landed on deck until after midnight. However, the next trawl should still be sampled and considered as the sample from the previous day. In such cases where the random time for the next day is early and overlaps with the previous night's sample, select the next random time on the list for the sample from the following day.

3.3 Selection of a sample from the catch

A sample of 100 fish is to be measured for each species from the catch. The number of fish comprising the sample does not change in relation to the size of the catch.

The sample of fish to be measured must be selected at random from the entire catch. All samples are to be selected from an appropriate sample point on board the vessel. The sample point should be established at a location that enables all fish in the catch to have an equal chance of being selected

in the sample. *The sample point should not change from day to day, but remain fixed for the whole trip. It is important that the sampling point chosen allows sampling before any fish are sorted.*

The position of the sample point will vary depending on the size of the vessel and layout of the processing area and/or fish hold. On larger vessels, an appropriate sampling point would be located at the conveyor in front of the fish ponds, while on small vessels it may be necessary to collect a sample directly from the codend of the trawl.

The sub-sample of 100 fish is to be selected from the catch at one time. Individual fish will be drawn from the sampling point by successively selecting the fish with the eyeball nearest the sampling point. In the Indian Ocean the volume of 100 orange roughy will require about ten to twelve 35–40 kg fish bins.

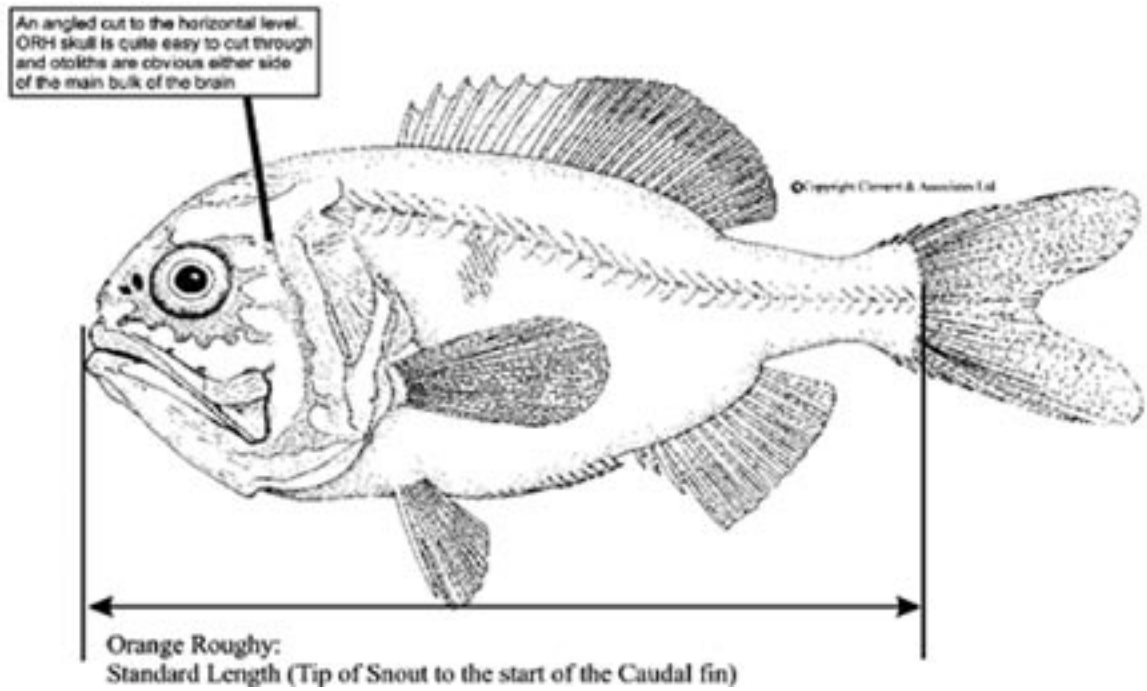
3.4 Measurement of fish length

To determine the length distribution of orange roughy they should be measured to the nearest centimetre below the standard length.[2] For example, a standard length of 35.8 cm should be recorded at 35 cm. Fish that have incurred damage to the tail (i.e. the caudal peduncle) during trawling or from previous wounds that prevent that accurate measurement of the fish should not to be included in the length sample.

Ensure that the following procedure is followed for each fish measured:

- Close the fish's mouth so that the snout rests up against the end-stop of the measuring board and straighten the fish out.

FIGURE IV.1
Methods for measuring orange roughy (SL) lengths and the cuts to be used for otoliths collection



[2] The length of a fish measured from the tip of the snout to the posterior extremity of the hypurals, the expanded bones at the end of the backbone that support the caudal fin: this point is usually indicated by a crease when the tail is bent through ≈ 45°.

TABLE IV.1
List of random times for each day of fishing

Day	Sample time	Check	Day	Sample time	Check	Day	Sample time	Check
1	23:20		41	17:19		81	01:06	
2	02:43		42	17:30		82	10:04	
3	09:09		43	20:53		83	23:17	
4	05:05		44	09:38		84	16:57	
5	02:41		45	18:57		85	08:34	
6	09:08		46	08:55		86	01:18	
7	19:53		47	09:08		87	12:43	
8	20:11		48	08:51		88	19:40	
9	23:54		49	12:30		89	02:07	
10	01:31		50	16:48		90	20:30	
11	20:32		51	20:19		91	14:54	
12	18:42		52	05:13		92	08:15	
13	04:33		53	11:36		93	18:51	
14	03:03		54	15:08		94	17:29	
15	18:35		55	22:19		95	10:43	
16	12:45		56	18:10		96	12:47	
17	21:41		57	11:39		97	16:21	
18	12:36		58	09:56		98	15:23	
19	11:58		59	00:54		99	11:10	
20	01:27		60	09:57		100	10:56	
21	23:19		61	05:11		101	13:32	
22	21:38		62	21:57		102	05:51	
23	15:12		63	16:26		103	02:32	
24	02:56		64	03:41		104	07:32	
25	13:44		65	05:35		105	00:27	
26	19:39		66	19:34		106	09:18	
27	05:16		67	04:57		107	14:32	
28	14:19		68	02:32		108	13:40	
29	17:42		69	05:10		109	09:01	
30	12:10		70	07:08		110	20:59	
31	01:58		71	21:29		111	08:26	
32	15:43		72	06:49		112	07:58	
33	15:55		73	06:16		113	22:17	
34	20:15		74	18:06		114	23:55	
35	03:02		75	14:37		115	03:46	
36	01:12		76	03:56		116	17:47	
37	09:53		77	15:52		117	01:25	
38	07:27		78	12:55		118	16:34	
39	12:44		79	11:53		119	13:18	
40	18:59		80	11:05		120	03:13	

- Place the cutting edge of your knife over the base of the tail fin (for ORH).
- Check that the knife is being held straight (i.e. at 90° to the long edge of the measuring board), and press the point of the knife down so that it rests on the scale of the ruler
- Record the length to the nearest cm below the true length, on the sampling sheet provided.

3.5 Sex and maturity data

All fish in the sample are to be sexed and the gonad state of female fish is to be determined using the stage development scheme outlined in Figure IV.2. This detailed sampling regime is not normally used by observer programmes, but is used by the NIWA in New Zealand, the CSIRO in Australia and also in Chile. It is important to determine the gonad state of every female fish included in the

FIGURE IV.2
Gonad stages for orange roughy

Females

1 **Immature or resting**
Ovary clear or pink, small. No eggs visible.

Immature

2 **Maturing**
Ovary pink, small eggs visible (as orange dots).
Ovary small.

Maturing

3 **Mature**
Orange, yolk filled eggs obvious
(diameter 0.5-1.5 mm), filling the ovary.
Ovary quite large, bright orange.

Mature

4 **Ripe**
Ovary large. Clear eggs are present
(more than just one or two).Ovary has
mottled orange appearance, with mixed
orange and clear eggs.

Ripe

5 **Running ripe**
Ovary large and thin walled, fragile.
Most eggs clear (hydrated).
Eggs flow freely when light pressure
applied to the abdomen.

Running ripe

6 **Spent**
Ovary flaccid and bloody. Some residual
eggs often present.

7 **Atretic**
Eggs yellow or blackish. Degenerating.

Spent

8 **Partially spent**
Ovary somewhat flaccid, slightly bloody.
Contains substantial numbers of clear freely
flowing eggs, may have orange eggs also.
Some eggs lost.

9 **Immature showing atresia**

Illustration used by courtesy of National Institute of Water and Atmosphere, Wellington, New Zealand.

sample. If you cannot identify the gonad condition do not record the fish in the "Female Tally" column. Instead, record the fish in the "Not sexed" column. This applies to all species sampled.

For female orange roughy it is important to separate out stage 4 and 5 fish. The gonads (roe) of a stage 5 female are running ripe when light pressure results in eggs being exuded. When the ovary

is cut, the eggs should be loose inside, in a liquid mass that flows. Stages 7, 8 and 9, intermediate stages to others, may be confusing and are not illustrated. Stage 8 occurs between stages 5 and 6, as the fish spawns batches of eggs and slowly reduces the total size of the ovary. Some stage 7 fish may be seen and these should be recorded.

3.6 Collection of otoliths

Otoliths will be required from fish in each of the stocks: A number of different orange roughy stocks exist in the Indian Ocean. There may be large biological differences between stocks as suggested by the different size of fish between Walters Shoal and the Southwest Indian Ridge.

Otoliths should be extracted from about ten of the fish in each 10–12 bin sample. It is important that these fish are **randomly selected** from the ten to twelve bin sample and that they are **not** chosen based on individual size. Chose the random, yellow-shaded lines on the Biological Sampling form to guide the selection of fish from the length frequency sample to be processed for otolith extraction (see Figure IV.3). The length of fish taken for otoliths is to be measured to the nearest half-centimetre below the standard length**.** For example, a standard length of 35.8 cm should be recorded as 35.5 cm.

Coin envelopes can be used if otolith envelopes are not available. If no otolith envelopes are available, fold the otoliths inside small squares of paper and use adhesive tape to seal them. Use of otolith envelopes is preferred. They are usually made of relatively strong brown paper, have gummed flaps, and measure about 10 cm by 5 cm. Any envelopes of similar design can be used. *Note: All station details and biological information for the otolith-sampled fish should also be recorded on the otolith envelopes.* As an initial step, 100 otoliths should be collected from each stock during the 2006 season.

3.6.1 Procedure for otolith extraction

To collect otoliths, a set of forceps and small envelopes are required. Two people are required for this task – one to do the measuring, cutting and otoliths extraction and another to record the information on the otolith envelopes and to ensure that the envelopes are kept dry.

Procedure

- Hold the fish upright, firmly resting the belly on the measuring board and cut down to the level of the mid-eye as illustrated in Figure IV.2
- Lift the fish and bend the head downwards to open up the cut and reveal the brain.
- The otoliths are located slightly behind and below the brain and are nestled within separate cavities, one on either side of the mid-line.
- Further careful cutting away of bone/cartilage may be required before the otoliths are located. Gentle probing with the forceps (tweezers) is often successful in locating unseen otoliths as they are hard and dense and 'feel' different from the bone/cartilage tissue.
- Carefully remove the pair of otoliths using the forceps. The otoliths are brittle and will break if handled roughly.
- The otoliths should be kept dry and warm, and retained by the company for future analysis.
- Carefully wipe the 'jelly' off the otoliths (otherwise the envelopes soak up the moisture, holes develop in the packets and otoliths may be lost) and place both otoliths in the envelope.

Ensure that you work over the measuring board/sampling table at all times so that dropped otoliths do not land on the factory floor where they may be swept away by water flow.

4. RECORDING INFORMATION

4.1 Trawl information

It is important to relate the biological samples to the catch and effort data from the trawl. Whatever catch and effort data recording system is being used by the vessel, be able to link the samples to the trawl shot that was undertaken. Record the Vessel Name, date and the shot number from that form on the top of the Biological Sampling Data Form(s) for that trawl. You should also include the Position name given by the vessel for that feature, or the latitude/longitude.

4.2 Biological sampling

Record all sampling data on the attached Biological Sample Data Forms. There are two forms: one is for recording detailed information on gonad state and fish weights to establish the gonadosomatic index (Figure IV.3). This form should be used during the spawning season when detailed information on spawning state is required to use in conjunction with acoustic information for each stock. During this period, 100 fish should be fully sampled each day for full biological information.

Alternatively, the form provided for Length Frequency (Figure IV.4), can be used, following the procedure described in Section 3.3. These forms are available in Excel format and copies can be printed at sea. Use a clip board and pencil to record information. Keep the forms dry and store them in a secure place. A spreadsheet should be maintained with the data records as shown. Record the standard length to the nearest centimetre below the actual length.

4.3 Guide to completing the biological sample data form

- Males and female fish are recorded in separate tally columns. Use a separate row for each 1 cm length class.
- To record individual fish gonad state write the stage number in the appropriate tally form column.
- Once the sample is completed, sum the number of male and female measured in each length class in the columns headed 'Total LF'. Record the total number of male and female fish in the 'TOT' row at the bottom of the form.
- Remember to record the gonad stage for every fish measured.

TABLE IV.2
Excel spreadsheet format for biological data

Date	Tow	Area	Length	Sex	Stage	Weight	Gonad	Otolith
8 Jul	1	Saddle	52	F	4	4.72	0.64	Y
8 Jul	1	Saddle	52	F	4			N
8 Jul	1	Saddle	54	F	4			N
8 Jul	1	Saddle	45	M	5			N
9 Jul	2	Saddle	51	M	4	3.5	0.5	N

FIGURE IV.3
SIODFA biological sampling form

INDIAN OCEAN ORANGE ROUGHY DATA
Biological data form

Date	
Tow	
Area	
Time	
Recorder name	

Number	Length	Sex	Stage	Weight	Gonad weight
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
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40					
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					

The yellow-shaded fields show six randomly-chosen rows representing the fish whose gonads are to be sampled.

FIGURE IV.4

Length frequency form

ORANGE ROUGHY INDIAN OCEAN

Length Frequency Data

Date

Time

Tow

Area

Recorder

Ln	M	F	Total M	Total F
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
41				
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APPENDIX V

Acoustic data logging protocols and procedures for commercial fishing vessels in the southwest Indian Ocean deepwater trawl fishery

Contributed by
G. Patchell
Sealord Group, New Zealand

1. INTRODUCTION

Members of the Southern Indian Ocean Deepwater Fishers Association (SIODFA) have all undertaken a range of research programmes in this fishery, from wide-area habitat mapping to fisheries acoustic surveys and biological data collection. However, some members have undertaken more work than others and the Association agreed that all vessels in the fishery will undertake a range of research activities during the 2006 season.

The primary method for assessing stock size in the Southern Indian Ocean deepwater fisheries is acoustic surveying. All parties have agreed to undertake survey work in 2006 as an adjunct to normal fishing activity. At least one 'splash' survey, i.e. a short-term (on the order of a few hours) survey will be undertaken of any significant aggregation that is fished and thus will only be done if a sizeable fishery aggregation has been encountered.

Future management of SIO deepwater resources will require setting of annual total allowable catches (TACs) ideally for each stock, but more practically on a defined-area basis; this will require biomass estimates for each of the many deepwater stocks in the Indian Ocean as the TAC will, no doubt, be set as a fraction of the existing biomass. Thus, stock biomass information is needed to show that the Association's vessels are fishing the resource in a sustainable way. This Appendix describes the use of the acoustic survey equipment, survey protocols and how to archive the data properly should additional analysis be needed at a later time. A checklist for addressing problems is included.

2. PRINCIPLES OF ACOUSTICS SURVEY METHODOLOGY

Standard scientific acoustic surveys require the use of rigorously calibrated echosounders: this is not the case for commercial fish finding where skippers are able to intuitively calibrate what they see on the sounder and what they expect to catch, i.e. relate what is seen on the system's display to the fish that are sonified in the water, based on their past experience. The calibration process determines the relation between the acoustic system's output results and the intensity of the echoes received at the system's transducer, which is usually mounted in the ship's hull. Modern commercial echosounder systems, such as the Simrad ES60, now have a high level of operational performance (i.e. electronic stability) and share most of their components with scientific versions, such as the EK60, and are increasingly used for quantitative assessment surveys. All vessels operated by the Associations members are equipped with Simrad ES60 acoustic systems.

If the acoustic results are to be used in support of pilot trawl surveys, the need for high-quality acoustic information is low: If the objective is to accurately estimate fish biomass and its absolute areal distribution then the system must give consistent and comparable estimates for the survey area. When a calibrated acoustic system is available it is usually easy to attach an echo-integrator system and thus run a scientific survey. These requirements are summarized in Table V.1.

TABLE V.1
The relationship between survey design/purpose and required data quality. These indicate minimum requirements.

	Instrument quality		
Survey design and purpose	***Unstable uncalibrated***	***Stable uncalibrated***	***Stable calibrated***
Scouting	✓	✓	✓
Distribution estimation	✓	✓	✓
Distribution estimation with improved comparability over time	×	✓	✓
Abundance estimation. Scientific quality.	×	×	✓

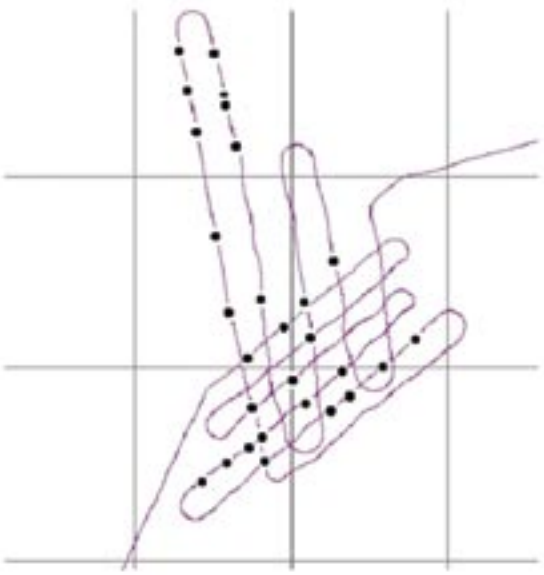
3. SPLASH OR "BICYCLE WHEEL" SURVEYS

Three fisheries in New Zealand and Chile currently use commercial fishing vessels to conduct acoustic surveys to estimate the biomass of orange roughy (*Hoplostethus atlanticus*), southern blue whiting (*Micromesistius australis*), and hoki (*Macruronus novaezelandiae*).

Several studies have evaluated the potential of this approach and how to optimize the use of commercial fishing vessels. The primary approach has been to combine standard fishing operations with scientific surveys, either by allocating time to survey the fishing grounds or an underwater feature using vessel 'down-time' when it is processing catch. This approach has worked successfully without significantly affecting fishing success and has often resulted in increased catches (see Appendix VI).

The *F.V. Will Watch* undertook a large number of opportunistic surveys, or 'splash surveys' in the Southwest Indian Ocean, in 2004 and 2005. These surveys took 2–6 hours depending on the species distribution, and the size of the area. Figure V.1 shows one survey. In this survey approach, the vessel steams transects that are spaced 0.2–0.3 nm apart. The last transect line should be outside where fish were last encountered. That is, additional transect lines must be added as long as fish are being detected; otherwise the extent of the fish aggregation will be underestimated. Avoiding this is critical for the assessment, otherwise the biomass will be underestimated and a lower TAC would be set accordingly.

FIGURE V.1
Transect acoustic survey – Southern Indian Ocean



The spaced-transect method is the most suitable for bottom ridge systems. For individual seamounts and knolls, the 'star' or 'bicycle wheel' pattern is better. This is especially useful commercially for detecting on which side of a knoll the fish are aggregating, e.g. in the Indian Ocean orange roughy are highly mobile, and can rapidly move around a knoll. Many successful skippers use this mapping technique during fishing operations.

Figure V.2 (left pane) shows an example of the 'star' pattern undertaken during a commercial voyage on the *Graveyard* knoll in New Zealand. Fish that were sonified are shown in the right pane. Figure V.3 shows the type of data that can be gathered with continuous logging. In this case, the information is of reduced value for stock size estimation as there are no transects beyond where the fish were most abundant. This stock needed one good snapshot of about seven transects across the ridge: these would have taken about two hours to complete.

FIGURE V.2
Star pattern survey

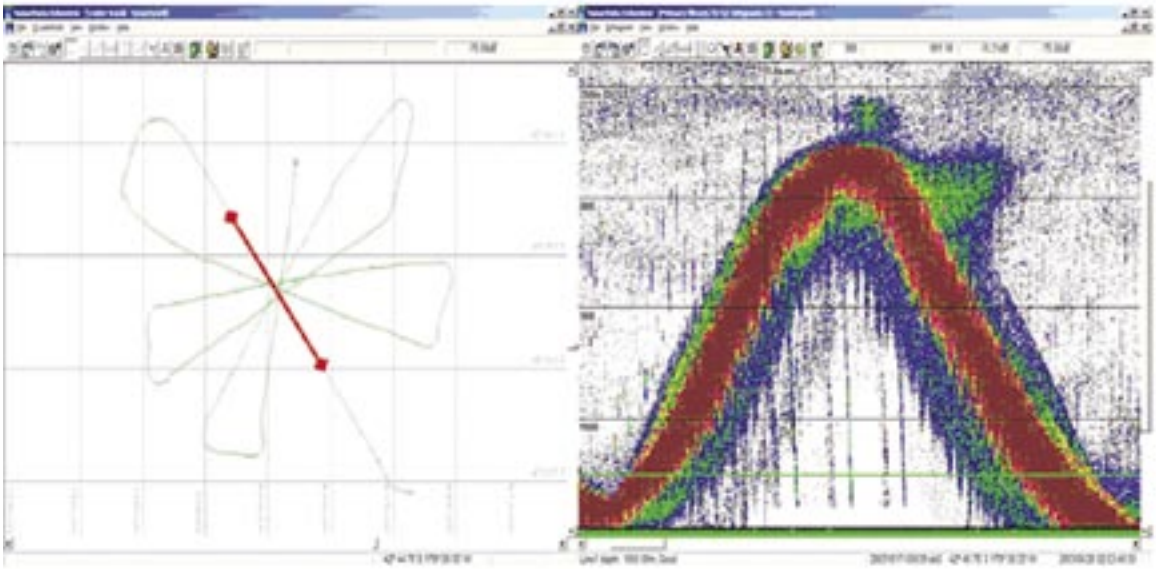
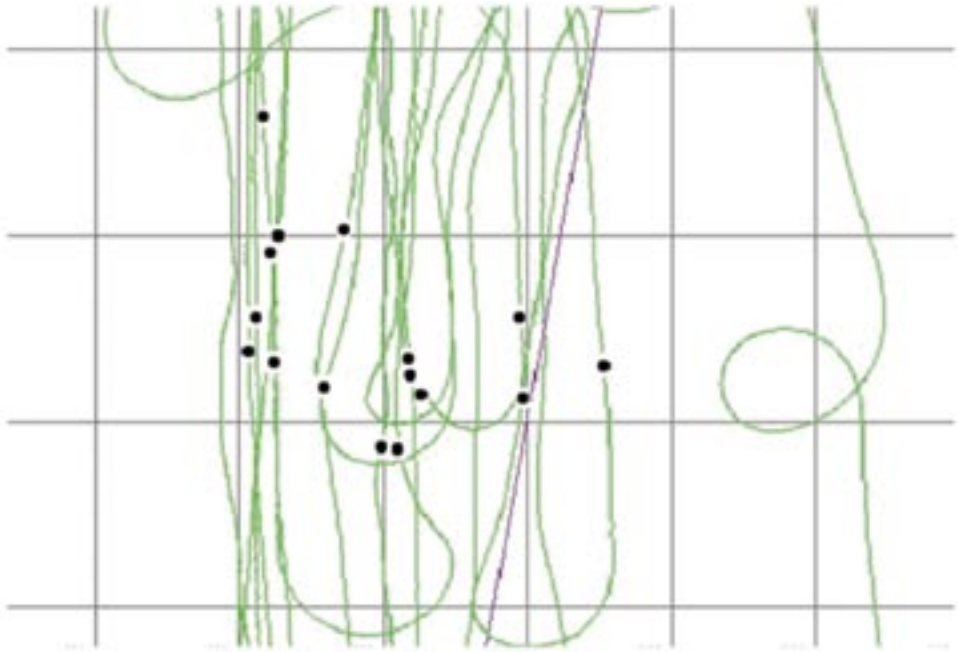


FIGURE V.3
Example of a quantitatively unusable acoustic survey pattern



The repetition of survey lines over the same area vastly complicates the analysis of the data that is collected. Data collected on repeated lines is of much lower value in making abundance estimates.

4. SURVEY SPEED

The best survey speed will depend on sea state, vessel trim and potential and actual noise characteristics of the vessel (See Appendix VI). Most fishing boats produce noise that can potentially scare fish and increase the noise-to-signal ratio of acoustic results, under different operating conditions.[1] The officer in charge must find the highest speed that still enables relatively noise-free acoustic data to be obtained – in this way the maximum area will be covered, or the time

[1] Much of this comes from the propeller and will depend upon the propeller design and its rate of revolutions: variable pitch propellers and those surrounded by Kort Knozzles are particularly noisy.

minimized, to survey the fish aggregation. In general, 7–9 knots has proven to be a suitable speed for surveying for several vessels.

If there are heavy seas, the concern is that air bubbles under the hull will result in acoustic noise and will attenuate the power of the sonified pulse volume so that echo intensities will be lower than they would otherwise be. Fish aggregations will seem smaller. Thus, different survey speeds may be appropriate depending on whether the vessel is steaming into, or with the swell. And, acoustic noise may give the false impression of the presence of fish.

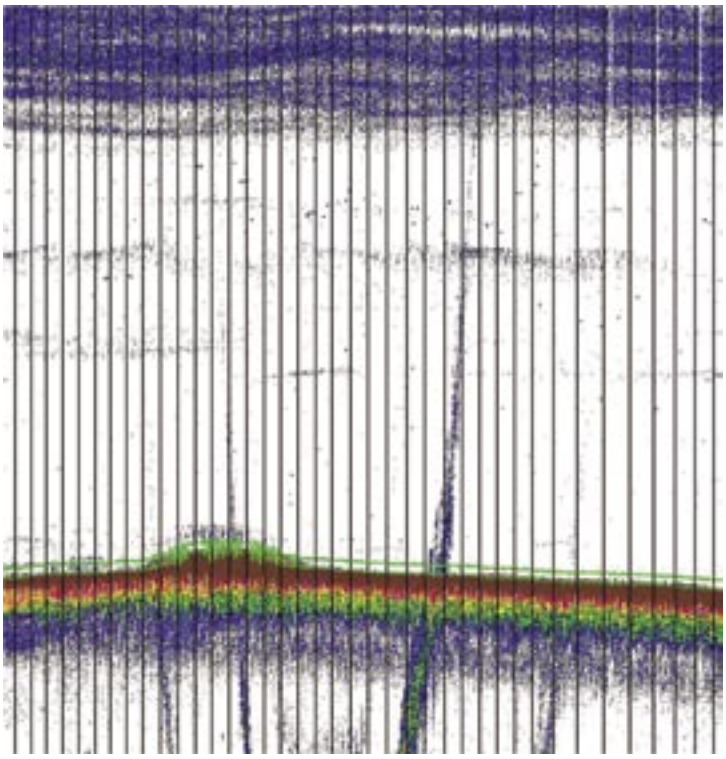
5. POWER SETTINGS AND TRANSMISSION (PING) RATE

It is desirable to use the ES60 with a fixed transmission rate.[2] When the ping rate is set to maximum we sometimes see a false bottom echo in midwater. In orange roughy fisheries, go into "File/ Operation..." menu to bring up the "Operation Dialog" box, select "Interval" under "Ping Rate" and set to 2 s.

Although the ES-60 can operate at power settings up to 4 kW, at such high power settings cavitation occurs at the transducer face, caused by excessive movement of the transducer. The bubbles that form on its surface reduce the echosounder's performance as there is less energy in the sound pulse. Echoes will be weaker and some fish echoes will be masked by ambient noise. Thus, the system's power should be set at 2000 W. Studies in New Zealand on vessels such as the *San Waitaki* have shown that there is less noise, and better fish detection at this setting compared even with 2.4 kW.

Figure V.4 shows an example of a characteristic recording of acoustic noise that is generated by the acoustic system or survey vessel. Figure V.5 shows an example of a noise recording where the noise has been generated by another vessel.

FIGURE V.4
Recording of acoustic noise



This can arise from different causes including time varied gain of returning echoes and, or, ambient noise, which is probably the case in this example.

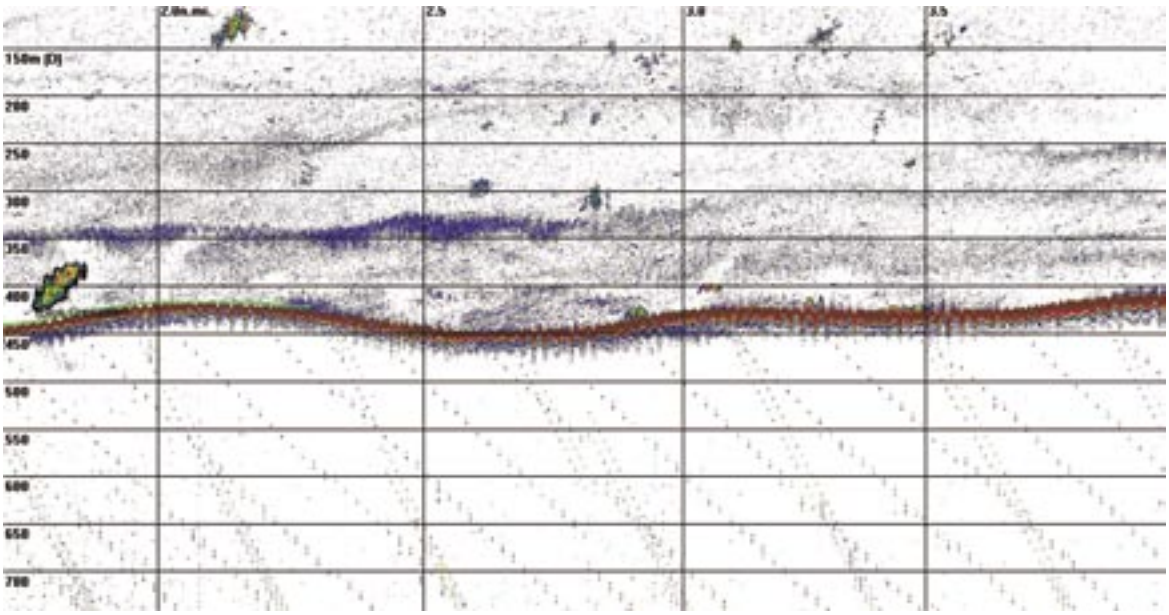
6. OTHER SOUNDERS

Acoustic interference may occur if other sounders of similar frequency are operating at the same time, even if they are synchronized. This is because extra sound is put into the water and the ES-60 treats the returning echoes from both sounders as though it is from its own transmission, thus fish echoes may be double counted.

When collecting survey acoustic data for assessment work, only run the ES60. Further, when an ES60 is triggered externally by a wide beam Furuno echosounder, the Furuno slows down the transmission rate

[2] The transmission rate is ultimately determined by the water depth. The following transmission must wait for the bottom echo of the preceeding transmission to return to the transducer – the deeper the water, the longer the wait and the slower the possible transmission rate.

FIGURE V.5
An example of a recording of sound coming from another vessel's echosounder(s)



of the ES60 and reduces the amount of information collected. This may not be apparent on the ES60 screen, but is obvious when the acoustic data are analysed. With the two sounders synchronized, you are actually missing fish!

7. ACOUSTIC DATA LOGGING FOR ORANGE ROUGHY SURVEYS

7.1 Background

It is useful to have the ES60 logging data even if the vessel is not surveying as unexpected fish aggregations may be encountered. However, it is advised that when moving between bottom features more than 3 hours apart and over deepwater (>1 800 m), there is little benefit in logging data. *All it takes is a "click" with the mouse to start and stop logging.*

When the vessel arrives on the fishing grounds, begin logging acoustic data by clicking on the file serial number (the LXXXX number at the bottom of the screen). If data were not being logged, this changes the colour of the serial number from black to bold **red**. (*NOTE: a red serial number indicates that acoustic data are being logged, black serial number indicates that data are NOT being logged*).

7.2 Surveys

When beginning a survey, create a new acoustic file. Close the current file by clicking on the file serial number (LXXXX) at the bottom of the screen, changing the colour of the serial number from red to black. Click on the serial number again so that the colour changes back to red. Note that the new serial number has advanced by one unit. When the survey has been completed, click on the serial number to change it to black, and stop logging. Record the name of the file, the date and the area in a hardcopy logbook.

7.3 Checking marks

Identification of fish marks is critical for correct analysis of the acoustic results. Following an acoustic survey, if you fish the marks that were observed, log the depth of these marks on the logbook and the depth of other marks that were not considered to be orange roughy. This information is critical for analysis of the results.

7.4 Biological sampling

Detailed biological sampling of the target catch should be done according to the Deepwater Sampling Instructions (see Appendix IV). The full species composition should be noted, whenever tows are undertaken during an acoustic survey. It is important to know what other species were represented in the acoustic marks.

SUMMARY OF PROTOCOLS

i. Map significant aggregations before they disperse or move, preferably after the first significant successful shot (~30 tonnes).
ii. Adopt a survey strategy appropriate to the feature you are working.
iii. Cover the full areal extent of any fish aggregation, to ensure that all of its biomass is assessed.
iv. Collect biological data and mark identification information in logbooks.
v. If you are still fishing the aggregation after two days, or if processing is constraining fishing, do more surveys.
vi. Set transmit power at **2 kW** only.
vii. Only have the ES60 running. No other sounders should be used when surveying.
viii. Ensure logging of raw data occurs.
ix. Leave the ping filter off when surveying, so you can identify noise problems.
x. Ensure maximum depth set is 1 800 m.

8. DETAILED ES60 INSTRUCTIONS FOR SETTING UP THE SYSTEM

This section provides an ES60 data-logging operator with detailed instructions for ensuring that the acoustic data are properly recorded and stored.

Hardware requirements and setup of portable hard drives

To archive data collected by a Simrad ES60 echosounder requires a USB port, an operating system that recognizes the USB port (typically Windows 2000) and a GPS unit connected to the echosounder. A keyboard attached to the echosounder is desirable.

There are a range of external hard drives that use laptop hard disks that can be connected to the ES60 computer via the USB port. The size of these drives range from 80–120 Gb and a drive with a capacity in this range should be chosen. A 80 Gb disk is generally sufficient to store detailed information collected over four months.

Some of the operations described below require basic file management operations using the ES60 computer – see the "Troubleshooting and Helpful Keystrokes" section at the end of the document.

Destination folder on portable drive

A destination folder for the ES60 data should be created on the hard drive. Two file types generated by the ES60 will be stored: (a) a "*.RAW" file and (b), a "*.OUT" file. Verify that a destination folder called "Vessel name datagram year" exists; if not, create one using your vessel name and the year.

Creating a file path for ES60 data storage and ES60 settings

The ES60 software requires that a destination file path be specified in order for ES60 data to be stored on the portable drive. To specify a file path, make the following menu selection "FILE STORE". Then,

- check the "Save Raw Data" box (raw data from the transducer saved as '*.raw' files)
- check the "Save Output Data" box (bottom data saved as '*.out' files)

- set “Line Number” to 1 (only at the beginning of the survey)-this controls the serial/file numbers of the raw data files
- do not check the “Local Time” box as this affects the time stamp in the file
- set “Maximum file size” to 100 Mb and
- finally, under “Survey” specify the file path corresponding to the destination folder that was created on the drive. The path reflects the appropriate drive letter, and the folder reflects area, year, and vessel (e.g, *E*:\Will-Watch datagram 2006).

Other settings

Bottom detector settings
Right-click on the depth display at the top of the echogram window. In the depth dialog window, do the following.

i. Set the “maximum depth” to 1 800 m.
ii. Check the “bottom smoothing” box.
iii. It is important to set the “Minimum depth” at 200–400 m, to ensure that any plankton layers do not prevent bottom detection. These settings do not affect the echogram that you see on the screen, but are important for the acoustic analysis.
iv. The backstep minimum level should also be set at –50 dB, the default setting.
v. NOTE: Do NOT check the “alternative bottom detector” box.

Right-click anywhere inside the echogram window. When the echogram dialog window appears:

iv. Check Surface – Manual (the ES60 will use the range setting in the Surface Range menu, above) and
v. Check “Event”.

It doesn’t matter whether the TVG is set to schools (20 Log R) or fish (40 Log R) – this does not affect the logged raw data. Then:

vi. select “variable depth”
vii. set “Bottom” to “on” and
viii. uncheck the Ping Filter (**turn it off**).

9. OTHER ES60 SETTINGS

Recording ES60 parameter settings
To record all ES60 settings:

- Right-click on the frequency “38 kHz” near the top and left of center of the screen.
- In the Transceiver settings dialog box, ensure the power setting is appropriate for your combination of GPT and transducer:
  o typically 1 000 W to 2 000 W for 38 kHz
  o A pulse length of 1.024 ms.
- Set Mode to ACTIVE (except when creating “noise files”-see below).
- Click on the “ADVANCED” button to display the ES60 settings. Record all settings (e.g., frequency, beam type, gain, S_a correction, etc.) on the log form.
- Alternatively, you can make a screen shot of the settings window:
  o Click CTRL+ALT+PRINT SCREEN
  o open a programme such as Paint, and Paste.
- Save the file on the on the portable drive cruise folder and record date and file name on log form.

How to verify you have the Version of ES60 software on your Vessel's System
Record the version of the ES60 software on the log form. To do this, go to "HELP ABOUT THIS ECHOSOUNDER".

Verifying that a GPS unit is connected to the ES60
To verify that a GPS unit is connected to the ES60 and functioning properly check for latitude and longitude data at the bottom of the screen in the ES60 software.

Creating "noise files"
If the opportunity arises, collecting measurements of the vessel-generated background noise may facilitate processing of the acoustic data after the survey. Collect noise files in 2 locations: (a) when the vessel is over deep water, e.g. >500 m depth and (b), when the vessel is on station. At each location, create one "noise file" while the vessel is running at cruising speed (e.g. ~10 knots), and one file while the vessel is sitting still or drifting. When on station, create an additional noise file when the vessel is trawling. Record the relevant file information on the survey log form.

To create noise files: Right-click on "38 kHz" in the upper left hand corner of the screen. Check "PASSIVE" in the dialog box. This puts the transducer in a passive "listening" mode (i.e. no acoustic transmissions). Next, assuming a data file is being logged, close the current file by clicking on the file number (i.e., LXXXX) at the bottom of the screen (its colour should go from red to black) and click again to start a new "noise file" (its colour should switch back to red and the LXXXX number should increase by one). Log data for approximately 10 minutes and then close the file (click on LXXXX). Note the file number and record it along with the vessel speed as a noise file on the log form (use file type "N"). Next, right-click "38 kHz" and activate the transducer by checking "ACTIVE". Finally, resume normal data logging operations by clicking on LXXXX so that it turns red. Record propeller RPM, vessel speed and weather conditions on the log form.

Helpful shortcuts

Closing ES60 software without shutting down the ES60 computer
To avoid shutting down the ES60 computer every time you shut down the ES60 software, simultaneously press the SHIFT+ALT keys and then go to FILE Shutdown. If the sounder does not have a keyboard, it is also possible to shut down the sounder software by going to the File menu, pressing the right mouse button, then pressing the left button and scrolling to 'shutdown' holding both mouse buttons. Then, release the left button before the right button.

Toggling between Windows Explorer and ES60 screen
To check disk space and make sure files are transferring properly have the Windows Explorer and the echosounder running simultaneously. Striking the "Tab" key while holding the "Alt" key down will toggle between the icons of the programmes currently running. Selecting the Windows Explorer icon will display this programme. If the Windows Explorer icon is not present, it may be necessary to shutdown the echosounder without shutting down the processor (see above), open Windows Explorer, then restart the ES60 software from the icon on the desktop.

APPENDIX VI

Use of commercial vessels for acoustic (and trawl) surveys of fish stocks

I. Hampton
Fisheries Resource Surveys cc.
Cape Town, South Africa

1. INTRODUCTION

Over the past decade or so, the quality of fishing echo-sounders has improved to the extent that many fishing vessels now carry sounders capable of delivering scientific-quality acoustic information on the distribution and abundance of fish stocks. As a result, there is an increasing move to conduct acoustic surveys from commercial vessels in the course of their normal operations, or under charter as a low-cost alternative, or supplement to, dedicated surveys using specially equipped research vessels. (e.g. Hampton and Soule 2002, O'Driscoll and Macaulay, 2005). The cost saving comes from the relatively low additional cost of the survey compared to the running costs of the vessel and, in cases where the vessel is chartered, usually lower running costs and, perhaps, sale of the catch to offset the survey costs.

In the following, the requirements for a successful operation in terms of the nature of the target species, the vessel and its fishing practice, equipment, survey design, personnel and other data collection requirements are outlined.

2. TARGET SPECIES

Species most suited to acoustic assessment from commercial vessels are those for which the major portion of the population at the time of the survey is concentrated into reasonably homogeneous aggregations that are acoustically detectable at typical survey speeds from hull-mounted transducers. The operation becomes particularly efficient when the fish are highly aggregated (e.g. Figure VI.1), leading to large catches and many hours of on-board processing before fishing can resume. This time can be used for surveying the area in the immediate vicinity of the catch. The catch itself provides the biological information necessary for interpretation of the acoustic data. If the fish are concentrated into a number of relatively small areas of known location, surveys of these areas by commercial vessels fishing on them can give an estimate of total stock size. If the fish are distributed over a wide area this strategy would not normally be effective. The vessel would then have to be chartered to cover the area representatively, in which case the only significant advantages over a research vessel are the (usually) lower operating costs, and the option of selling whatever catch is made to offset some of the charter costs.

3. VESSEL

Ideally, the vessel should have the following characteristics.

- Be acoustically quiet enough at the survey frequency (often 38 kHz) for acoustic detection, using hull-mounted transducers, of low densities of the fish of the species of interest to their maximum depth within the survey area, at speeds of around 10 knots in good to moderate weather (sea states up to 4–5). If the vessel's hull-mounted transducer is too noisy or otherwise unsuitable, a shallow-towed or pole-mounted external transducer may be an option.

- Be capable of catching the species of interest in all localities within the survey area to their maximum depth. This requirement will usually be met where the target species are those on which the vessel normally fishes commercially.

- Have sufficient range, endurance and hold capacity to enable the vessel to remain in the survey area for long enough to complete the survey work.

- Have sufficient space on the bridge for mounting and operating the acoustic data logging equipment: there should be adequate space for biological sampling of the catch in the factory or on deck. And there should be adequate additional accommodation for the scientific staff.

4. EQUIPMENT

The minimum equipment requirements for an acoustic survey from a commercial vessel are:

- A stable echo-sounder with an accurate time varied gain (TVG) function operating at the chosen survey frequency (usually 38 kHz), with data outputs suitable for logging and subsequent analysis through available software packages.

- Calibration of the sounder to scientific standards, e.g. using the standard sphere method (Foote *et al.* 1987) at least once during the survey period. For ease of calibration and greatest calibration accuracy, the transducer should be a split-beam type.

- A high-capacity (100 GByte+) removable hard-drive for logging of raw acoustic data files.

- Fish-measuring equipment and materials, i.e. scales, measuring boards, data capture hardware and software, etc., log forms and measuring forms.

A common option for the echo-sounder is the Simrad ES60 sounder that is widely used as a fishing sounder on commercial vessels world-wide, and which has been shown by direct comparison (e.g. Hampton and Soule 2002) to be capable of generating abundance information on a par with that of its scientific version, the Simrad EK60 sounder (see Figures VI.1 and VI.2). The data outputs are suitable for logging and analysis through off-the-shelf packages such as Sonardata EchoLog/ Echoview and the Simrad BI500 or BI60 is possible.

FIGURE VI.1

Orange roughy aggregation recorded by alternate pings from Simrad ES60 (left) and EK60 (right) echosounders on Chatham Rise, New Zealand, July 2002 (Hampton and Soule 2002)
Note the similarity of recordings.

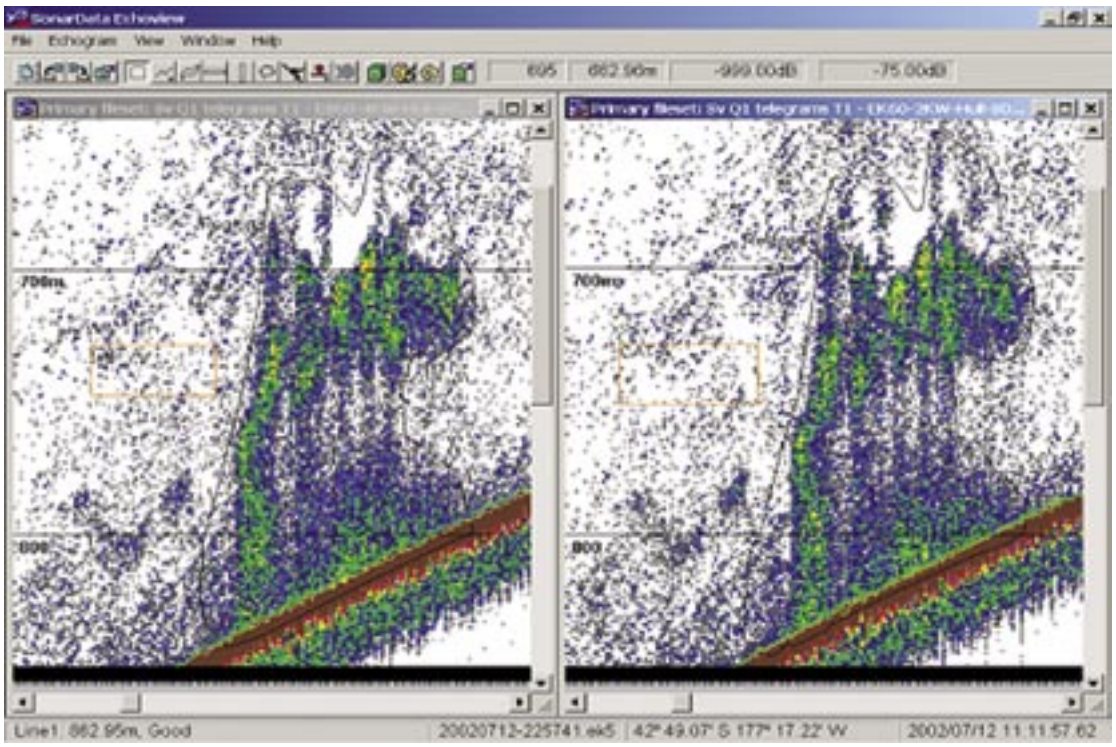
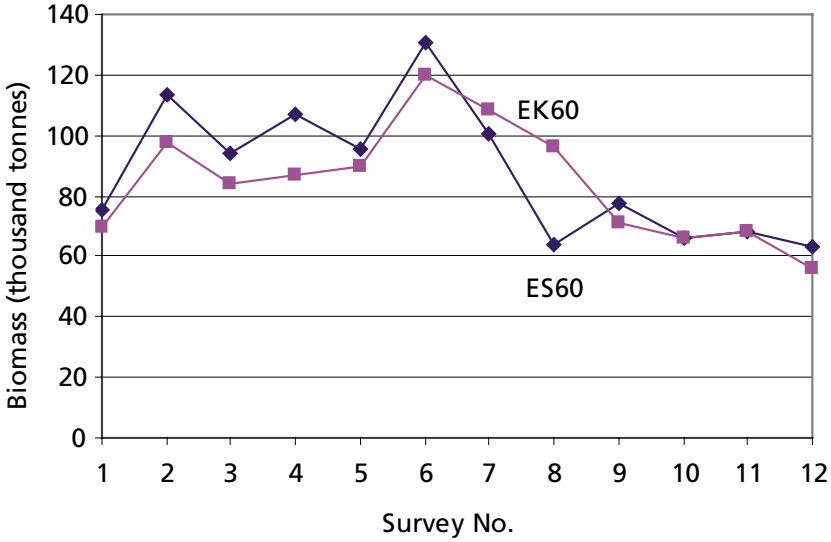


FIGURE VI.2
Acoustic estimates of orange roughy biomass in repeated surveys of spawning plume on Chatham Rise, New Zealand, July 2002, using Simrad ES60 and EK60 sounders (from data in Hampton and Soule 2002)



Calibration of the system gain and beam pattern needs to be done by a specialist under calm conditions with at least 20 m of water below the keel (for 38 kHz transducers). This should preferably be done before the survey so that any malfunction can be identified before the instrument is used for data collection.

The above equipment enables high-quality acoustic data to be collected at sea for subsequent analysis ashore. If the data have to be examined on board, e.g. for use in ad hoc decisions on survey design and strategy, some means of re-playing and perhaps analysing the data at sea needs to be provided. In some instances it may also be necessary to record information on vessel motion, wind speed and thermo-haline structure to correct for loss of signal due to weather effects, and, where the targets are deep, for error in the echo-sounder's internal compensation for sound absorption. Wind speed and vessel motion can be measured by a stand-alone anemometer and pitch and roll sensors, and water column thermal structure measured using a temperature sensor on the vessel's net monitor during trawls. Though more complex and expensive, pitch and roll measurements can be integrated with the acoustic data and the thermo-haline structure determined from a portable CTD attached to the net.

A practical alternative method of correcting for weather effects, which can be applied where the bottom in the survey area is a relatively flat, constant-reflecting surface, is to correct estimates from surveys done in poor weather on the basis of the reduction in the average strength of the bottom echo compared to that in surveys of the same area in good weather.

5. SURVEY DESIGN

If the survey is integrated with commercial fishing, the design will be dictated by the time available for surveying between catches. Normally, the area to be surveyed would be covered on a grid of parallel lines running in the direction of the greatest gradient in fish density. If an area is to be surveyed repeatedly, the lines of the first few grids can be equally spaced and far enough apart to establish the limits of the distribution and the location of the high density areas. Subsequent transects grids can then focus on smaller areas where the fish are most highly concentrated, and the transect spacing randomized to enable a statistically valid estimate of sampling variance to be obtained from the variation in density estimates between transects (Jolly and Hampton 1990). Alternatively, if there are enough replicate estimates (say about five), the sampling variance can be estimated from the variation between the estimates. Another design, which has been used in

surveys of hills, is the star-pattern design in which the hill is surveyed on equally spaced radial lines intersecting at the top. In this case the density estimates along the transects should be weighted according to the distance from the centre to correct for the over-sampling of the centre compared to the outer regions (Doonan *et al.* 2003). The sampling variance can be estimated from the variation between the weighted transect means.

6. TARGET IDENTIFICATION

The commercial catch made between acoustic surveys or transects will ordinarily provide information about the species composition of the echoes that is needed for biomass estimation. Since catches will tend to be made in the regions of highest density of the target species, this provides a *de facto* natural abundance weighting to species compositions and other biological parameters derived from the catch, which is desirable.

The above method works well when the proportion of non-target species in the area is small, or when these species can be distinguished acoustically and excluded in the analysis. However, if this is so and a significant part of the population in the survey area occurs in places where commercial fishing is avoided, a bias will be introduced if the characteristics of this component are significantly different from those of the component that is fished commercially. This must be borne in mind, and if possible, an effort made to sample targets not normally targeted commercially, even if this entails using a certain amount of the fishing time, and paying for it from whatever catch is made during this period.

7. PERSONNEL

At one extreme, acoustic data can be collected without scientific personnel on board, provided that the ship's personnel are well briefed on equipment settings, data logging and survey design, and carry out the instructions strictly. All that is then needed in addition for a basic operation is regular sampling of the catch to establish the species composition and mean length or weight of the target species. A number of such surveys have been successfully carried out on orange roughy in New Zealand, for example, where the results have been comparable in quality with those obtained from dedicated surveys run by scientific personnel (e.g. Hampton and Soule 2004).

At the other extreme, if no vessel crew are to be involved in the process, a scientific team of up to as many as five or six people may be needed to maintain 24-hour acoustic watches, sample the catch in detail when necessary, and perhaps perform some basic data processing on board to assist in decision making regarding survey design and strategy.

8. DATA ANALYSIS

Ordinarily, data analysis would be done ashore, although any form of on-board analysis, such as scrutiny of echograms to isolate the targets of interest and link catches to acoustic marks, can be extremely helpful in the subsequent analysis. If at all possible, the persons who collected the data should also be involved in its analysis.

9. CONCLUSION

With due consideration of the above requirements, successful acoustic surveys of important commercial fish stocks is possible from commercial vessels at considerably lower cost than from research vessels. The approach appears to be particularly suited to regions and fisheries not adequately served by research vessels for cost, or other, reasons.

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APPENDIX VII

Likelihood-based geostatistical biomass estimation using acoustic data collected by industry vessels in the South West Indian Ocean

Edwin Niklitschek and Ruben Roa
Centre for Quantitative Marine Ecology
Universidad Austral de Chile
Portales 73, Coyhaique XI, Chile

1. INTRODUCTION

Inherent and practical limitations must be overcome to use acoustic data logged by commercial vessels. Some of these limitations, such as low accuracy of logbooks and biological sampling data, have been reduced through automated logging of vessels' digital instruments, onboard observers and a better understanding by skippers and officers of their role in research. Other limitations, such as vessel noise, are physical and change from boat to boat. A further major challenge is data analysis, which requires proper tools for dealing with issues such as:

i. survey design, which may be nonexistent for the most part, or all, of available data
ii. survey and fish-stock areas that are unknown or uncertain with considerable uncertainty as to their boundaries
iii. high spatial correlation, specially when the surveyed stock is highly aggregated and fragmented as is the orange roughy case and
iv. multiple vessels participate in, and/or there are repeated surveys in the same area so that additional sources of intra-vessel and/or intra-survey correlation occur.

The likelihood-based geostatistical method we use and propose for analyzing South West Indian Ocean data collected by the commercial fleet was developed by Roa & Niklitschek (submitted) and has been applied to scallop (*Zygochlamys patagonica*) and squid (*Loligo gahi*) in the Falkland (Malvinas) Islands (Roa-Ureta and Niklitschek, submitted) orange roughy (*Hoplostethus atlanticus)* and hoki (*Macruronus magellanicus*) in Chile (Niklitschek *et al*. 2006a, b). This method was also used for analyzing the orange roughy data obtained by the *F.V. Will Watch* in the Southern West Indian Ocean (SWIO) in 2005 and 2006 (Niklitschek and Patchell, unpublished).

The method reduces the need for a probabilistic sampling design as other model-design approaches require (Aubry and Debouzie 2000) and allows for a proper estimation of maximum likelihood confidence intervals. Hence, although a fair coverage of the whole study area is still required, alternative and more flexible designs can be used, leaving some room for adaptive sampling of higher concentration areas, as fishing vessels normally do when exploring a fishing area.

Our approach provides independent estimations of mean fish density and stock area through spatially explicit likelihood-based geostatistical models (Diggle *et al*. 1998, 2003) for both the continuous density and discrete presence/absence data obtained from fisheries surveys. Each of these models accounts for sources of correlation in addition to the spatial arrangement of the data (vessel, survey, time interval) following a generalized linear mixed model framework described by Searle (1987), further developed by Littel e*t al*. (1996). Estimations of mean fish density and stock area are then combined to estimate biomass using the theory of a positive random variable with a spike of probability mass at the origin (Aitchison 1955).

2. DATA COLLECTION

In a strict sense, there is no need for a fixed sampling design, as long as a representative fraction of the whole area of inference is surveyed in a reasonably short period of time, ideally <12 h. We

strongly recommend avoiding any extrapolation of results beyond the actual surveyed perimeter. A major source of potential bias we have detected is the systematic change in the surveyed area with time as one vessel tracks the fish movement. Therefore, a fair sampling of the whole inference area needs to be kept during the entire survey period. Unfortunately, this limits the possibility of devoting long sampling periods to the highest concentration areas.

Parallel transects are a classical design, and were used in 2004 and 2005 by the *F.V. Will Watch*. Another practical design we suggest is a radial (star) arrangement of four or more semi-orthogonal transects passing through a fixed center, defined after a preliminary survey as the highest density point. Transects are continued until they reach either the pre-set study area perimeter or a pre-defined distance (i.e. one mile) without observing echo traces attributable to the targeted species. Multiple surveys should be conducted whenever it possible, for which we suggest a systematic or random shift in the headings of orthogonal transects. Changing the centroid is acceptable, as long as a consistent (minimum) study area is covered in each survey repetition.

3. POST-PROCESSING

Recorded data echograms need to be digitized in space and, sometimes, in time. The latter is needed when data are continuously logged and no survey sampling design data are analyzed. For orange roughy, we divide the survey tracks in 100 m elementary sampling units, and the surveyed space in 500×500 m cells. For the *Will Watch* 2004 and 2005 data, the sampling effort was organized in discrete surveys and there was no need for arbitrary time discretization. If the latter is needed, the period of each analysis unit should be defined considering the time required to cover the sampled area and/or noticeable shifts in the sampling pattern or the specific zone being observed.

Post-processing of orange roughy data normally requires automated and manual definition of missing, weak and noisy echoes from transmissions (as "bad data"), which can be properly removed before computing are scattering coefficients (S_A) through the virtual echograms module implemented by Sonardata Pty in Echoview©. Identifying and delineating orange roughy echo traces is complex and challenging and both trawl information and expert judgement[1] are used to consider the shape, size and depth characteristics of detected echoes. Proper consideration of trawl data often requires displaying the digital data along with echo traces in a three dimensional picture, where links between horizontal segregation and topography may be evident. Although catch data supports the assumption that orange roughy form uni-specific schools, there is a risk of misclassification when similarly shaped cardinal fish (*Epigonus telescopus*), black oreo (*Allocyttus niger*) and smooth oreo (*Pseudocyttus maculatus*), which might occur at similar depths in the SWIO, are sonified.

4. ECHO INTEGRATION

Echoes obtained from the sampled space are integrated into a nautical area scattering coefficient (NASC or S_V) and calculated for each elementary sampling unit *k* following the equation:

$$S_{Ak} = 4\pi \cdot 1852^2 \cdot \left(\sum_{p=1}^{m} \delta \sum_{d=1}^{\frac{h}{\delta}} 10^{\frac{Sv_{dp}}{10}} \right) \qquad (m \cdot m^{-2})$$

where,

m	:	number of pings (p) in section k
δ	:	height of the digitized quanta d
h	:	height of the echotrace.
Sv_{dp}	:	volume backscattering coefficient for quanta d in ping p.

[1] Edwin Niklitschek, Graham Patchell

Raw S_{Ak} obtained directly from the logged data record needs to be corrected for several sources of bias, some of which are particularly applicable to deep-water demersal fishes:

i. echosounder calibration
ii. signal attenuation from transducer movement (pitch/roll)
iii. incidental echo (backscattering)
iv. differences between nominal absorption coefficient and calculated values from oceanographic data and
v. the dead zone

5. ABUNDANCE DENSITY

Observations of the areas scattering coefficient, S_A, in each ESU *(x, y)* are transformed into biomass density estimates of orange roughy *z(x, y)* from the mean area scattering coefficient (S_A) and the mean scattering cross-section (σ_{sp}) calculated for each survey area and assessment period as follows,

$$z(x,y) = \frac{\overline{S}_A}{1.852 \cdot \sigma_{sp}} \; (ind \cdot km^{-2})$$

where,

$$\sigma_{sp} = 4 \cdot \pi \cdot 10^{(0.1 \cdot TS)} \text{(m)}$$

$$TS = 16.15 \cdot \overline{\log(SL)} - 76.15$$

$\overline{\log(SL)}$ = $\log_{10}$-transformed standard length standard length in cm

6. ESTIMATION OF TOTAL ABUNDANCE

Orange roughy have a highly aggregated patchy distribution where most of the observed survey area has no fish. We have adopted the approach of Aitchison (1955) & Pennington (1983),where the zero density observations are treated separately from the positive density observations. Let *a* be size of the surveyed area A, *p* the probability of a positive observation in A, and $\bar{z}$ the mean abundance density of the targeted stock in A, then a maximum likelihood estimator of the true abundance is defined by

$$\hat{N}_A = \hat{\bar{z}} \cdot a \cdot \hat{p}$$

with estimated variance,

$$\hat{v}(\hat{N}_A) = a^2 (\hat{p}^2 \cdot \hat{v}(\hat{\bar{z}}) + \hat{\bar{z}}^2 \cdot \hat{v}(\hat{p}))$$

Assuming basic data stationary and an isotropic Gaussian model, the random variable $\tilde{Z}(x,y)$ can be represented by a function $f(Z_i)$ that is an approximate description of the true density (Z_i) in each of the *m* discrete samples with non-zero values. It is expected that it follows the generalized mixed model

$$\tilde{Z} = \breve{Z}(x_i, y_i) + Fw + \varepsilon_i$$

where ε_i are independent identically distributed normal variables with mean zero and variance τ^2, ***F*** is the random effects[2] design matrix and ***w*** is a vector of realizations of a random variable ***W***,

[2] Random variables allow for sources of dependence in the data in addition to spatial proximity. For example when several acoustic surveys are carried out over the same stock, and/or when several vessels are used to cover a large field.

which has a distributed multivariate normal with mean zero and covariance matrix ***G***. Under this generalized mixed model the distribution of $\tilde{Z}$ is given by

$$\tilde{Z} \sim MVN(\beta 1, \sigma^2 R + \tau^2 I + F' GF)$$

where **1** is an *m* times 1 vector of 1s, ***R*** is a matrix whose (*i*,*i*')th element is $\rho(h_{i,i'}|\kappa,\phi)$, and ***I*** is the *m* times *m* identity matrix (Diggle *et al*. 2003). The log-likelihood function in relation to the original observations for the vector of parameters

$$\theta' = [\beta\ \sigma^2\ \tau^2\ \kappa\ \phi]$$

is

$$l(\theta \mid z_i) \propto \sum_{i=1}^{m} \ln(z_i) - 0.5 \ln|\sigma^2 R + \tau^2 I + F' GF| - 0.5\,(f(z_i) - \beta \mathbf{1})'(\sigma^2 R + \tau^2 I + F' GF)^{-1}(f(z_i) - \beta \mathbf{1})$$

From the traditional intrinsic geostatistic model, the parameters σ^2, τ^2 and ϕ are equivalent to the sill, the nugget and the range.

The surface area, *a*, is assumed to be known exactly from the survey design. If no design had been followed and intensive sampling has been done, the total area can be calculated from summing the number of 500×500 m cells in the survey area. If none of the previous methods are feasible, it is possible to calculate the area inside the convex hull defined by the whole set of observations.

For estimating $\hat{p}$, we computed the number m_k of positive observations in observing the aggregation out of the n_k observations in at each 500×500 m cell *k* (*k*=1,*K*). This gives a binomial process with spatially correlated observations

$$M_k \quad Bin(p, N_k)$$

connected to the underlying Gaussian process through the logit link function

$$g(p) = \ln(p/(1-p))$$

Under a geo-statistical generalized linear mixed model equivalent to the one used for the mean density, the distribution of $\tilde{M}_k$ can be modeled as

$$\tilde{M}_k \approx MVN\ (\beta_M, \sigma_M^2 R_M + \tau_M^2 I + F' GF)$$

The likelihood function for this type of generalized linear spatial model is, in general, not expressible in closed form but only as a high-dimensional integral that can be evaluated by Monte Carlo Markov Chain Maximum Likelihood (Diggle *et al*. 2003). The results of the model are related to the parameter of interest, *p*, through the inverse link function, g^{-1}. By the property of functional invariance of MLEs (Zhena 1966; Berk 1967) and by Taylor series approximation, we have

$$\hat{p} = \frac{e^{\hat{\beta}_M}}{1 + e^{\hat{\beta}_M}}, \qquad \hat{v}(\hat{p}) = \hat{v}(\hat{\beta}_M) \cdot \left(\frac{e^{\hat{\beta}_M}}{(1 + e^{\hat{\beta}_M})^2} \right)^2$$

Total biomass estimates are obtained directly from total abundance N_A and mean weight estimated $\hat{\bar{w}}$ for the inference area A, by:

$$\hat{B}_A = \hat{N}_A \cdot \hat{\bar{w}}$$

and estimated variance by

$$\hat{v}(\hat{B}_A) = (\hat{N}_A^2 \cdot \hat{v}(\bar{w}) + \bar{w}^2 \cdot \hat{v}(\hat{N}_A))$$

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APPENDIX VIII

SIODFA and IUCN

News Release

Fishing companies announce world's first voluntary closures to high-seas deepwater trawling

and

Questions and Answers

Fishing companies announce world's first voluntary closure to high-seas deepwater trawling

SIODFA
SOUTHERN INDIAN OCEAN
DEEPWATER FISHERS' ASSOCIATION

IUCN
The World Conservation Union

News Release

Embargoed until 6 July 2006, 00:01 GMT

Fishing companies announce world's first voluntary closures to high-seas deepwater trawling

Marine species protected in eleven deep-sea areas of the Indian Ocean

Wellington, New Zealand, Rome, Italy and Gland, Switzerland, 6 July 2006 (IUCN) - In a global first, four major fishing companies announced today a voluntary halt to trawling in eleven deep-sea areas of the southern Indian Ocean. This will protect and conserve the bottom of the sea floor, or benthos, associated fish fauna and related biodiversity in one of the largest marine protected area enclosures ever.

"By setting aside an area almost equal to Australia's Great Barrier Reef National Park, these businesses are sending a clear signal that they want to keep fish on people's plates for generations to come," commented **Graham Patchell**, a scientist with the newly formed **Southern Indian Ocean Deepwater Fishers' Association (SIODFA)**, which represents four companies - Austral Fisheries Pty Ltd (Australia), Bel Ocean II Ltd (Mauritius), Sealord Group (New Zealand) and TransNamibia Fishing Pty Ltd (Namibia), the main trawling operators in this area.

Using the scientific knowledge gathered over a decade of activity in the Indian Ocean and in consultation with staff of the Fisheries Department of the United Nations Food and Agriculture Organization (FAO), SIODFA have delimited 309 000 km^2 of ocean floor in eleven separate benthic protected areas where their vessels will no longer fish. The combined zones have an area approximately the size of Norway. To verify compliance with these self-adopted restrictions, the companies will track their vessels' locations and activities via a special satellite monitoring system.

On top of the voluntary establishment of these no-fishing *Benthic Protected Areas,* SIODFA has pledged to share extremely valuable scientific data collected using complex underwater technology with the soon-to-be-formed regional *Southern Indian Ocean Fisheries Agreement* and the FAO.

"Such deep-sea habitats are among the least known areas of the oceans and by pledging not to fish in them, these companies have taken a great step towards sustainability," said **Carl Gustaf Lundin**, Head of the Global Marine Programme of the World Conservation Union (IUCN).

By not fishing in these areas, which span the southern Indian Ocean, their deepwater corals and the accompanying benthic fauna will gain protection in one of the least explored and unutilized deepwater areas of the world. He noted that at present, less than one percent of the world's oceans fall within protected areas compared to over 12 percent of the planet's terrestrial surface.

Areas of sea floor whose benthos and habitat are protected on the high-seas, or in areas beyond national jurisdiction, are a novelty and often these areas do not benefit from any formal protection.

"These voluntary closures are a unique innovation for effectively managing and conserving deepwater biodiversity of high-seas areas where there are no regional management arrangements in place. We hope that the governments involved in meetings at the United Nations recognize these voluntary protected areas and follow their example to underpin future efforts of the proposed Southern Indian Ocean Fisheries Agreement," concluded **Graeme Kelleher of the High Seas Task Force of IUCN's World Commission on Protected Areas**. He stressed that *"it is recognized that voluntary actions of this kind are extremely valuable and should be complemented by enforcement arrangements that apply to other fishing companies."*

ENDS

Notes to the editors

Facts, figures and maps on benthic protected areas and their location, bottom trawling, fish stocks and the new Southern Indian Ocean Deepwater Fishers' Association (SIODFA) can be found in the accompanying Q&A information.

For more information or to set up interviews, please contact:

Carolin Wahnbaeck, Global Media Relations Officer, The World Conservation Union (IUCN), Tel.: +41 22 999 0127, e-mail: carolin.wahnbaeck@iucn.org, www.iucn.org

Carl Gustaf Lundin, Head, Global Marine Programme, The World Conservation Union (IUCN), Tel.: +41 22 999 0204, e-mail: cgl@iucn.org, www.iucn.org

Ross Shotton, Senior Fishery Resources Officer, Marine Resources Service, Fisheries Department, Food and Agriculture Organization (FAO), e-mail: ross.shotton@fao.org

Graham Patchell, Marine Resources Manager, Sealord Group Ltd, Nelson, New Zealand, E-mail: gjp@sealord.co.nz (for SIODFA)

Photos (audio/video material) are available at/from:

The Southern Indian Ocean Deepwater Fishers' Association (SIODFA)
SIODFA, the Southern Indian Ocean Deepwater Fishers' Association, was formed by four major fishing companies: Austral Fisheries Pty Ltd (Australia), Bel Ocean II Ltd (Mauritius), Sealord Group (New Zealand) and TransNamibia Fishing Pty Ltd (Namibia). The objective of the Association is to ensure sustainable fisheries in the southern Indian Ocean in collaboration with the upcoming Southern Indian Ocean Fisheries Agreement.

The World Conservation Union (IUCN)
Created in 1948, the World Conservation Union (IUCN) brings together 81 States, 113 government agencies and 850 plus NGOs in a unique worldwide partnership. The Union's mission is to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable.

The World Conservation Union is the world's largest environmental knowledge network and has helped over 75 countries to prepare and implement national conservation and biodiversity strategies. The Union is a multicultural, multilingual organization with 1000 staff located in 62 countries and is based in Gland, Switzerland. http://www.iucn.org; press@iucn.org

The IUCN World Commission on Protected Areas (WCPA)
WCPA is the largest worldwide network of protected area managers and specialists. It comprises over 1 200 members in 140 countries. WCPA is one of the six voluntary IUCN Commissions and is administered by the Protected Areas Programme at the IUCN Headquarters in Gland, Switzerland. The WCPA mission is to promote the establishment and effective management of a worldwide network of terrestrial and marine protected areas, as an integral contribution to the IUCN mission.

SIODFA
SOUTHERN INDIAN OCEAN
DEEPWATER FISHERS' ASSOCIATION

IUCN
The World Conservation Union

Questions & Answers

Fishing companies announce world's first voluntary CLOSURE TO high-seas deepwater trawling

Questions & Answers about the deep seas and benthic protected areas

What is a benthic protected area?

The term "benthic" signifies on the bottom or under a body of water. The region at the bottom of a body of water, such as an ocean or a lake is known as the "benthic zone". The fauna in this zone is the "benthos".

Benthic protected areas are zones set aside in the oceans and delimited by latitude and longitude coordinates or other boundaries such as those of Eclusive Economic Zones (EEZ) or territorial waters. The benthic protected areas declared by the Southern Indian Ocean Deepwater Fishers' Association (SIODFA) are a **global first** as no such zones in the high seas existed prior to this. These closures will contribute to the sustainability and conservation of water corals, other fixed benthos and related faunal communities.

What lives in benthic zones?

The benthic zone adjacent to the seabed in deep-sea areas is inhabited mostly by organisms that tolerate low temperatures and can survive without light. Between 500,000 and 100 million species are thought to live in deep ocean habitats. Benthic zones may consist of a variety of substrates including sand, rock outcrops (e.g. seamounts, knolls, tectonic ridges) and coral although much of the deep sea floor is covered with soft mud. The type of substrate influences the kind of creatures that live there. Fauna that inhabit the benthic zone of the deep sea include tiny clams, worms and crustaceans while a variety of larger animals such as sea cucumbers and starfish wander across its surface. A myriad of fishes live in the water column above this zone.

What is bottom trawling?

Bottom, or demersal, trawling refers to a fishing method whereby nets are towed along the sea floor. In pelagic trawling, the net is towed in the water column. Bottom trawling is practiced by vessels from small motor boats to large ocean-going trawlers; in the Southern Indian Ocean, these vessels may be up to 85 m in length.

A bottom trawl net is kept open by two inclined trawl doors that act as planes as they are pulled by the vessel. Fish in the path of the trawl pass over the ground rope and beneath the head line down the net into the "cod-end", which has a smaller mesh size, where the fish are collected. The size and design of these nets depends on the species targeted, the engine power and design of the fishing vessel and local regulations.

Trawling in this area may occur from 150 m down to 1400 m with most bottom trawling in the range 500 to 1400m.

What are the main effects of bottom-trawling?

Bottom trawling in areas where corals and sponges live can cause significant damage to such animals as these species are extremely slow growing and may take hundreds or even thousands of years to recover from the damage. Where benthos is of great age and of scientific importance, it is important to avoid demersal trawling of their habitats to protect such animals and their ecosystems.

What are the benefits of marine protected areas such as benthic protected areas?

Protecting marine biodiversity in critical areas ensures the survival of slow growing benthic fauna and conserves sea floor biodiversity and fish habitat. Such zones also act as reserves for genetic material, an area of potential scientific research. Existing marine protected areas cover less than one percent of the seas and oceans; to date, not a single area exists on the high seas, which make up 64 per cent of the world's oceans.

What research has been done in the areas of the benthic protected areas?

The seafloor contour and bottom characteristics of these areas have been determined by the fishing operators using swathe-mapping, a method that uses low frequency sidescan sonar and multiple transducers to map the sea bed. In some areas, e.g. the Atlantis Benthic Protected Area, considerable submarine geological research has been undertaken. Fisheries and related scientific data exist for most of the benthic protected areas and a considerable amount was collected by research vessels of the Soviet Union, especially from the Ukraine.

What are the commercially important deepwater species fished in the Indian Ocean?

Commercially-exploited deep-water fishes include the very slow-growing orange roughy (Hoplostethus atlanticus) and oreos *(Allocyttus niger, Neocyttus rhomboidalis,Pseudocyttus maculatus),* the relatively fast growing alfonsinos *(Beryx splendens),* boarfish *(Pseudopentaceros richardsoni)* and *Epigonus telescopus (Cardinalfish),* Bluenose *(Hyperoglyphe antarctica),* ruby fish *(Plagiogeneion rubiginosum),* Cape bonnethmouth *(Emmelichthys nitidus),* bluenose warehou *(Hyperoglyphe antarctica),* violet warehou *(Schedophilus velaini),* imperial blackfish *(Schediohilus ovalis),* wreckfish *(Polyprion americanus)* and rudderfish *(Centrolophus niger). In some areas, deepwater shrimp such as royal red shrimps (Haliporoides* spp*., Solenoceridae)* may also be exploitable, though they have not supported ongoing fisheries in the southern Indian Ocean.

What is the current state of the Indian Ocean fish stocks?

Assessments of the current state of the different deepwater fish species and stocks of the Indian Ocean, in the lack of a regional fisheries management organization, have not yet been done. Data recording of fishing activities has been undertaken by various fishing companies but concerted efforts to collect, collate and analyze these data are only now beginning.
Overall, overfishing and unregulated fishing are perhaps the greatest threats to the fisheries and biodiversity of this area. In the absence of an effective ocean governance framework, future supply of fish and other vital marine resources for the world's population is at risk.

What marine protected areas currently exist in the Indian Ocean?

Under the web link http://www.mpaglobal.org/ protected areas are listed by country and these are shown on a global basis in Figure 1. Prior to this closure, the Southern Indian Ocean had more than 200 marine protected areas, covering some 77 000 km^2 but all are in national exclusive

economic zones. The high-seas sea-floor areas that will be voluntarily closed to bottom trawling cover 309 150 km^2, an area slightly larger than Norway. The areas closed to SIODFA vessels in the southern Indian Ocean are shown in Figure 2 and full details of the benthic protected areas are provided in Table 1.

Figure 1
Locations of MPAs on a global basis

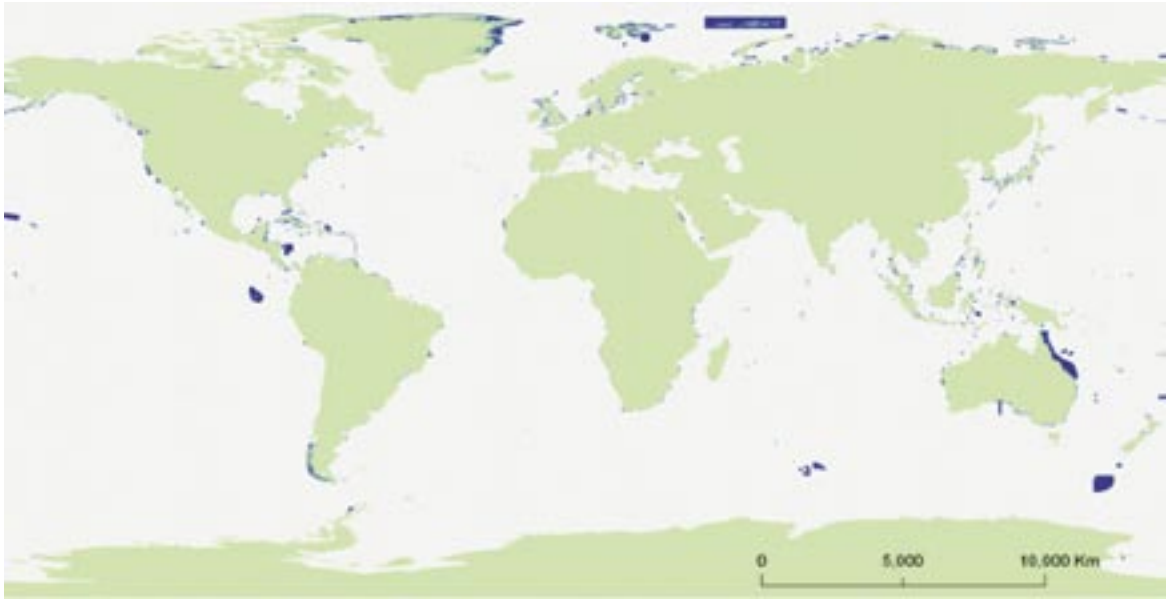

Figure 2

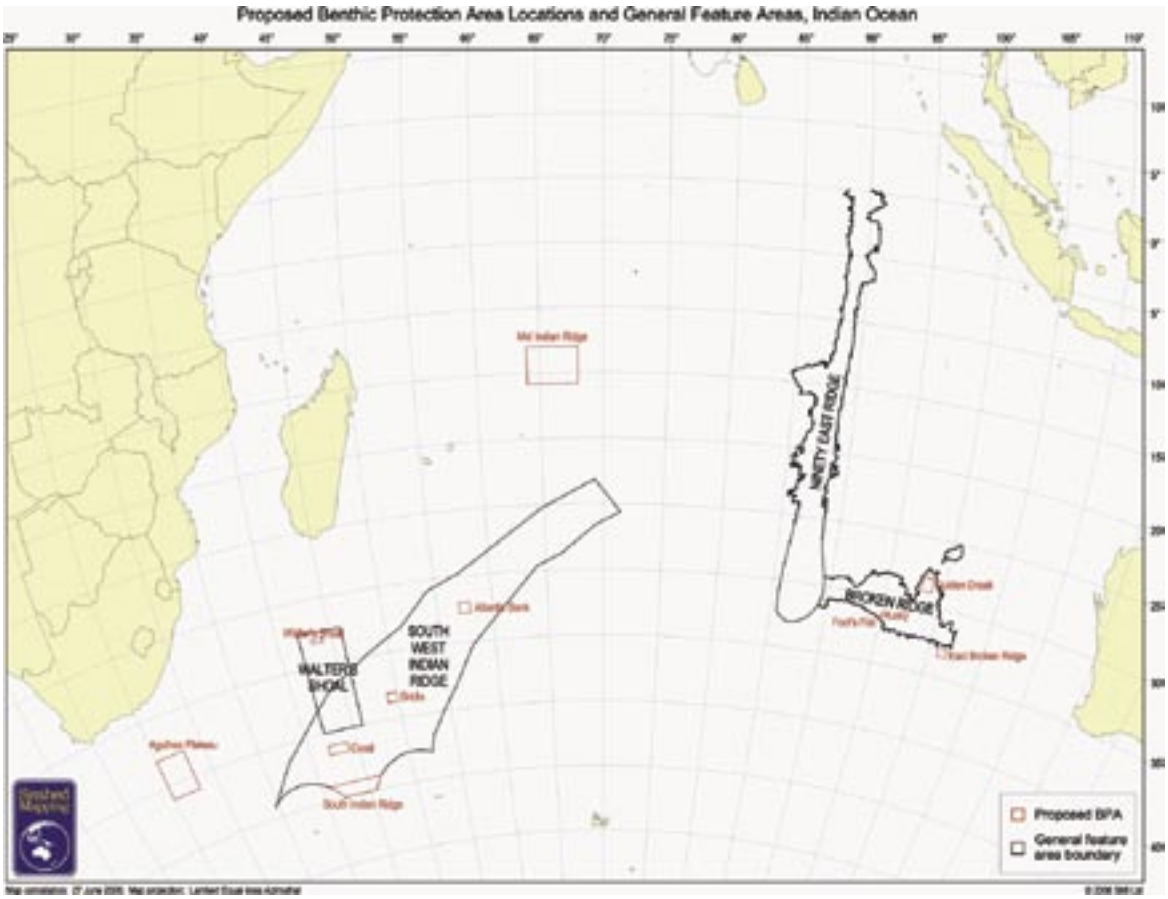

Table 1
SIODFA benthic protected areas

Area	Coordinates				Area (km²)	Area features
	Lat (S)	Long (E)	Lat (S)	Long (E)		
Gülden Draak	28° 00'	98° 00'	29° 00'	99° 00'	10 867	A massive mid-ocean seamount in pristine biological condition.
Rusky	31° 20'	94° 55'	31° 30'	95° 00'	147	A productive knoll located on extensive ridge; extensive black coral exists with the benthos in an almost pristine state.
Fools' Flat	31° 30'	94° 40'	31° 40'	95° 00'	585	A deep-sea bank with numerous canyons incising its slopes; strong upwelling currents sustain extensive coral beds; in pristine condition, this is a previously unmapped area of the seabed.
East Broken Ridge	32° 50'	100° 50'	33° 25'	101° 40'	5 037	A seamount rising to 1000 m, biologically pristine; its benthos and topography previously undescribed.
Mid-Indian Ridge	13° 00'	64° 00'	15° 50'	68° 00'	135 688	An area of seamounts rising to 650 m; a tropical region in pristine biological condition.
Atlantis Bank	32° 00'	57° 00'	32° 50'	58° 00'	8 694	This seamount was formed from an ancient island; extensive research has been conducted on this BPA by a number of agencies; it is the location of a productive fishery
Bridle	38° 03'	49° 00'	38° 45'	50° 00'	6788	An area of knolls and ridges in almost pristine condition; previously unmapped and undescribed.
Walters Shoal	33° 00'	43° 10'	33° 20'	44° 10'	3 443	This area, which rises from 4000 to within 10 m of the surface provides a habitat for a variety of whale species; the area is characterized by high biodiversity
Coral	41° 00'	42° 00'	41° 40'	44° 00'	12 376	A spreading centre with seamounts and ridges with depths from 4500 m to 180 m. Extensive coral beds, a near pristine area.
South Indian Ridge (North/ South)	44° 00' 45 00' S	40.878° S 42.124° E	44° 00' 45° 00' S	46.544° E 45.711° E	39 358	An area of seamounts adjacent to the CCAMLR region to the south; in pristine biological condition. This area is bounded to the east and west by the EEZs of South Africa and France.
Agulhas Plateau	38° 00'	25° 00'	41° 00'	28° 00'	85 828	Region of seamounts north of the proposed South African Antarctic MPA; contiguous with the South African EEZ to the west.

WHY WAS SIODFA CREATED?

SIODFA, the Southern Indian Ocean Deepwater Fishers Association is fundamentally committed to biologically-sustainable and economically-viable commercial fishing operations in the southern Indian Ocean. Its members recognize their responsibility to contribute to resource management activities and fish habitat protection and in this context they will continue to expand their programme of fisheries research in the area.

SIODFA is comprised of Austral Fisheries Pty Ltd, Perth, Australia; Bel Ocean II Ltd, Port Louis, Mauritius; Sealord Group, Nelson, New Zealand; TransNamibia Fishing Pty Ltd, Walvis Bay, Namibia. SIODFA membership is open to reputable companies who are fishing in the deepwaters of the Southern Indian Ocean and who support the objectives of the Association.

Fishing effort by SIODFA members has been fairly stable since 2002 at around four vessels. This is a major reduction from the peak of over 40 vessels operating in 2000, a level of fishing that would have been unsustainable during that period of opportunistic fishing by the numerous transient fishing operators.

APPENDIX IX

Resolution on data collection concerning the high seas in the southern Indian Ocean: coordinates of the fishing areas in Annex 2

Cited from the Final Act of the Conference on the Southern Indian Ocean Fisheries Agreement Food and Agriculture Organization of the United Nations Rome, Italy

6–7 July 2006

Area 1: Mozambique Ridge
Start: Landfall on the continent of Africa of the parallel 20° S; from there east along 20° S to its intersection with meridian 40° E; from there south along 40° E to its intersection with parallel 36° S; from there west along 36° S to its intersection with meridian 30° E; from there north to its landfall on the continent of Africa; from there north along the coast of the continent of Africa to the start point.

Area 2: Madagascar Ridge
Start: intersection of parallel 20° S with meridian 40° E; from there east along 20° S to its intersection with meridian 49° E; from there south along 49° E to its intersection with parallel 36° S; from there west along 36° S to its intersection with meridian 40° E; from there north to the start point.

Area 3: Southwest Indian Ocean Ridge
Start: intersection of parallel 20° S with meridian 49° E; from there east along 20° S to its intersection with meridian 65° E; from there south along 65° E to its intersection with parallel 45° S; from there west along 45° S to it intersection with meridian 30° E; from there north along 30° E to it intersection with parallel 36° S; from there east along 36° S to its intersection with meridian 49° E; from there north along 49° E to the start point.

Area 4: Ninety Degree East Ridge
Start: intersection of parallel 20° S with meridian 80° E; from there east along 20° S to its intersection with meridian 90° E; from there south along 90° E to its intersection with parallel 36° S; from there west along 36° S to its intersection with meridian 80° E; from there north to the start point.

Area 5: Broken Ridge
Start: intersection of parallel 25° S with meridian 90° E; from there east along 25° S to its intersection with meridian 105° E; from there south along 105° E to its intersection with parallel 36° S; from there west along 36° S to its intersection with meridian 90° E; from there north along 90° E to the start point.

Area 6: Mid-Indian Ocean Ridge
Start: intersection of parallel 20° S with meridian 65° E; from there east along 20° S to its intersection with meridian 80° E; from there south along 80° E to its intersection with parallel 45° S; from there west along 45° S to its intersection with meridian 65° E; from there north along 65° E to the start point.

Area 7: Southeast Indian Ocean
Start: intersection of parallel 20° S with meridian 90° E; from there east along 20° S to its landfall on the continent of Australia; from there south and east along the coast of Australia to its intersection

with meridian 120° E; from there south along 120° E to its intersection with parallel 55° S; from there west along 55° S to its intersection with meridian 80° E; from there north along 80° E to its intersection with parallel 36° S; from there east along 36° S to its intersection with meridian 105° E; from there north along 105° E to its intersection with parallel 25° S; from there west along 25° S to its intersection with meridian 90° E; from there north along 90° E to the start point.

Area 8: South West Indian Ocean north of 20° S
Start: landfall on the continent of Africa of parallel of 10° N; from there east along 10° N to its intersection with meridian 65° E; from there south along 65° E to its intersection with the equator; from there east along the equator to its intersection with meridian 80° E; from there south along 80° E to its intersection with parallel 20° S; from there west along 20° S to its landfall on the continent of Africa; from there north along the coast of the continent of Africa to the start point.

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