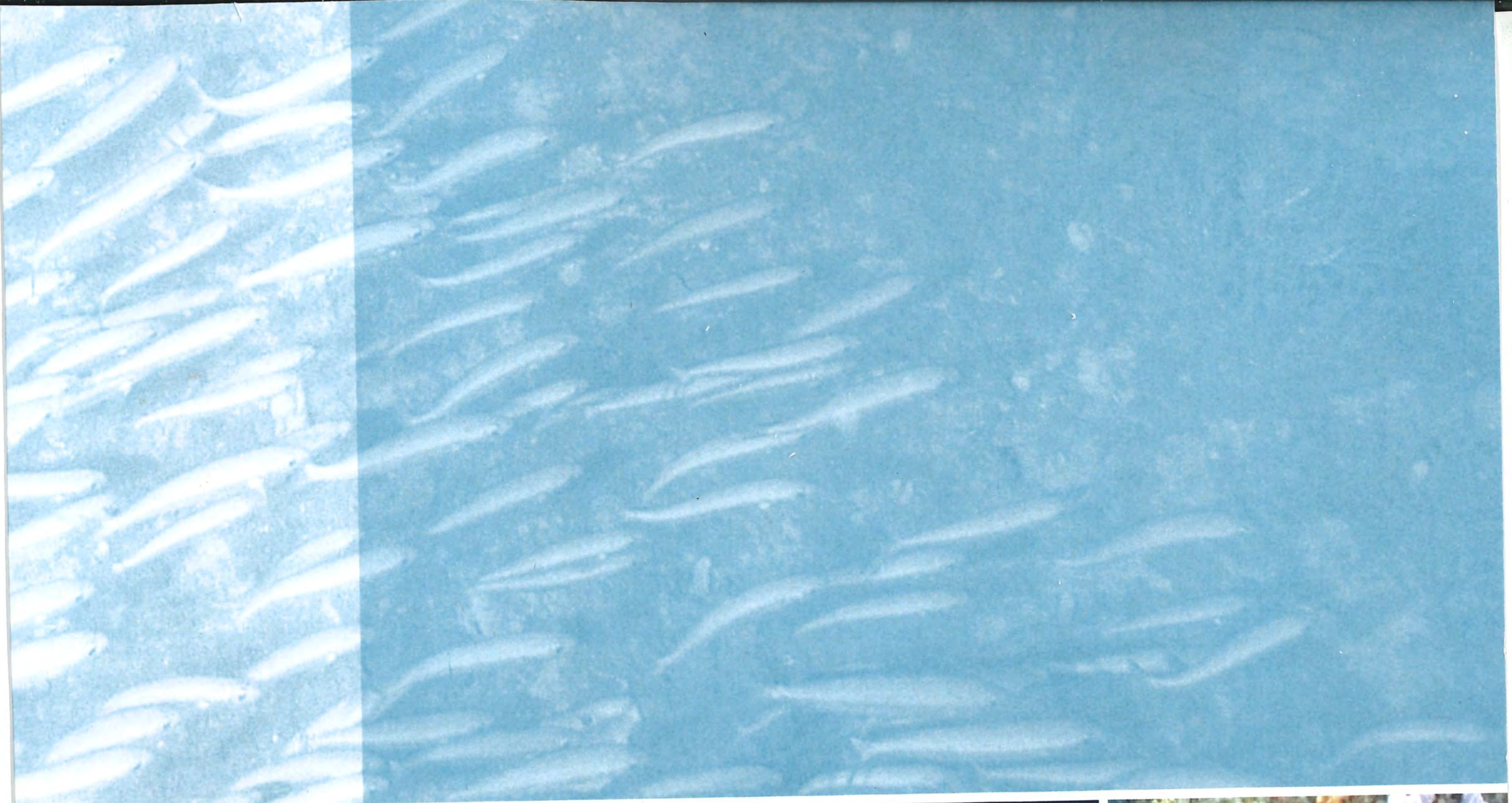

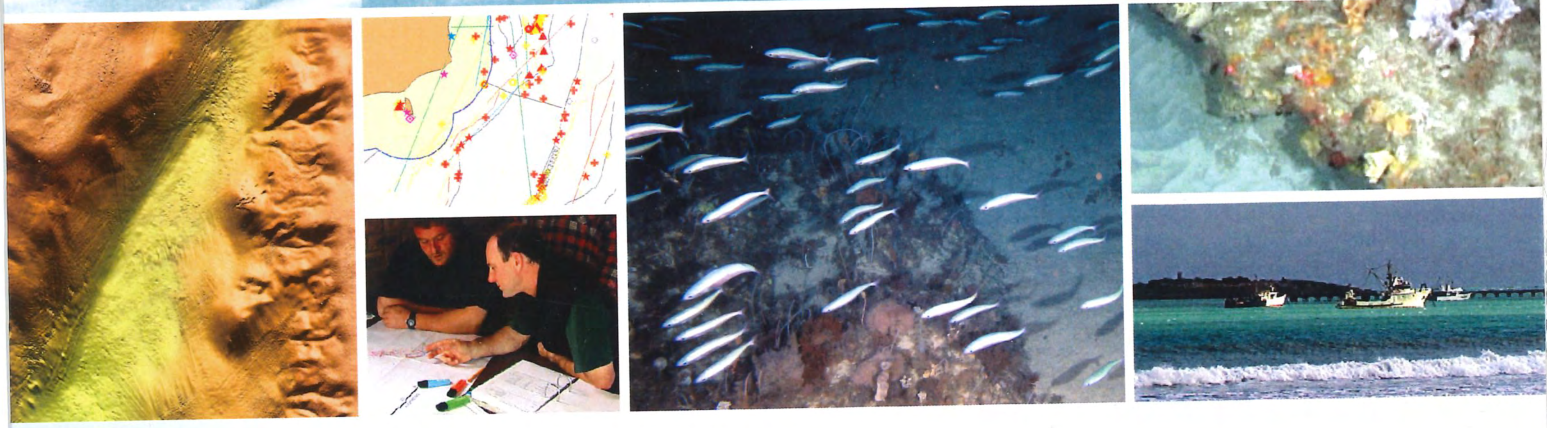

CSIRO - INDUSTRY SOUTH EAST FISHERY
mapping project

Integrating fishing industry knowledge of fishing grounds with scientific data on seabed habitats for informed spatial management and ESD evaluation in the SESSF

FINAL REPORT
FRDC 2000/153

CSIRO

Australian Government
Fisheries Research and Development Corporation

SETFIA

SENTA
SOUTH EAST NON TRAWL ASSOCIATION

Integrating fishing industry knowledge of fishing grounds with scientific data on seabed habitats for informed spatial management and ESD evaluation in the SESSF

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June 2006

CSIRO

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NON-TECHNICAL SUMMARY

2000/153 **Integrating fishing industry knowledge of fishing grounds with scientific data on seabed habitats for informed spatial management and ESD evaluation in the SESSF**

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OBJECTIVES:

1. Proactively and cooperatively develop industry policy in response to the requirements of the Wildlife Protection Act (especially Principle 2).
    - **1.1** Acquire, collate and map industry (trawl and non-trawl) information on the spatial extent and use of fishing grounds in the SEF.
    - **1.2** Evaluate and summarise this information in relation to the Wildlife Protection Act (especially Principle 2) guidelines.
2. Integrate fishing industry knowledge and scientific data to give quality assured information on linkages between seabed habitats, biodiversity and fishery production for informed sustainable management of the SEF and to build broad public understanding.
    - **2.1** Develop deployment equipment to provide an ongoing capacity to photographically monitor habitats from industry vessels.
    - **2.2** Validate and complement industry information gathered for Objective 1 by ground-truth sampling from industry vessels.
    - **2.3** Consolidate all the information from this project, together with existing ecological and physical (geological, topographical and hydrological) data, and provide a draft paper for industry that addresses relevant elements (primarily Principle 2 of the Wildlife Protection Act guidelines).
    - **2.4** Support, through a series of workshops, the development by industry of spatial management options to protect biodiversity and fishery production in the SEF based on the information provided through this project.
    - **2.5** Develop a Public Relations strategy for the project and its outcomes, including media release kits/releases and supporting video/ photographic images, collaboratively between SETFIA, SENTA and the project team.

NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED

1. Active collaboration between scientists, numerous fishing operators from the main offshore SEF fishing sectors, and the peak associations SETFIA and SENTA, produced a credible, quality controlled, map-linked database of seabed habitats that covers the entire offshore SEF region of the SESSF fishery (3 n.m. to 1,300m

depth) with information at scales relevant to fishing operations and spatial planning for conservation and fisheries management needs.

2. Detailed project maps of habitat types and corrected fishing effort distribution are being used by the fishing industry to pro-actively respond to the challenges presented by AFMA and DEH's spatial management policies on sustainable fisheries management. Industry has used detailed maps to provide comment on spatial management plans, including supporting alternative industry proposals.
3. Data products were released in accordance with agreements and measures put in place to preserve data confidentiality and security of industry information (no unauthorised release occurred). These agreements and measures remain in place.
4. A world-class portable camera system, designed and built with assistance from this project, provided a considerable quantity of high quality imagery of deep seabed habitats off SE Australia. This visual description of benthic habitats influenced the SE Commonwealth MPA design process in regard to MPA location and zoning, and was the basis for habitat assessment in the Ecological Risk Assessments for SESSF sub-fisheries.
5. Enduring value is provided by this project in the form of an extensive data collection that, with industry agreement, is being used, and has further potential to be used, in stock assessments, ecosystem models, ecological risk assessment, and developing strategic management options in the SESSF.
6. The aims and collaborative nature of the project were communicated broadly via a project website – which had 10,940 hits at the completion of the project.
7. The approach developed in this project is planned to be extended to the GAB region of the SESSF fishery at AFMA's request.

The project's achievement

A successful collaboration between scientists and the fishing industry has enabled seabed habitats to be mapped across the entire offshore South East Fishery (SEF) – an area of some 141,000 km^2 in depths from ~50 m to 1,300 m. The project highlights the advantages that come from an active collaboration between the fishing industry and the research community, and demonstrates the commitment of working skippers to the long-term sustainability of the fishery. Fishing knowledge was contributed primarily by 33 working skippers – most of whom had more than a decade of experience at sea – and contributions were made by individuals from all the major southeastern Australian ports (Beachport to Sydney). Skippers provided their confidential electronic trackplotter data, and worked with the scientists in an iterative fashion to ensure that their data were accurately represented in maps produced for the project. The combined map of over 500 fishing grounds is linked in a spatial database to a variety of information including logbook data, scientific data on habitats, and a habitat classification scheme. The integrated map is superior to either industry or science data in isolation because it combines the strengths of industry knowledge – mapping, naming and repeated sampling of large areas over long periods – with detailed scientific observation of relatively small areas during infrequent surveys using novel samplers such as cameras. In addition, by combining the information from many skippers in a common format, we were able to provide an overview of habitat use at the scale of the entire fishery, which does not depend on individual skippers extrapolating from their own experience.

The mapping database

The project output is a credible, quality controlled, map-linked database that covers the entire offshore SEF region of the SESSF fishery (3nm to 1300m depth) with information at scales relevant to fishing operations and spatial planning for conservation and fisheries management needs. The database combines industry data with other relevant information including processed logbook data (resolved to a 1 sq km grid), scientific data on habitats and a habitat classification scheme. A total of 516 different areas were identified as separate fishing grounds. Most data came from the trawl sector, although some areas were interpreted from other data sources, including cross-reference to information from inshore and offshore non-trawl sectors; 153 individual offshore non-trawl grounds have been maintained as a separate data set. Logbook catch and effort data were overlaid on the map of fishing grounds and reflected off untrawlable ground prior to analysis. In this report, we restrict analysis of the database to large spatial scale patterns and trends in effort distribution between 1996 and 2001, but there is, with industry discretion, considerable scope to further 'drill down' into this information by examining habitat, catch, effort and catch value at the level of individual grounds and individual species. While the data remain confidential, and the agreements and measures put in place to preserve data confidentiality and security are strictly observed, industry has authorized release of information in the form of maps for a series of future planning workshops organized by AFMA in June 2006.

Seabed habitats of the SEF fishery region and their use

Habitat information is provided at multiple spatial scales. The starting units are the 516 '*fishing grounds*', of which 75% are less than 200 sq km in size. These are classified as four simple categories of *terrain* (heavy reef, clear sediments and two intermediate classes of mixed reef and sediment), and as *features* (7 types matching those used for MPA development, e.g. canyon, terrace, scarp). "Zooming in" to individual grounds is possible using more detailed descriptions of *bottom types* (12 types of substratum e.g. mud, sand, low relief rock), as well as logbook data (in a 1 sq km grid) and scientific information (photographs or acoustic maps, illustrated here by several high resolution scientific maps and over 200 photographic images). "Zooming out" is achieved by aggregating grounds into 16 fishery subregions or five depth zones, or both. It is possible to summarize fine-scale properties at fishery scale, e.g. bottom types by depth zone and subregion.

The overall make-up of the SEF seabed, in terms of *terrain*, is about 50% 'sediments with many reef patches', ~30% 'sediments with few reef patches', and ~20% clear sediment. Although 45 grounds are classified as 'heavy reef', they make up less than 2% of the total area. As *features*, 121 large plains (mixed sediment/ reef) and 38 smaller rocky banks make up virtually all the continental shelf seabed (depths < 200 m; ~73% of the SEF), while 143 muddy terraces and 121 muddy/ rocky escarpments (scarps) make up most of the continental slope (depths > 200 m; ~27% of the SEF). Other features – 56 canyons and 11 groups of hills – are restricted to the continental slope, and form relatively small areas.

Habitats are not evenly distributed. There are considerable "east-west" differences (Beachport to South Tasmania vs Maria to Sydney) with the west characterized by a relatively wide continental shelf comprised of a series of massive plains of mixed sediments and rocky reef (mostly terrains of sediments with *many* reef patches). In contrast, the east has a generally relatively narrow shelf (except off eastern Bass Strait) with large areas of terrains of clear sediment or sediments with *few* reef patches, but most of the *region's* continental shelf rocky banks situated between Babel and Wollongong. The west has a broadly similar sized continental slope to the east but differs by having nearly three times more upper slope terrace, less than half the upper slope scarp, and virtually all the area containing hills (although the vast majority are scattered in two large areas of mid-slope in South Tasmania). Of interest is that slabby and heavy reef habitats that provide important refuge habitat for several key species are concentrated on the deep shelf and upper slope, with relatively large areas of both occurring in the Babel and Eden/Smithys subregions in association with the massive deep shelf and upper slope escarpments of Bass Canyon.

We estimated that 26,469 sq km, or about 19% of the SEF fishery region as defined here (3 n.m. to 1,300 m depth contour), was trawled during 2001. This demonstrates that overall, more than 80% of the SEF fishery region was not trawled in 2001, representing considerable potential for developing conservation and fishery managed areas. Fishers estimated that 48% of the SEF is untrawlable, with far more untrawlable ground in subregions to the west of Tasmania (76% untrawlable ground; range for individual subregions 52-86%), compared to subregions east of, and including, South Tasmania (15% untrawlable ground; range 0-48%). We estimate that 37% of the trawlable area was trawled in 2001. Untrawlable ground is available to fishing by the non-trawl sector and thus the percentages of unfished and unfishable grounds will be lower than the values given above. Although the percentage of the SEF fishery region used by the non-trawl sector is poorly estimated (because of the spatial scale at which logbook data are collected), and is changing rapidly, we estimated that only about 5% of the region was used for non-trawl fishing in 2001.

While the percentage of the SEF used for trawl and non-trawl fishing can be considered low overall, the area used is increasing and there are particular depth ranges where the percentage used already exceeds 50%. The percentage area trawled increased from 16 to 19% between 1996 and 2001, a net expansion of 4,057 sq km (or 17%). This may be an underestimate if some of the area fished in 1996 was no longer fished in 2001. Although there was an increase in area fished in all depth zones except for the shallowest (< 50 m depth), the greatest increase was in the upper slope depth zone (200-700 m), from 54% of trawlable area in 1996 to 63% in 2001, where increases were evident in all subregions except 'Eden/Bermagui'. This depth zone contains the majority of productive fishing grounds for a suite of key commercial species (including ling, blue eye trevalla, blue grenadier, gemfish, ocean perch and some shark species) as well as some threatened species (gulper sharks). Within the trawlable area there are particular habitats that are limited in extent, vulnerable to direct impact, and important to particular key species such as ling. Non-trawl auto-longline fishing has also expanded on the upper slope but could not be quantified because logbook data are insufficiently detailed.

Future trends and future work

As this project concluded in 2006, the relevance of spatial information to sustainable development of the SESSF is evident. While trawling occurred annually (in 2001) on less than 20% of the offshore seabed, and non-trawl fishing on about 5%, both fishing methods continue to expand into new areas, and sectors increasingly compete for shared target species in prime locations. These prime locations are frequently in depths and habitats that are fished most intensively – particularly on the upper slope, over 60% of which was estimated to have been trawled in 2001. As well, there has been widespread adoption of computing technology to display echosounder data as sophisticated 3-D maps that prospectively increase the ability of skippers to open up structured habitats. Thirteen Marine Protected Areas have been proposed in Commonwealth waters, and AFMA has announced its intention to introduce wide-ranging fishery closures to supplement the existing management arrangements based on TACs.

The mapping database developed in this project provides an inventory of one of the fishery's capital assets – seabed habitat. Capital assets do not need to be locked up, but rather used to the benefit of the various ecosystem outputs desired by society – including fresh fish. At the same time, habitat as a capital asset is something to be preserved to provide continuing benefits (biodiversity, fish production) for future years and future generations – including future generations of trawl and non-trawl fishers. The results of this project demonstrate that spatial management – including gear restriction – has the potential to help achieve sustainability in the SESSF, and that integrated science-industry data have more power to inform this process than either source of data alone. Importantly, the results demonstrate the benefits of collaboration for providing scientists, the fishing industry and other stakeholders with an informed appreciation of the status of the fishery and its future potential.

KEY WORDS: South East Fishery, SEF, SESSF, seabed mapping, fishing industry, collaboration, fishing grounds, trawling, non-trawl fishing, fishery habitat, effort expansion, spatial management, impacts, biodiversity, video.

ACKNOWLEDGEMENTS

The greatest acknowledgement is due to the contributing individual fishers who shared their personal fishing knowledge and enabled this project to be completed successfully in the face of some criticism and concern within industry. Special thanks are given to Allan Campbell, a trawl fisherman from Beachport in South Australia, who as the SETFIA representative, supported the project through its highs and lows. Allan also generously contributed time aboard his vessel FV *Celtic Rose* to trial the portable towed camera system, and then his time aboard FRV *Challenger* to act as a guide during a photographic survey of some of the Beachport fishing grounds.

Several people are thanked for their input into the project Steering committee: Katrina Maguire (AFMA), Katherine Short (WWF), Charlie Farquahar (SENTA EO), David Johnston, Merideth Hall and Paul Hedge (NOO), Leanne Wilks (DEH), Dr Tony Smith (CSIRO Marine Research), and several industry operators representing the trawl and non-trawl sectors (Allan Campbell and Greg Keatley from Beachport, and Will Muir and Michael Souter from Hobart). Representatives from the fishing industry Associations helped with various aspects of the project, including coordinating presentations at meetings: Gail Richey (SETFIA), Charles Farquahar (SENTA) and Michael Clarke (for the Danish Seine operators).

Three scientists with strong links to the SESSF fishing industry provided important inputs at various times: Dr Jeremy Prince helped establish support for the project within the trawl industry sector; Dr Pascale Baelde helped with the design of data collection protocols during the early phase of work; and Dr Ian Knuckey provided an important communication role during the latter part of the project – facilitating contact between the project team and industry, and communicating the project's results on behalf of the project.

Staff at the Sydney and Melbourne fish markets were very helpful by providing data on species prices and volumes.

Collectively, Ian Helmond, Matt Sherlock and Matt Horsham and the CSIRO Mechanical Workshop provided the technical input into the design and fabrication of the camera system. The skipper and mate of the FRV *Challenger*, Matt Francis and Jack Gibson, took us to sea to trial the system and complete a survey off Beachport.

Several staff at CSIRO Marine Research in Hobart also supported the project: Greg Lyden and other administrative staff helped with administrative matters, and Lea Crosswell designed the cover and helped collate some of the figures. Key contributions to the science were made by Dr Tim Jones in designing and implementing the GIS-linked database, and Dr Neil Klaer in processing and summarising the logbook data.

The report was improved following comments from industry – relayed primarily by Fritz Drenkhahn, Allan Campbell, Charles Farquhar and Dr Ian Knuckey, and from our colleagues Drs Neil Klaer, Keith Sainsbury, David Smith and Tony Smith (CSIRO Marine and Atmospheric Research).

The project was funded jointly by the FRDC and CSIRO with the fishing industry operators supplying substantial in-kind support. Some of the video transects were completed as part of other FRDC projects (notably 2004/006).

1 BACKGROUND

There is a growing interest within the SESSF fishing industry to become more pro-active on conservation issues. This is due, in part, to increasing community attention to the effect that fishing, particularly bottom trawling, can have on complex marine ecosystems and benthic habitats. This increased attention has resulted in a number of recent conservation initiatives that are expected to have widespread impact on the management and operation of fisheries. National initiatives include Australia's Oceans Policy, removal of the blanket exemption given under Schedule 4 of the Wildlife Protection (Regulation of Exports and Imports) Act to marine species caught and exported by fisheries, and the Environmental Protection and Biodiversity Conservation Act.

A key issue for the SESSF related to the changed use of the Wildlife Protection Act (amended in 2000). From 31 December 2001, export of marine fish and their products has required a permit from the Department of Environment and Heritage (DEH), and the assessment process for this permit involves demonstration that the fishery is ecologically sustainable. DEH's guidelines for assessing the sustainability of fisheries are based on two Principles: (1) avoiding overfishing of stocks and recovery of overfished stocks, and (2) minimising impact on the structure, productivity, function and biological diversity of the ecosystem. Objectives and sub-objectives are given under each principle.

Against this background, it seemed almost certain that the management of fishing effort by time and spatial restriction would increase in the SESSF. The conservation agencies of the States of New South Wales and Victoria had already mooted development of closed areas within State waters, while spatial management of human activities was clearly going to be an important component of Regional Management Planning under the Government's Ocean's Policy: the first Regional Management Plan was for southeastern Australia and this included the implementation of offshore marine protected areas (MPAs).

Despite the policy and management impetus to manage marine systems in a spatial context, the data available to achieve this were unavailable, except for isolated examples. What was needed was mapping of marine habitat and habitat use, similar to those that drive the spatial management of terrestrial systems. Our proposal was to map the SEF region of the SESSF fishery using fishing industry information, 'ground truth' it with a field program of physical and photographic sampling, and supplement it with existing survey data on seabed and water column habitats.

The fishing industry had considerable knowledge and understanding of seabed habitats and components of SESSF fishery ecosystem which, when combined with recent and ongoing research results, had the potential to greatly inform both the environmental assessment of the fishery, and public understanding about fishing and the fishing industry. In a recent study of the SESSF ecosystem (CSIRO/FRDC 94/040), Bax and Williams (1999) mapped a section of the SESSF continental shelf seabed and defined seabed habitats in the context of their role for productivity of the fishery. Fisher's knowledge of the seabed landscape and fishery ecology was successfully combined with survey information to provide additional and unique interpretation of ecosystem processes.

That study provided detailed maps of a section of continental shelf seabed in the southeastern SESSF. However, the study area of some 24,000 sq km (Wilson's Promontory in eastern Victoria to Eden in southern NSW) represents only 11% of the SEF continental shelf, which is itself only a fraction of the fishery region.

Fishing in the SESSF had been managed with input and output controls since the late 1980s, but there has been little control over the areas of seabed being fished. While the AFMA stock assessment process provided information on the target species (Principle 1 of the Wildlife Protection Act), there was no consolidated information available to address Principle 2. A step towards mapping effort has been made through an ARF funded mapping project by BRR based on positions of trawl shots as reported in the SEF1 logbook. These maps plot the entire SEF area on a square kilometre basis assuming that trawls are straight lines between reported start and end points. However, data cannot be shown where less than 5 vessels tow through a given square kilometre, and the maps are not interpreted with respect to habitats. Moreover, the technique may upwardly bias the area of trawl ground in areas towed by many vessels and under state trawled area in regions where only few vessels operate.

The process of gathering industry information will enable intensive one-on-one dialogue about the industry-wide need to respond coherently to the broader ESD issues that have been catalysed by the Wildlife Protection Act. A key element of the project is to progress this dialogue through a series of Industry Workshops. These aim to facilitate industry policy towards spatial management in the SESSF, and will involve representatives for conservation issues from relevant NGOs.

The project will involve a team of scientists with a strong history of liaison with the SESSF fishing industry and a history of working on issues of resource sustainability working closely with the SESSF industry at both peak levels and its grass roots. The project addresses a stated need of the SESSF Research Sub Committee – "Identification of fishery habitats in the SESSF, including industry information".

2 NEED

The SESSF fishing industry, particularly the trawl sector, has a need to be pro-active in the face of growing community attention to trawling based on its potential to modify benthic habitat and threaten biodiversity values. This need is focused by the timetable for the regional marine planning process (the end of 2001 for the SESSF region), as well as to meet provisions under Schedule 4 of the Wildlife Protection (Regulation of Exports and Imports) Act and the Environmental Protection and Biodiversity Conservation Act. Solid information and/ or a developed industry position regarding the spatial management of its fishing grounds, will assist the fishing industry to engage in this process as active partners.

This project will assist the fishing industry, primarily through SETFIA and SENTA, to drive a process by which options for spatial management are developed for their fishery. The project will provide the process and the context against which spatial management options can be developed for the SESSF and be evaluated scientifically.

The outcomes of this project will have direct relevance to:

- advancing AFMA's legislated aims of sustaining biological production and economic efficiency
- seeking certification for inclusion on Schedule 4 of the Wildlife protection Act
- attaining ESD accreditation in the longer term.
- responding to the near-term needs of participating in the process of developing DEH's South East Regional Marine Plan

The finely detailed and annotated maps to be generated by this project will provide a template on which the distribution of fishing effort and catches can be plotted, and will form the basis of industry proposals to introduce spatial management to their fishery. Without these maps and the process supported by this project there is a risk that uninformed spatial management of fishing effort would contribute neither to conservation goals nor the fishing industry and could be to the detriment of both. Moreover, inappropriate spatial management would be counter-productive to ESD planning for the SESSF.

3 OBJECTIVES

1. Proactively and cooperatively develop industry policy in response to the requirements of the Wildlife Protection Act (especially Principle 2).

1.1 Acquire, collate and map industry (trawl and non-trawl) information on the spatial extent and use of fishing grounds in the SEF.

1.2 Evaluate and summarise this information in relation to the Wildlife Protection Act (especially Principle 2) guidelines.

2. Integrate fishing industry knowledge and scientific data to give quality assured information on linkages between seabed habitats, biodiversity and fishery production for informed sustainable management of the SEF and to build broad public understanding.

2.1 Develop deployment equipment to provide an ongoing capacity to photographically monitor habitats from industry vessels.

2.2 Validate and complement industry information gathered for Objective 1 by ground-truth sampling from industry vessels.

2.3 Consolidate all the information from this project, together with existing ecological and physical (geological, topographical and hydrological) data, and provide a draft paper for industry that addresses relevant elements (primarily Principle 2 of the Wildlife Protection Act guidelines).

2.4 Support, through a series of workshops, the development by industry of spatial management options to protect biodiversity and fishery production in the SEF based on the information provided through this project.

2.5 Develop a Public Relations strategy for the project and its outcomes, including media release kits/releases and supporting video/ photographic images, collaboratively between SETFIA, SENTA and the project team.

4 METHODS

4.1 Industry liaison

4.1.1 Participating fishers

Thirty-three fishers participated directly in this project, and many others participated indirectly. Direct contributors were fishers who shared their knowledge during formal 'one-on-one' interviews in ports when mapping information was provided and reviewed; indirect contributors provided feedback at Association meetings or during informal meeting in ports. Several key individuals provided data and attended Association meetings.

Instead of broadcasting a request for assistance with the project, a number of key operators were approached directly to contribute knowledge and mapping information. There were several reasons for taking this approach. Firstly, and most importantly, it was not practically possible, nor necessary, to collect mapping data from all industry members. Secondly, we anticipated that a geographically complete and high quality data set could be generated by liaising with a cross-section of individuals with whom trusting relationships already existed, together with others who also had extensive fishing knowledge in the SEF (often built on more than a decade as a skipper) and who represented different sectors and geographical areas of the fishery.

4.1.2 Port tours

Fishers making direct contributions of data were each visited a number of times to collect, review and refine maps (Table 4.1.2.1), and to provide interpretation via a questionnaire (Appendix 2). Fishers from all the primary SEF ports contributed: the northern and eastern ports (Sydney, Wollongong, Ulladulla, Bermagui, Eden, Lakes Entrance); the western ports (Portland, Beachport) and the southern port (Hobart).

Table 4.1.2.1 List of industry liaison meetings showing dates, locations and aim of meetings

Date	Location	Aim or result of liaison
January 25, 2001	Hobart	Project liaison with SENTA president
February 7, 2001	Hobart	Project liaison with SETFIA EO
February 8, 2001	Hobart	Project liaison with SENTA EO
March 18, 2001	Canberra	Project aims presented to SETFIA executive and at Association meeting
March 19, 2001	Melbourne	Project aims presented at SENTA meeting
April 2-3, 2001	Portland	Project aims presented during SEFAG port tour
May 23, 2001	Hobart	Project liaison
May 31-June 2, 2001	Eden	Data collection; data verification
	Bermagui	Data collection; data verification
June 27-28, 2001	Sydney	Data collection
July 29- August 1, 2001	Eden	Data collection; data verification
	Bermagui	Data collection; data verification
August 3, 2001	Hobart	Project update presented to project Steering Committee
August 14-17, 2001	Beachport	Data collection; project liaison
	Melbourne	Project liaison
October 29- Nov 1, 2001	Lakes Entrance	Data collection
November 5-9, 2001	Canberra	Brief project update for FRDC (at COMFRAB meeting)
	Greenwell Point	Data collection
December 3-5, 2001	Portland	Data collection; data verification
December 6, 2001	Portland	Project update presented at SETFIA meeting
February 26, 2002	Adelaide	Review data security document
Feb 27-2 March 2002	Portland	Data collection; data verification
	Beachport	Data collection; data verification
March 4-5 2002	Lakes Entrance	Data collection; data verification
March 6, 2002	Melbourne	Project update presented at SENTA meeting
March 25-28, 2002	Greenwell Point	Data collection; data verification; map return
	Ulladulla	Data verification; map return
	Wollongong	Data collection
April 10, 2002	Hobart	Data collection
April 16-17, 2002	Mooloolabah	Data verification; questionnaire
April 20, 2002	Hobart	Data verification; questionnaire
April 22-26, 2002	Lakes Entrance	Data collection; data verification. General liaison
	Eden	Data collection; data verification; questionnaire
	Bermagui	Initial map return
	Ulladulla	Overview map return
	Greenwell Point	Initial map return
	Wollongong	Data collection
May 7, 2002	Canberra	Project update presented to SETFEAG spatial workshop
June 16-17, 2002	Canberra	Project update presented at SETFIA meeting
	Canberra	Project update presented at SENTA meeting

August 28, 2002	Hobart	Discuss content and format of initial map products with trawl representatives
September 16-19, 2002	Beachport	Data verification; questionnaire
	Portland	Data verification; questionnaire
September 25-29, 2002	Eden	Data verification; questionnaire
	Bermagui	Data verification; questionnaire
	Ulladulla	Data verification; questionnaire
	Greenwell Point	Data verification; questionnaire
September 30, 2002	Canberra	Project update presented at SETFIA meeting
	Melbourne	Project update presented at SENTA meeting
November 18-19, 2002	Lakes Entrance	Data collection; data verification. General liaison
November 28-29, 2002	Ulladulla	Project update presented at SETFIA meeting
	Wollongong	Initial map return
	Sydney	Liaison; data collection
December 4, 2002	Hobart	Project update presented at SENTA meeting
January 29-30, 2003	Hobart	Data collection
	Hobart	Data verification; questionnaire
January 31, 2003	Wollongong	Final map revision
	Sydney	Liaison; data verification; initial map return
February 3, 2003	Canberra	Project update presented to AFMA Board
March 5, 2003	Melbourne	Project update presented to SENTA/ SENTMAC
March, 2003	Canberra	Project update presented at SETFIA meeting
March 6, 2003	Canberra	Project update presented to SETFEAG meeting
March 3, 2003		
April 4, 2003	Portland	Project update presented to AFMA board
June 2, 2003	Ulladulla	Project update presented at SETFIA meeting
June 26, 2003	Hobart	Project update presented to project Steering Committee
July 1, 2003	Hobart	Project update presented to National Oceans Office
July 4, 2003	Canberra	Project update presented to AFMA Environment Manager
November 10, 2003	Lakes Entrance	SETFIA meeting

4.1.3 Industry associations

Project updates were presented at all quarterly SETFIA and SENTA meeting during 2001, 2002 and until June 2003 (Table 4.1.2.1). These were mostly slide show presentations by the project scientists, except for four SETFIA meetings where a written summary was presented by the EO or industry scientific representative, and comments provided by the project's trawl representative. In addition, updates were broadcast via the SETFIA newsletter, and the majority of project information posted on a project website.

4.2 Formal arrangements

4.2.1 Memorandum of Understanding

At the start of the project CSIRO Marine Research and the peak bodies (SETFIA and SENTA) entered into a Memorandum of Understanding that set out the ground rules for exchange and release of data so that all parties had a common understanding of the intentions of the project. Specifically, the MOU detailed how CSIRO would inform the peak bodies and individual fishers about results from the project, how industry would be incorporated into the project and provide support for it, and how project results would be released to a broader audience. It also specified how industry would contribute to the project. The MOU is shown in Appendix I.

4.2.2 Data security agreement

Industry's knowledge and data was differentiated from project data through an annex to the MOU in order to protect data from unintended distribution and use during the project, and to identify the fate of the project data beyond the 2-year life of the project (see Appendix 2).

4.2.3 Intellectual property

The wording of the IP clause in the contract with FRDC was also changed to reflect the ownership by industry of industry data, as distinct from pre-existing scientific and derived project data.

4.2.4 Steering Committee

An external Steering Committee was formed to aid communication and consultation. The committee was made up of representatives of SETFIA and SENTA (respectively, Allan Campbell and Greg Keatley – who was replaced by Mick Souter midway through the project), the NOO (David Johnston was replaced by Meredith Hall midway through the project), an NGO (Katherine Short from WWF), AFMA's environment section (Katrina Maguire), and SEFAG (Tony Smith). Other individuals from a range of organizations (including OceanWatch, DEH and industry) attended as observers.

4.3 Industry data types and outputs

4.3.1 Electronic mapping data

Most industry mapping data were provided in electronic form on floppy discs from navigational trackplotters in Furuno GD88 or C-Plot format. Way-point data that showed the existence and boundaries of different seabed types were most useful in defining grounds and habitats; track data (marking trawl tows or sets for lines, meshnets and traps) were incomplete, but were useful to confirm the locations of fishing operations in relation to the boundaries of grounds or features. Trackplotter data were converted to a form suitable for use in the GIS software "MapInfo".

4.3.2 Charts and existing maps

A small proportion of mapping information was provided in paper form. These charts were digitized and added to the electronic data holdings in the GIS.

4.3.3 Defining fishing grounds

The spatial units of analysis in this study are fishing grounds. We defined 'fishing grounds' as seabed areas recognized by commercial fishers for fishing or not fishing (avoiding), or areas where the distributions and abundances of commercial fishes are distinct. Typically, grounds are related to natural geological features – substratum type and geomorphology – and mostly distinguish sediment plains (used for trawling), patches of consolidated substrata such as rocky banks (used by static non-trawl gears), and prominent features such as canyons and seamounts (targeted by a variety of fishing methods). Fishing grounds may have the same type of seabed throughout, or be highly variable in terms of both their make-up (bottom type) and what they look like (geomorphology). These attributes were recorded separately for each ground using a questionnaire (Appendix 2).

Boundaries of grounds may be based on distinct or indistinct physical features, on distinct or indistinct depth contours, on political lines (e.g. State-Commonwealth and State-State borders), aligned with adjacent seabed features (typically prominent reefs or canyons) or historical landmarks (such as mountains), measured by distance from port or shore, or arbitrary. As such, fishing ground boundaries have two important properties: type and distinctness. Boundary type is unlikely to be similar for the entire perimeter of a ground, and its distinctness is likely to be variable – ranging from highly distinct (such as the edge of a prominent rocky bank) to fuzzy (such as depth-related boundaries over extensive sediment plains). To enable these attributes to be recorded with the data, each ground (polygon) boundary was treated as being composed of four segments – typically these were relatively well defined inner and outer segments together with two 'ends'. To achieve a consistent approach to recording information for all grounds, the segments were nominally classed as being north, south, east and west segments.

Most fishing grounds are named by fishers, and many provide insights into their bottom types, locations, features, or landmarks used to find them before the advent of GPS navigation, e.g. those from the eastern Bass Strait region (Williams and Bax, 2003a). Names are fundamental components of maps and, as well as providing a common reference for fishers, are also very useful for scientists to visualize and navigate around the unseen working landscape of the offshore fleets. The names used for the fishing grounds making up the SEF seascape come predominantly from fishers.

4.3.4 Additional data on grounds from questionnaire

Descriptive and semi-quantitative attributes of the seabed were collected systematically for each fishing ground using a simple questionnaire developed with industry help (Appendix II). These data were subsequently linked to maps via a spatial database (see Section 4.4).

Terrain type and habitat attributes

At the coarsest scale of resolution, fishing grounds were classified into one of five 'terrain type' classes based on their estimated proportions of sediment plains and rocky reefs. In concept, this classification was a first step towards defining fishery habitats and was designed to assist in the delineation of grounds during the process of map making. It provided a simple thematic map product that could be returned to contributors as part of the quality assurance process, and could be used for error checking by the project team. It took no account of the different types of sediment and rocky bottoms at different depths, and the sediment: reef ratios were initial estimates. The five terrain types were:

1 - 'heavy reefs'(contiguous rocky banks or densely scattered reef patches)

2 - 'sediments with many reef patches' (reef making up ~30-70% of total ground area)

3 - 'sediments with few reef patches' (~5-30% reef)

4 - 'clear sediments' (reef less than 5%)

5 - 'unknown'

Subsequently, usually when revised map products were available, fishers provided their descriptions of geomorphology ('what the bottom looks like') and their best estimates of the proportions of bottom types ('what the bottom is made of') for each ground. The responses were recorded using a set of tick boxes linked to a set of terms commonly used and understood by fishers. Comments boxes were used to record other notes about habitats and other features of grounds, such as patterns of use, seasonality of species, and any other relevant information.

Geomorphology ('what the bottom looks like') was recorded as presence or absence of the following features or characteristics:

1 - Flat

2 - Sloping

3 - Steep

4 - Undulating

5 - Rugged

6 - Bank

7 - Valley

8 - Canyon

9 - Hill

10 – Seamount

Bottom type ('what the bottom is made of') was recorded as the estimated percentage cover of 10 classes, or as unknown:

1 - Mud - soft & boggy

2 - Mud - compact

3 - Sand

4 - Gravel

5 - Rubble

6 - Sandstone

7 - Mud boulders

8 - Slabby

9 - Heavy low reef

10 - Heavy high reef

Fishing ground use

The questionnaire also recorded how a ground was 'used' to provide supplementary information on the extent/ intensity of use, and reasons for non-use. Six simple classes were used:

1. Fished
2. Fished in part: restricted/ few locations
3. Fished in part: no information
4. Not fished
5. Unfishable
6. Unknown

Collectively, terrain type, habitat attributes, fishing use and supplementary notes were used as the basis for determining if grounds were untrawlable when analysing logbook data (see section below on SEF logbook data and processing).

4.3.5 Fishery subregions

Since this project commenced, the traditional South East Fishery (SEF) has become part of a larger fishery region, the Southern and Eastern Scalefish and Shark Fishery (SESSF). Both acronyms are used in this report: SESSF for the fishery generally; SEF when the issue relates explicitly to the area studied in this project.

Summary data on habitats were provided for 18 subregions of the Commonwealth South East Fishery region bounded at Barrenjoey Point in the north east, and Cape Jervis in the south west. This set of sub-fisheries represents a coarse-scale sub-division recognized by offshore fishers, and corresponds in many cases to areas fished from particular ports. Geographic location is reflected in the names of subregions – mostly following either the key fishing ports or topographic features such as islands. The associated names are those most commonly used by industry (Fig. 4.3.5.1).

In all spatial analysis, the inner and outer boundaries of subregions are the 3 nautical mile boundary and 1300 m (~700 fathom) depth contour, respectively. These represent the boundary between State and Commonwealth jurisdictions, and the approximate deep limit of demersal fishing activity. The boundaries between subregions align with the ends of recognized grounds, and often these coincide with prominent seabed features.

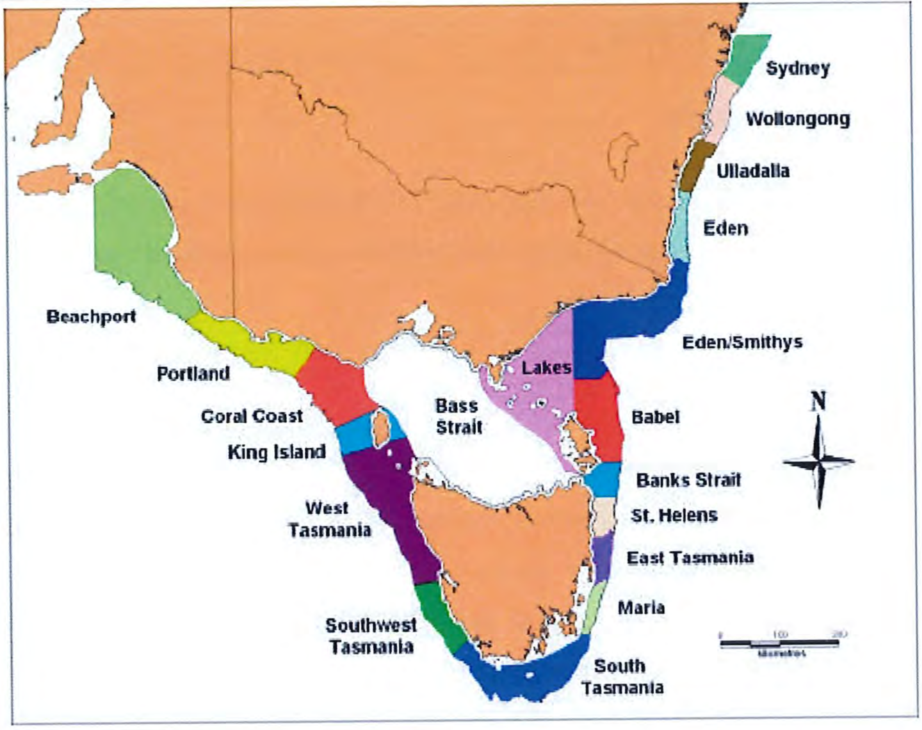


Figure 4.3.5.1 Map showing the fishery subregions defined for this project; the inner boundaries are the 3 nautical mile State waters limits, and central Bass Strait; the outer boundary is the 1,300 m depth contour.

Maps are not provided for this report at levels below fishery subregion because industry did not want to publish maps of grounds at the time this report was written. Exceptions were made in certain areas to demonstrate the detail in the underlying maps, and to link to seabed photographs. Summaries of habitat types, numbers of habitat patches, and catch, effort and CPUE, are calculated at the level of grounds, but presented in table form. However, it is intended that maps of grounds will be made available for specific purposes; the first was the series of AFMA workshops on future management arrangements for the SESSF in June 2006 at which the entire project map was provided with overlays of effort and reflected effort.

4.3.6 Depth zones

In addition to providing summaries by fishery subregion, data are also summarized by major depth zones using boundaries at 3 n.m, 50 m; 100 m, 150 m, 200 m, 700 m and 1300 m. These represent the primary biophysical divisions of the offshore seabed environment, which changes much more rapidly with increasing depth than distance alongshore. For example, communities of fishes have distinct depth-related boundaries on the SE shelf (Williams and Bax, 2001) and SE slope (Koslow et al., 1994; CSIRO Marine Research, 2001).

4.4 Map data processing

4.4.1 Database structure

A customised relational database was designed in the database software "Access" to store the project data; all habitat attribute data were linked to geo-referenced maps of fishing grounds in the GIS.

4.4.2 Data security

One aspect of providing security for project data was to implement a data registration and tracking feature in the database. The underlying concept was similar to a library loans and returns scheme where raw data were registered in the database and then any form of released product (most often paper maps) was tracked between contributors and the project team. Maps sent out for review and revision by contributors were classed as loans. Paper copies were kept to a minimum, and all were marked with a coded label showing contributor, map version (Fig. 4.4.4.1), the number of copies produced (almost always one only) and the purpose for printing the map. One set of original maps of trackplotter data with interpretations was stored for reference at the CSIRO Laboratory in Hobart, but supplementary revised maps were destroyed once the information had been transcribed.

4.4.3 Quality assurance

The quality of the mapping and attribute data provided by fishers was estimated by CSIRO, both for reporting purposes and because the quality was variable. This variation in quality was due to a number of factors, including the detail of bottom type and spatial resolution of a boundary that was, or could be, provided. Most commonly, variable quality stemmed from a limited knowledge of particular areas and bottom types, e.g. rugged and complex areas that are only fished by static (non-trawl) gears which provide little in the way of physical material to back up a fisher's impression of bottom type. This resulted in some distinct sector-specific differences, with trawl skippers generally having the best impression of bottom types through the wear on gear and material caught in trawl nets, and area boundaries because the limits of trawl areas are marked in plotter data.

We classified our confidence in the raw information provided by fishers with respect to bottom types and boundaries using the following criteria, and the scoring system shown in Table 4.4.3.1.

Confidence levels for fishing ground boundaries

Confidence was defined as: "CSIROs confidence that the lines used to define a polygon map object are valid'. The frame of reference is: "defined seabed areas (as polygons) are identifiable or natural areas for commercial fishes (distribution and abundance), or commercial fishing, or a major geomorphological unit where fishing doesn't occur".

General guidelines for scoring confidence (and see Table 4.4.3.1):

- Corroborated is defined as a generally good (unquantified) agreement on a boundary in two or more maps. Agreement is not an exact match but the coincidence of polygons with generally similar boundaries. Often, two or more contributors contribute to, and agree on, features in one map. This isn't counted as corroboration for these criteria unless both operators have a strong working knowledge of the areas as skippers.

- Validation is not included in this score because very few boundaries are validated (and then only in part) or can be validated (e.g. boundaries based on the depth distributions of fish assemblages). Verification of distinct boundaries would require swath maps and these exist for only a few areas.

- No distinction is made between original media types - electronic track plotter data, lat/long coordinates or paper charts - because positional errors can not be estimated or compared between each. Any medium can be highly accurate.

- No account is taken of transcription errors for similar reasons; CSIRO was assumed to be consistent; fisher error (between boundaries and between fishers) is unknown.

- Fisher ability is not factored in because only experienced skippers contributed information for grounds they know well (experience is documented in questionnaire)

- Only very distinct physical features have natural boundaries; most boundaries are indistinct in nature

Confidence levels for fishing ground terrain type

Confidence level is defined as: "CSIRO confidence that the general description of terrain type within a polygon map object is valid". The frame of reference is: "terrain type is the impression formed by fishers based on soundings, material caught, and wear on gear – including gear damage. Terrain type is generalised because it is assessed for areas ranging in size from a few square nautical miles to 100's of square nautical miles"

General guidelines for scoring confidence (and see Table 4.4.3.1):

- Corroborated is defined as a generally good (unquantified) agreement on a terrain type in two or more maps. Agreement is not an exact match but the coincidence of generally similar terrain types within matching polygons. Often, two or more contributors contribute to, and agree on, features in one map. This isn't counted as corroboration for these criteria.

- 'Validation' is included only in the terrain type score because many terrain types are validated with scientific soundings, photographs or sediment samples.

- Terminology has been standardized to the extent possible through extensive discussions with fishers and the use of a standard list of terms in the questionnaire.

- Fisher ability is not factored in because only experienced skippers contributed information for grounds they know well (experience is documented in the questionnaire)

We also applied quality assurance procedures to the other data used, especially logbook data – see relevant section above.

Table 4.4.3.1 Scoring boundary and bottom type confidence for CSIRO-Industry SEF mapping data

Boundary types definitions	
Distinct	Defined physical feature (usually a reef or canyon)
	Depth (distinct surrogate for broad faunal boundary; inc 1300m line)
Moderately distinct	Poorly defined physical feature (e.g., mosaic of patchy reefs)
	Depth (less distinct boundary)
	Arbitrary (but unimportant) - ground based on tow time/ boundary in line with other feature or landmark
	Political (3 mile; limits of SESSF region)
Indistinct	Unknown (estimated) (e.g., gaps, no information provided)
Confidence levels and criteria	
1: Boundary known with certainty	All known + distinct + corroborated
2. High confidence	All known + distinct/ moderately distinct + corroborated
3. Good confidence	All known + [most distinct + uncorroborated OR moderately distinct + corroborated]
4. Moderate confidence	All known + moderately distinct + uncorroborated
5. Low confidence	One or more indistinct (unknown) and/ or disagreement
General bottom types definitions	
Distinct	Homogeneous substratum (e.g., 1, rocky reef to 4, sediment plain)
	Homogeneous geomorphology (as above)
Moderately distinct	Heterogeneous substratum (mixed types, e.g., canyon)
	Heterogeneous geomorphology (mixed types, e.g., canyon)
Indistinct	Unknown (only partly sounded/ unsampled) or terminology confused
Confidence levels and criteria	
1: Bottom type known with certainty	Distinct + corroborated + validated
2. High confidence	Distinct/ mod. distinct + corroborated + validated
3. Good confidence	Distinct/ mod. distinct + [corroborated OR uncorroborated but validated]
4. Moderate confidence	Distinct/ mod. distinct + uncorroborated + unvalidated
5. Low confidence	Indistinct (unknown) and/ or disagreement and/ or terminology confused

4.4.4 Revisions and versions

A simple classification was developed to code maps as they developed (Fig. 4.4.4.1). The electronic data from each contributor was initially processed (in a number of ways depending on data format) and then printed on to paper. This first hard copy, coded 'M1', was used for the first level of interpretation – hand drawn lines for the boundaries of fishing grounds and features, and free-form annotation with notes on bottom type and geomorphology. A series of versions then followed using GIS electronic copies of 'M1 versions' to review and revise the developing maps with fishers. In practice, this usually took two or three meetings over a period of months. The final contributor approved 'M5' versions were the ones on which questionnaire information (habitat attributes) were based.

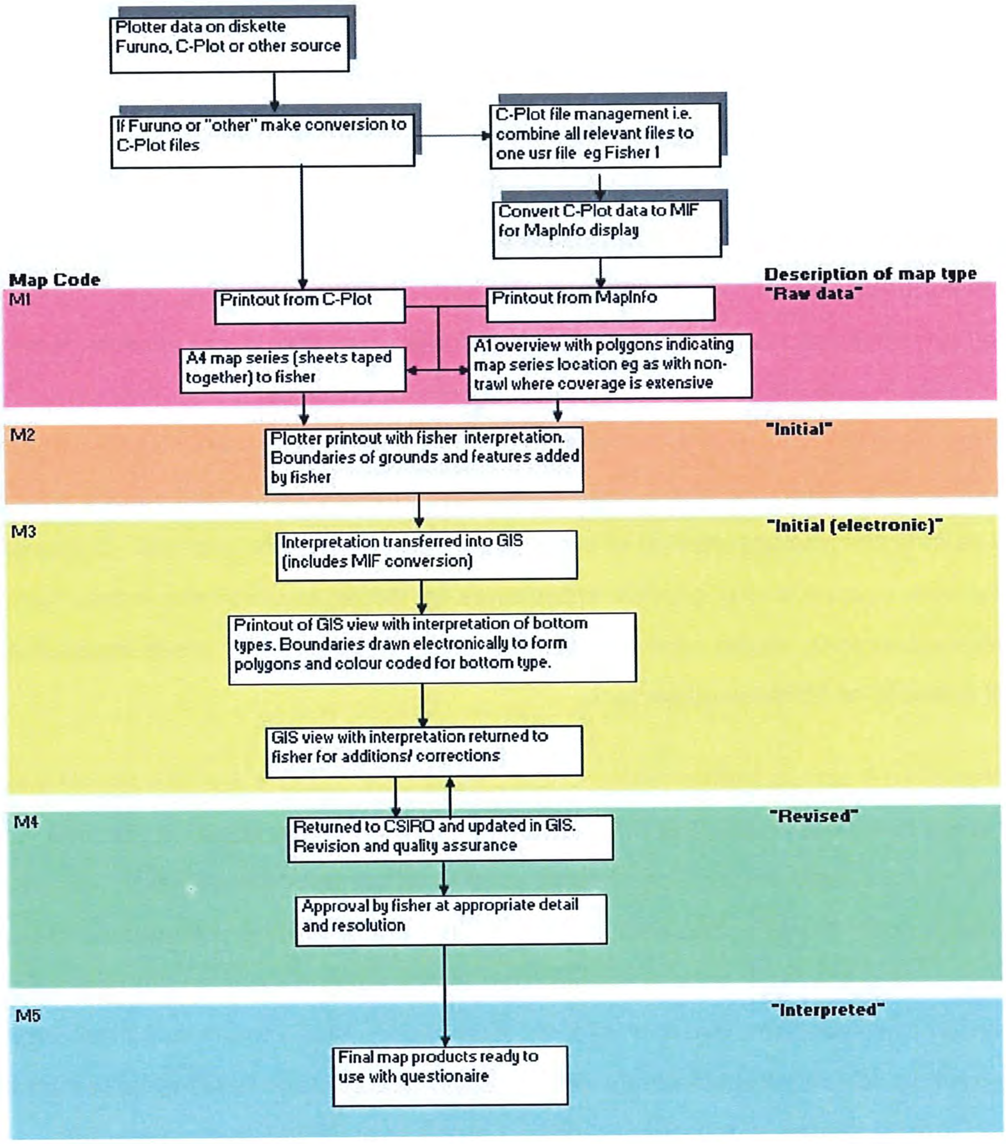


Figure 4.4.4.1 Scheme showing the progressive development of fishing ground maps from raw data through to final map products. Map codes were used to track progress in the project database, and added to labels on all paper maps as part of data security measures.

4.5 Scientific and other data types

4.5.1 SEF logbook data and processing

SEF 1 and SEF 2 logbook data were processed to provide geo-referenced measures of effort, catch and CPUE suitable for overlay on maps of grounds and habitats.

Positional information recorded by the trawl and non-trawl sectors differs in its spatial resolution: trawl start and end points are given as latitude and longitudes, whereas non-trawl gear setting positions are recorded variously as latitude and longitude, and as one-degree grid cell positions. As a consequence, trawl data were amenable to analysis at the spatial scales of interest to this project, whereas non-trawl data were not, and were not further analysed.

Trawl data were analysed at 1-kilometre grid cell resolution following the general method of Larcombe et al. (2001). In the first instance, trawl tows were extrapolated as straight lines between start and end points and overlayed on a 1-km grid. Every trawl operation was then segmented within grid cells they crossed, and each segment assigned a set of catch (kg per species) and effort (hours) values. Grid cells therefore represent small unit areas in which trawling has occurred; the proportion of each cell trawled remains unknown. The values were in proportion to the total catch and time of tow, based on the relative length of the segment to the entire trawl operation. These proportional values were then used to calculate summary metrics of catch, effort and CPUE per grid cell. Subsequently, grid cells were aggregated to provide summaries for larger areas of which they form part, i.e. fishery subregions, depth zones, fishing grounds, habitat types, areas trawled, and areas of interest for MPA development.

A key departure from the methodology of Larcombe et al. (2001) was the use of industry habitat maps to reflect trawl effort off untrawlable seabed. Two effects result in a 'smearing' of trawl data across untrawlable seabed when using unreflected data: straight line extrapolations do not account for trawl tows that curve around untrawlable features, and the recording of vessel position rather than the position of gear on the seabed extends the recorded tow line in the direction of tow. Both biases serve to increase the area of seabed trawled and mask untrawlable areas, e.g. reefs, in maps of effort based on logbook records. Our refinement to the method of Larcombe et al. (2001) was to identify untrawlable seabed using interpreted trackplotter data in conjunction with responses to the questionnaire. The process of reflecting data involved transferring the effort and catch from an 'untrawlable cell' to its nearest 'trawlable' neighbours. Reflection was only carried out when confidence in the identity and extent of an untrawlable feature was high (Section 4.4.3). An algorithm was written to distribute data to the nearest trawlable 1-km grid cells. The algorithm functioned as follows: the neighbouring 8 cells adjacent to the cell to be reflected were searched to see if at least 5 of them were trawlable. If so, the catch and effort was divided equally among those trawlable cells and added to any existing catch and effort for those cells, and removed from the original untrawlable cell. If at least 5 cells were not found, the square of cells to be searched was expanded by one cell in all directions and the procedure repeated. In total, 131 areas (about one quarter) were reflected. All our estimates of catch, effort and fishery value for trawl data are based on reflected data.

All SEF1 records were screened for validity using criteria relating to position, duration and extent (distance). Trawl records were deemed invalid, and discarded, if positions (start or finish, latitude or longitude) were missing or obviously incorrect (latitude < 20°; longitude < 100°); if duration was > 10 hours, or < 0.5 hour in depths < 600 m, or <.05 hour in depths > 900 m (the latter to take account of short targeted trawl shots for orange roughy); and if length of trawl > 1 degree (60 n.miles). The numbers and proportions of discarded records are shown in Table 4.5.1.1. Identification of method (gear type) was difficult due to the broad and sometimes inconsistent way this is recorded in logbooks – especially for non-trawl methods. We were able differentiate otter trawl from Danish Seine in trawl records, but not differentiate records of mid-water trawl from bottom trawl.

Because data prior to 1996 were either recorded at a coarser spatial scale, or unreliable due to alleged under-reporting of catch and effort in some areas (reported in State waters during OCS negotiations in 1994-1995), only trawl data for the period 1996 to 2001 were used. In total, approximately 30,000-34,000 individual complete trawl records were used per annum (Table 4.5.1.1). Following sub-division across 1-km grid cells, the number of records processed and held in our database was about 5.5 million.

Table 4.5.1.1 The number of discarded and retained records from the SEF1 trawl logbook database used in analysis. Invalid records are for: Trawl position (trawls recorded at a latitude less than 20 degrees South or longitude less than 100 degrees East); Trawl duration (individual tows greater than 10 hours, or less than 0.5 hours if less than 600 m deep, or less than 3 minutes if depth greater than 600 m; Trawl length (individual tows greater than 1 degree).

Year	Trawl position	Trawl duration	Trawl length	Valid records	Total	% of records valid
1996	3941	4564	177	32121	36905	87.0
1997	4158	4701	162	32803	37666	87.1
1998	4500	5067	152	30949	36168	85.6
1999	4533	5118	151	32587	37889	86.0
2000	1101	1777	170	34991	36941	94.7
2001	9	734	337	33649	34727	96.9

4.5.2 Market prices and volumes

Market prices of key species were used to convert logbook catch data to a 'total catch dollar value' metric that could be overlaid on maps. Price data were kindly supplied by staff of the relevant sections of the Melbourne and Sydney fish markets for the years 1996-2002 (the period during which accurate locations were available for catch records in SEF 1 data).

Price data provided were the volume-weighted averages per month per species or product. In cases where multiple prices related to one species (e.g. size grades), a single volume-weighted average was calculated. In cases where multiple products related to one species (e.g. whole fish, fillet or trunk), the whole fish price was used. All species recorded in SEF 1 logbooks for the period 1996-2002 were reconciled with market categories. Some species needed to be aggregated into the relevant market categories, and categories for some products varied slightly between markets (e.g. deepwater dogfish species). Final price values used for analysis were the volume-weighted average per species across the Melbourne and Sydney markets (Table 4.5.2.1); these were reviewed by industry before being used in analysis.

For analysis, logbook records for all 166 species were included. Individual prices were used for the 54 top-ranked species (by contribution to the total SEF1 catch across the fishery) for which there were market categories. Collectively, these species made up 99.4% of the SEF 1 total catch. An averaged price of $1.57, based on the mixed species' market category, was applied to the remaining species.

To account for the difference in SEF1 and SEF2 estimates of catch (the difference between estimated catch on deck and actual landed weight, respectively), we scaled data on a species by species basis. The SEF1-SEF2 difference was always positive for quota species (i.e. more was landed than estimated), but varied greatly between species and between years and was negative for a few non-quota species. This required a table of specific 'species-year' conversion factors to be used.

Table 4.5.2.1 Market species and 2001 market prices used to calculate total catch value ($) from to catch by species (details of calculation and assumptions provided in Section 4.5.2). Price shown is based on a volume -weighted average per month per species or product across the two markets.

Species	Market name: Melbourne	Market name: Sydney	Price
Alfonsino	ALFONSINO	Alfonsino	$1.53
Arrow squid	SQUID-ARROW	Squid Seined (Arrow)	$1.42
Australian angel shark	SHARK-ANGEL	Shark Angel	$3.33
Barracouta	BARRACOUTA	Barracouta	$1.19
Black shark	SHARK-BLACK PEARL	Shark Black Roughskin	$2.69
Blue grenadier	GRENADIER-BLUE	Grenadier Blue	$3.91
Blue morwong	N/A	Snapper Queen	$1.67
Blue-eye trevalla	BLUE EYE	Blueye	$7.32
Cuttlefish	CUTTLEFISH	Cuttlefish	$2.23
Deepwater dogshark	N/A	N/A	$4.31
Deepwater flathead	FLATHEAD-DEEPWATER	Flathead Sand	$3.30
Eastern school whiting	WHITING-SCHOOL	N/A	$2.73
Frostfish	RIBBONFISH	Ribbonfish	$1.11
Gemfish	GEMFISH whole	Gemfish	$4.84
Gummy shark	SHARK-GUM/SCH	Shark Gummy	$8.17
Hapuku	HAPUKU	Hapuka	$7.44
Jack mackerel	MACKERAL-JACK	Cowanyoung	$0.96
Jackass morwong	MORWONG	Morwong	$2.57
John dory	DORY-JOHN	Dory John	$8.21
King dory	DORY-KING	Dory King	$3.62
Latchet	GURNARD-butterfly & red	Latchet	$1.72
Longsnout dogfish	N/A	N/A	$4.31
Mirror dory	DORY-MIRROR	Dory Mirror	$2.49
Mixed fish	MIXED FISH	Mixed Fish	$1.66
Ocean jacket	LEATHERJACKET lge	Jackets Chinaman	$2.52
Ocean perch	PERCH-OCEAN	Perch Ocean	$3.73
Octopus	OCTOPUS	Octopus	$4.46
Orange roughy	ORANGE ROUGHY	Orange Roughy	$4.06
Pink ling	LING whole	Ling	$5.89
Platypus shark	N/A	Shark Roughskin	$4.31
Red gurnard	N/A	Gurnard Red	$1.16
Redfish	REDFISH	Redfish	$1.63
Ribaldo	RIBALDO	Ribaldo	$2.64
Royal Red Prawns	(Sydney only)	Prawn Royal Red	$3.89
Royal Red Prawns	(Sydney only)	Prawn Royal Red	$3.89
Sawsharks	SHARK-SAW	Shark Saw	$3.32
School shark	SHARK-GUM/SCH	Shark School	$5.07
Shark, other	SHARK-OTHER	Shark Others	$2.16
Shark, other	SHARK-OTHER	Shark Others	$2.16
Silver dory	DORY-SILVER	Dory Silver	$1.67
Skates	SKATE	Ray Flap	$1.12
Smooth oreo	DORY-SMOOTH	Dory Smooth	$2.35
Southern Calamary	CALAMARI-SOUTHERN	Calamari Southern	$6.78
Spiky oreo	DORY-SPIKEY	Dory Spiky	$1.98
Spotted trevalla	WAREHOU-SILVER	Warehou Silver	$2.11

Stargazers	STARGAZER	Stargazer	$2.05
Tiger flathead	FLATHEAD-TIGER ave sm&lg	Flathead Tiger	$3.12
Triggerfishes and leatherjackets	LEATHERJACKET sml	Triggerfish	$1.69
Warehou	WAREHOU-BLUE	Warehou Blue	$2.68
Warty oreo	DORY-OREO	Dory Warty	$1.62
White trevally	TREVALLY-SILVER	Trevally Silver	$2.30
OTHER SPECIES			$1.57

4.5.3 Geology

Seabed bottom type (substratum) and form (geomorphology) are key features of fishery habitats, being key factors determining where commercial aggregations of fish species occur, and where fishing is, or can be, carried out. Pre-existing geological data sets relevant to considering habitat in the context of fishery production were sourced, and supplemented with examination and identification of rocks (a variety of consolidated substrata) collected by fishers and the project team in the SESSF.

Pre-existing data sets were those of Bax and Williams (2001), Jones and Davies (1983) and work in progress by Geoscience Australia on standardized terminology and classification for geomorphic units (Harris et al., 2003).

4.6 Seabed photography

4.6.1 Design and fabrication of 'fishing vessel' camera system

A key objective of this project was to deploy a camera system from industry vessels to provide images of the seafloor. To achieve this objective we designed and fabricated a camera system employing state-of-the-art technology. The system provides high-resolution still images and high quality, real-time video to the wheelhouse of the vessel. The system is designed to be portable and suitable to use from a variety of vessels.

Using 800 meters of fibre-optic cable, the system is deployable to ~700 meters in static 'drop' mode, and to about 400 m in slow tow mode. A custom built electric-hydraulic winch requires the vessels 3-phase power to drive the hydraulics; it holds the cable and is remotely controlled using a joy-stick controller. The design includes an accurate level wind – essential when using a conducting cable of this type – and a digital readout of wire out. The winch is bolted to a base plate that is welded to the deck of the vessel. A gantry was fabricated to facilitate deployment and retrieval. This gantry provides the mounting point for a large diameter sheave block for the fibre-optic cable, in the absence of a suitable mount point on the vessel used.

The camera platform contains two colour video cameras, two 240 V flood-lights, a 4-megapixel digital stills camera, two strobes for the stills camera, and an electronic package that controls all the components and communicates with the wheelhouse computer controls. Pressure casings for components were designed and fabricated at CSIRO's engineering and workshop facilities; the electronic components for control and performance monitoring were also designed by electronics engineers at CSIRO. The system was successfully tested at sea from FRV *Challenger* during two trial voyages prior to being used from fishing industry vessels.

4.6.2 Survey design and data collection

A simple and flexible survey design was needed to ensure efficient and safe use of the camera system on working fishing vessels that did not have prior experience of deploying this kind of gear. Unknown factors included the time required to safely deploy and retrieve the gear, how sampling could be fitted around fishing activity, and the time needed to locate and adequately sample the target habitats.

The underlying goals were to target boundaries of contrasting habitat types, and target a range of important or specific grounds that would provide particular insights into fishery habitat and its use. The data collected were digital video, high resolution digital stills, a digitized analogue of the ships echosounder readings, the ships position (using a DGPS) and the estimated layback of the camera system on the seabed, and a general operations log.

4.7 Communication and reporting

4.7.1 Industry meetings

Key aims of the project, as stated in the objectives, were to communicate project progress and results back to industry operators, and to a broader audience. Regular (quarterly) meetings of SETFIA and SENTA and the port visits provided good opportunities to both present results to the relevant industry sectors, and to discuss how the project could facilitate communication of industry involvement and initiatives to other agencies and the general public. Reporting to industry is covered in section 4.1above, while the mechanisms for reporting outside the project are detailed in the following sections.

4.7.2 Flyers and mini-posters

Information summaries in the form of 'flyers' and 'mini-posters' were found to be an effective way to provide an overview of the project's methods and intended outputs to industry, and to present summaries to other audiences. Initially these were a collection of annotated diagrams and photographic images in A4-format, but evolved to A3 format as the project developed. Several were produced at various stages of the project for circulation at meetings and during port visits, and for postal delivery.

4.7.3 Website

During discussions in the first year of the project there was strong support from industry to develop a project website. The site was designed with industry input, and launched in December 2001 at the end-of-year industry meetings, and has been maintained by the project. It has multiple sections that provide background on the research proposal, repositories for the documents detailing the formal arrangements, commentary sections from SETFIA and SENTA, reporting (including milestone reports to FRDC), maps, and progress updates. The site can be visited on-line at www.marine.csiro.au/sefmapping.

4.7.4 Reporting to special meetings

In addition to regular reporting to industry association meetings and milestone reporting to the FRDC, a variety of formal and informal reports were made to other meetings. These are listed in Appendix III.

4.7.5 Conferences

Methods designed for the project, and its results, made large contributions to two papers presented by the project investigators at international conferences in 2001 and 2002; respectively the First International Conference on 'Putting Fishers' Knowledge to Work' and the International Congress on Aquatic Protected Areas. Both papers are published and included as Appendix IV

5 RESULTS/DISCUSSION

5.1 Industry data

5.1.1 Industry liaison and data collection

The success of the project depended, in large part, on communicating and justifying the goals of the project to 'grass-roots' fishers in ports. Although the project was supported by some (but not all) of the Associations' executives, it was individual fishers who provided data and they needed to know why the project was being undertaken, and why it was in their interests to help. We found that many working fishers had little or no knowledge of the relevant management background, and that repeatedly in its early phase, this project was an important source of information about the near-term likelihood of area management affecting their access to fishing grounds. It was equally important to expand and update the knowledge of members attending Association meetings for the same reasons. These individuals were better briefed, but still gained the most up-to-date information about the MPA process through this project until a formal stakeholder process was initiated in 2003.

A concern held widely by industry was that its information would be distributed to other fishers or management agencies and ultimately used against its best interests. Accordingly, a large effort was put into providing relevant information about the management environment – including information to illustrate what benthic habitats are (such as example photographic images), providing examples of how and when industry mapping data could or could not be used, and in formalising these arrangements to provide protection for the information held by the project. A number of documents – including flyers and mini-posters with photographs and example maps – presented habitat and mapping data in visual form, and demonstrated how industry information could be contributed without compromising commercially sensitive information. This information was widely distributed to the ports and in a variety of Association and agency meetings (Table 4.1.2.1), and posted on the project website.

One element of our communication with industry was to provide a visualisation and interpretation of benthic habitat. In many ways, our liaison program provided an opportunity to discuss the role of habitat for sustaining fishery production, the ways in which it is vulnerable to certain types of fishing impact, and the likely goals for sustainable fishery management. One of the important, but rather intangible, outcomes of this project was to put these issues on industry's radar.

A two-pronged approach to industry liaison – the combination of one-on-one meetings in ports together with regular communication at Association meetings – proved to be very successful for data collection and reporting. Port visits demanded a high degree of flexibility by the project team, primarily because meetings with working skippers needed to fit in around busy, and sometimes unpredictable, working routines. Last-minute changes in arrangements were often required for reasons associated with boat maintenance or weather patterns affecting arrival or departure times from port. In spite of this, industry members were always willing to make time, and data collection moved steadily forward, and between January 2001 and January 2003, data were collected from contributors in the ports of Beachport, Portland, Melbourne, Hobart, Lakes Entrance, Eden, Bermagui, Ulladulla, Wollongong and Sydney (Table 4.1.2.1).

Information was provided by a cross-section of fishers, some with whom trusting relationships already existed, and others who were willing to contribute to the project; all were highly experienced SEF skippers (Table 5.1.1.1). Meetings were held in a variety of venues to suit the availability of contributors. These included the wheelhouses of vessels (often necessary to obtain the raw trackplotter data), fishing coops, but most frequently we were kindly invited to fishers' homes where computers and printers were set up and paper copy maps spread over the dining table. Meetings took place at a variety of times: some over breakfast, several running into the early hours of morning.

The time required for each step in the map making and interpretive processes was considerable, and several iterations (including revisions) of the data from each contributor were required to achieve complete and robust final-stage "interpreted" map products (Fig. 4.4.4.1). This required at least two, and often three or four, periods of contact with contributors and therefore multiple visits to all ports. The effort and resources required to complete industry data collection was underestimated in the project planning stage. Ultimately, however, a large volume of accumulated way-point data from 63 primary navigational trackplotter files (and a large number of small files) enabled final-stage "interpreted" map products to be made for the entire fishery area.

The trawl sector coverage was the most extensive and involved contributors from all of the ports listed above. We focussed on "market fishers" that comprise the majority of the fleet and have a diverse pattern of activity for many species over the continental shelf and slope. We excluded coverage of the offshore orange roughy fishing grounds (Cascade Plateau and South Tasman Rise) because these are isolated and remote parts of the SESSF seabed.

Table 5.1.1.1 Years of fishing experience of contributing fishers

		Role (years)			
Contact ID	**Deck hand**	**Skipper**	**Boat owner**	**Owner skipper**	**Total fishing experience**
15	2	10		8	12
48	1	33	24		34
22		40			40
37	9	34			43
6	1	27			28
60	6	16			22
9		30	27	25	30
43	3	15		2	18
7	1	24	15	15	25
62		4		23	23
34		34			34
33	2	17		1	19
24	5			13	18
21	14			10	24
47	1			39	40
23	6	11			17
25		2	10	5	5
56		8			8
63		1		7	7
32			7	15	15
61		14		11	14
16	10	15		11	25
36	9	3			12
57	6	11			17
Average (years)	**5**	**17**	**17**	**13**	**22**

Coverage of the offshore non-trawl scalefish sector (hook and line, meshnet and trap) was geographically less extensive than trawl because the sector operates in a smaller part of the fishery (see Section 5.1.4 below). We focussed our effort on the specialist non-trawl operators, most of who attended each SENTA meeting, and did not engage with the large number of small operators who complete small amounts of non-trawl scalefish fishing as a sideline to another method such as lobster fishing.

Liaison with the Danish Seine sector was limited due to its relatively simple structure in terms of geographic extent, habitat use and target species (see section 5.1.4).

5.1.2 Liaison with other stakeholders

We provided project updates to many other stakeholders during the life of the project: through the project website, formal talks and distributing flyers/ miniposters, and via the

Steering Committee. These have included presentations to the AFMA board; the Fisheries Minister; FRDC, to the NOO, DEH, AFMA Environment Section and WWF (Steering Committee); SETFEAG, and SEFAG port tour (Table 4.1.2.1).

5.1.3 Data security and confidentiality

All data sets and map products were registered and tracked during the course of the project. No electronic or paper map product was shown or distributed to anyone other than the contributing fisher without prior direct approval. Maps sent to contributors for checking and not returned or destroyed remain as 'outstanding loans' in the project database. Derived (summary) map products, such as the poster made for SETFIA, were used only with the relevant fisher's and Association's approval. At the time of writing, the only instance of project information being contributed to the MPA process was the release of general information on terrain types in the Zeehan candidate area (MPA1) through SETFIA and ASIC.

5.1.4 Characteristics of industry sector data sets

Despite some similarities in the raw form of the electronic data collected from each sector, there were many important differences that affected the ways in which the data could be used. A range of important characteristics is summarised in (Table 5.1.4.1) and detailed below to provide the context for the subsequent analyses:

Important characteristics of otter trawl sector data included:

- data related to one type of fishing: otter board trawling
- data were relatively widespread around the fishery, reflecting fishery-wide activity targeting a wide range of species across a range of depths
- data sets provided complete mapping coverage of the seabed because boundaries of fished and unfished areas were marked in track-plotter data. Note, however, that some 'in-filling' (additional 'CSIRO' polygons) was necessary for areas for which there was no track-plotter data – mostly locations where trawling did not occur.
- the geographical extent of information from each individual usually covered one or two fishery subregions, i.e. an extent of 100s or 1000s of sq km
- most areas (fishing grounds) were named (a valuable attribute for navigation and communication purposes)

- many data were made available to the project because they were already widely distributed within the sector and were regarded as having a lower level of confidentiality. The existence of this type of data, termed 'community' information, results both from the history of many operators mapping out the same grounds over decades of fishing, and from its distribution on floppy discs (sometimes unauthorised) during the era when track plotters and personal computers were widely adopted by the sector.
- comparisons of multiple data sets and interpretations for the same areas was possible due to the relatively large number of trawl data sets available
- spatial extent of effort was relatively stable over the project's duration, i.e. only localised expansion of seabed areas used for fishing
- spatial distribution of fishing positions were recorded in SEF1 logbooks as latitude and longitude of start and end points of trawls. This enabled fine-scale analysis, including overlay onto industry map of grounds.
- Important characteristics of non-trawl sector data included:
- data related to four types of fishing: drop-line, autolongline, fish trapping, fish meshnetting (gillnetting)
- data were considerably more restricted in distribution reflecting fewer active operators# and the greater degree of targeted effort for fewer species on specific (harder, rocky) seabed types in relatively restricted depth ranges (most activity was reported from the shelf edge and upper slope)
- way-point data tended to mark exact fishing positions rather than boundaries of areas or seabed types, resulting in multiple localised coverages
- the geographical extent of information from each individual was highly variable, ranging from part of one fishery subregion to many subregions
- most areas (fishing grounds) were unnamed
- because most data were localised they tended to be highly confidential (only the individual or a few operators using the same grounds)

- interpretation of seabed types enabled a degree of cross-referencing to trawl data (types not boundaries)
- little comparison was possible in any fishery subregion due to the relatively small number of non-trawl data sets available
- spatial extent of effort relatively unstable, i.e. large scale expansion of auto-longlining into previously unused seabed areas; reduction of meshnet fishing for scalefish; extension of trap fishing area; reduction of drop-line effort
- spatial distribution of fishing positions recorded in SEF1 logbooks as half-degree grid cells. This precluded any fine-scale analysis, including overlay onto industry map of grounds.

Important characteristics of Danish Seine sector data included:

- data related to one type of fishing: Danish Seining
- data were highly concentrated in one region of the fishery (the continental shelf off Lakes Entrance), reflecting a small number of target species in a relatively narrow depth range (continental shelf)
- few way-point data collected
- few names for areas (fishing grounds)
- no comparison of data sets
- spatial distribution of fishing positions recorded in SEF1 logbooks as latitude and longitude of start and end points of sets.

many part-time and multi-permit fishers not interviewed

Table 5.1.4.1 Summary characteristics of industry sector data sets influencing their use in this study

	Fishing sector		
Characteristic of data set	**Otter trawl**	**Non-trawl**	**Danish Seine**
No. of primary gear types	1	4	1
Geographical extent of data	Fishery-wide	Selected parts of fishery	One primary location
Depth range of operation (m)	25-1300	mostly 200-600	25-200
Mapping coverage*	Complete	Localized	Localized
Extent of areas known by individuals	Large	Small to large	Small to large
Named fishing areas	Most	Some	Few
Relative level of confidentiality for data provided	Moderate	High	N/A
Multiple data sets compared	Yes	No	No
Spatial distribution of effort stable	Moderately stable	Highly unstable	Stable
Resolution of SEF1 logbook data	Lat/ long for start and end of all trawls	Half-degree grid cell	Lat/ long for start and end of all sets

*complete= no gaps in coverage; localized= many small areas with large gaps in between

5.1.5 Fishing grounds – a working definition

Our spatial units for analysis in this study are 'fishing grounds', and in general terms, we have defined them as natural areas of the seabed characterised by a mix of biological and geological features relevant to fishing (see Section 4.3.3). A consequence of the complex interactions between boundaries and terrain types is that individual fishing grounds vary greatly in size.

Fishers' perceptions of how to define particular grounds using boundaries and terrain types were based on a variety of information: what fishing (sampling) gear they use, what they see on their echosounders, the types of target species and bycatch material in catches, gear damage, a broad knowledge of species distributions by depth, and knowledge of the surrounding seascape (adjacent grounds).

How grounds were defined was also determined by fishers' willingness to provide information; importantly, the precision of that information was also determined by the degree of commercial confidentiality associated with it. Confidentiality on fishing grounds is determined, in large part, by their spatial extent, importance and degree of use (how widely they were known by other fishers). The degree of confidentiality is broadly different between sectors (see Section 5.2.1), highly variable around the fishery (least known grounds are often furthest from major ports), and related to the complexity of terrain types (complex grounds such as canyons may have localised hot spots and be difficult to access). Because this project required only mapping at the resolution of grounds we were able to minimise the amount of sensitive information recorded, and therefore minimise the risk that the information supplied would be compromised.

Fishers were confident to define fishing grounds as static locations in space, but repeatedly emphasised how their ecology varied over smaller spatial scales and through time. While the location, depth and terrain type of a ground determines what types of target species are likely to occur, and what types of fishing gears can be used to fish them, its productivity (availability of target species of marketable size in commercial quantities) may be highly variable in time and space. A particular ground may 'fire' for certain species over large or only localised areas, over only certain terrain types or in certain depths, over seasons or only periods of days, and may be productive every year or only in certain years.

5.1.6 Producing a map of fishing grounds

Two relatively small example areas illustrate results of the map making process: trawl vessel way-point data in an area off the Victorian/ NSW border surrounding the prominent Gabo Reef (1,320 sq km) showing data for two fishing grounds; non-trawl way-point data in a canyon area (10.6 sq km) off eastern Tasmania (Fig. 5.1.6.1 a to h). The top images (a, b) show the general locations on navigational charts. The second pair of images (c, d) show trackplotter data for the same areas printed on paper (usually chart-sized A1 format) for interpretation (M1 level map). The next pair of images (e, f) include interpreted fishing ground boundaries (M3 level map), and (g, h) the final GIS map view of grounds following removal of plotter data. At this stage, prior to collection of questionnaire data on habitat attributes, the grounds have been coloured to show general contrasts in seabed type (reef vs sediments).

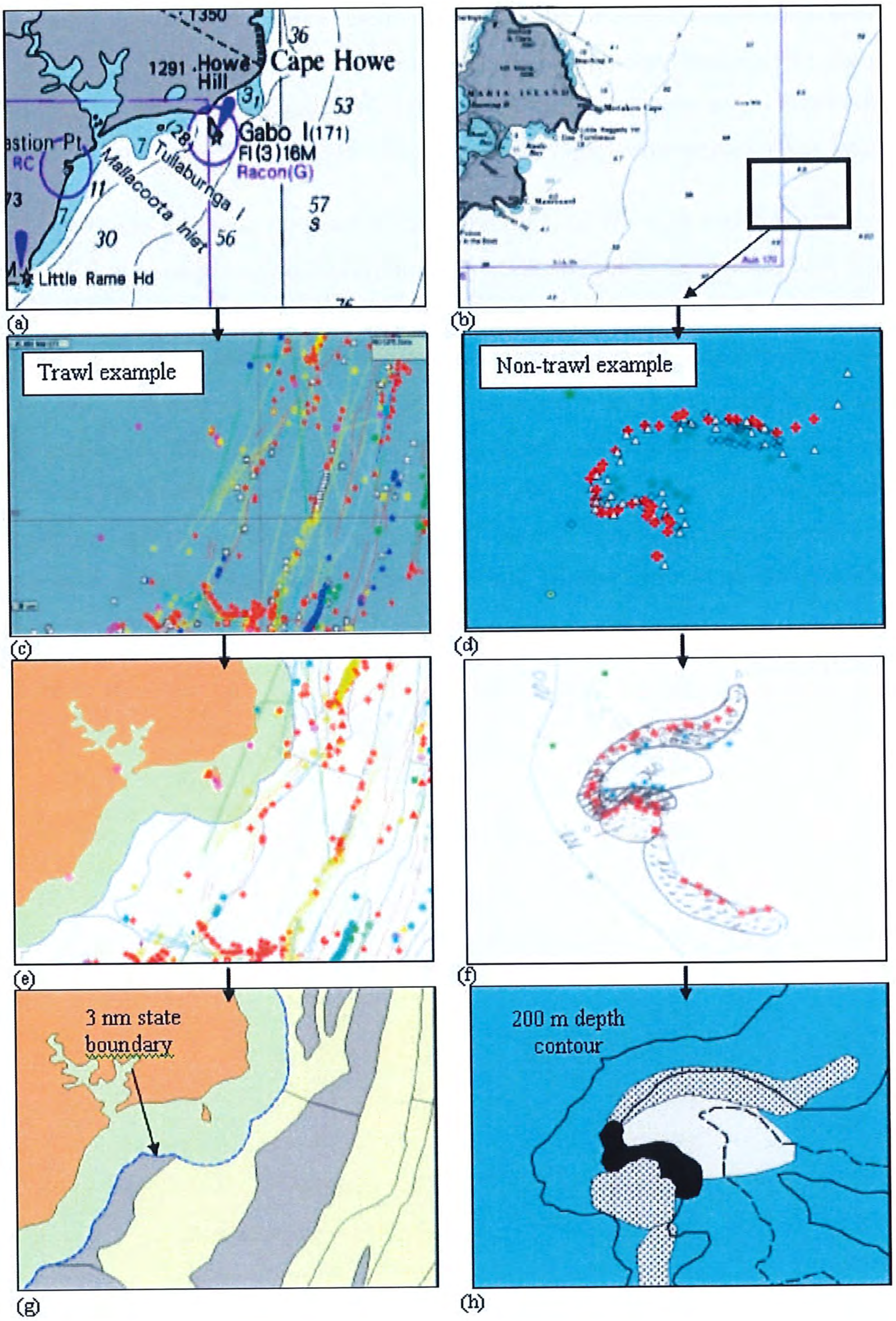
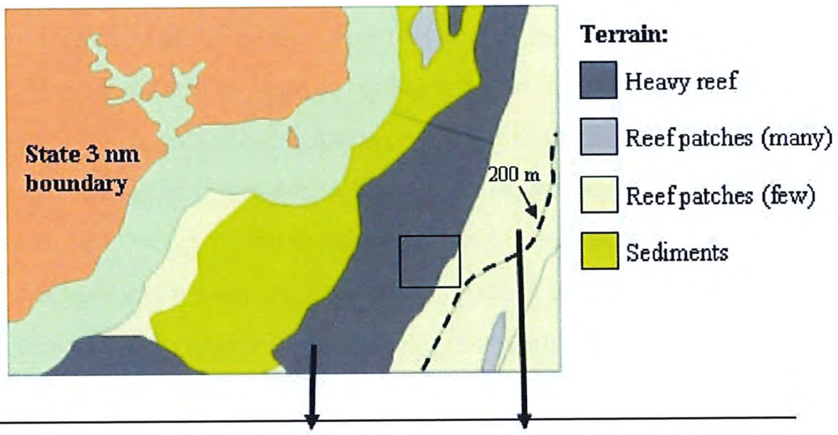


Figure 5.1.6.1 Sequence of map making process, with reference to Fig. 4.4.4.1 (Section 4.4.4). (a, b) Navigational chart for portions of the SEF showing the level of generally available information (c, d) Track plotter data for the same areas printed on paper for interpretation (M1 level map). (e, f) Track plotter marks with interpretation of fishing ground boundaries transferred from paper copy to a GIS map (M3 level map). (g, h) GIS map view of grounds following removal of plotter data. At this stage grounds have been coloured to show general contrasts in bottom type not by habitat attributes.

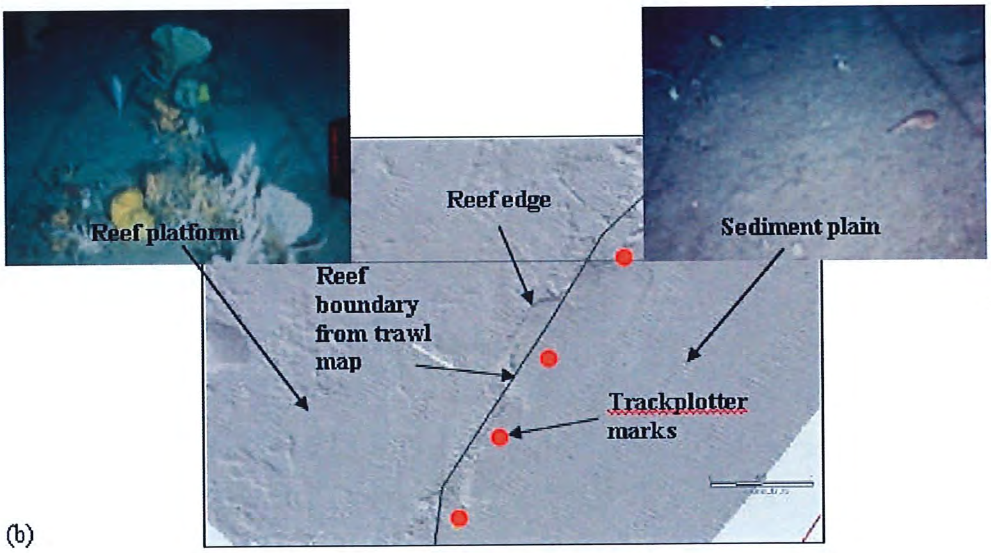
Once the map had been linked to other data attributes in the questionnaire database, maps could be coloured according to particular themes ('thematic mapping'). An illustration here shows the next stage of the Gabo Reef example with thematic mapping of terrain type and example data given for two grounds (Fig. 5.1.6.2 a).

The second part of this figure (Fig. 5.1.6.2 b) also shows how scientific mapping data from part of the reef that can used for validation and interpretation (see Sections 5.1.12 and 5.3). The map is a multibeam 'swath' acoustic image showing seabed relief, annotated with seabed photographs taken with a towed camera system (see Sections 4.6 and 5.4). A very small difference in position between the mapped boundary between Gabo Reef and the "Outside the Reef Ground" and the original trawl data points (~200 m) results simply from the process of drawing boundaries in pencil along the trackplotter marks and then visually re-drawing these in the GIS map. This example shows clearly how precisely industry's information has defined the reef boundary, how well the information was transcribed, and the types of science data that are useful for validating and interpreting the habitat information.



(a)

Name	"Gabo Reef"	"Outside the Reef (431k)"
Area (sq km)	277	431
Terrain	Heavy reef	Reef patches (few)
Bottom type	70% High heavy reef 20% Low heavy reef 10% Gravel	40% Sand 40% Gravel 10 % Sandstone 5% Slabby 5% Heavy low reef
Boundary confidence	2	2
Bottom type confidence	2	3



(b)

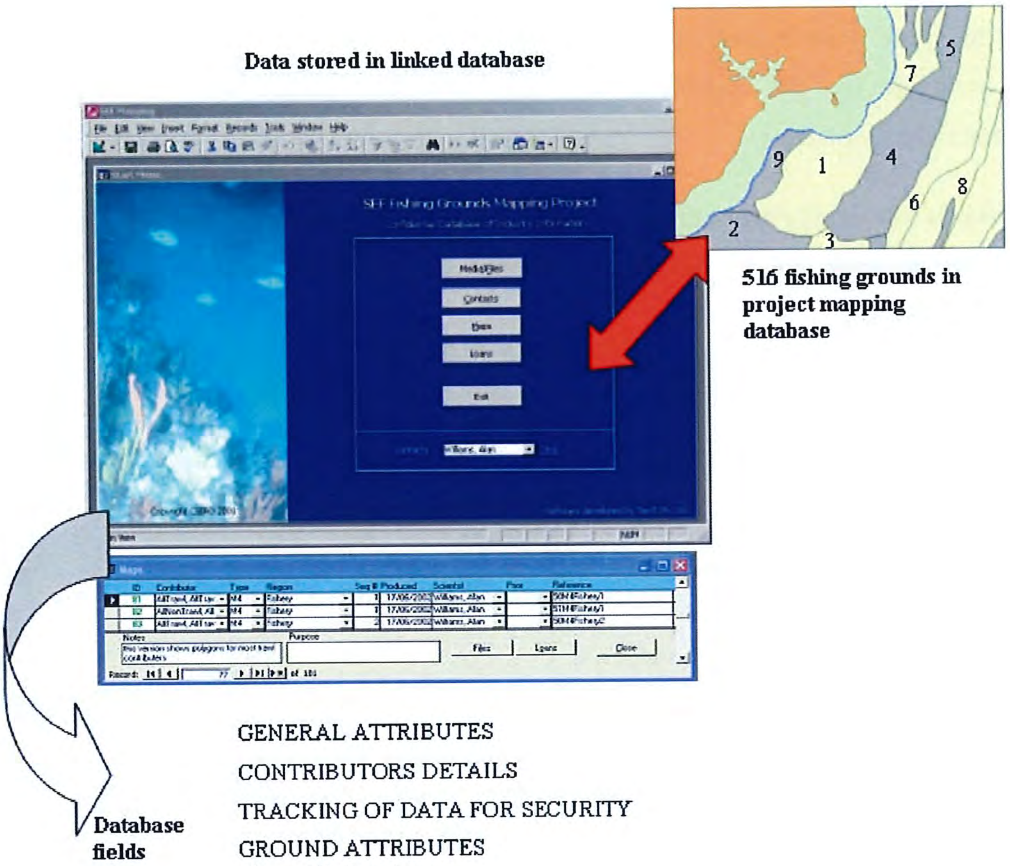
Figure 5.1.6.2 Example from project map showing Gabo Reef and adjacent fishing grounds (a) industry data with mapping of grounds based on terrain and some summary data for two grounds, b) showing scientific data for a small section of the outer reef edge: a multibeam 'swath' acoustic map with the original trawl trackplotter data and matching boundary line overlaid, and photographs illustrating the habitat types of the reef platform and sediment plain.

Producing a fishery scale map of fishing grounds in this way can be visualised as making and assembling a jig-saw puzzle. For the purposes of this project, it was desirable to have complete coverage for the entire fishery region – a complete set of jig-saw pieces covering the area of interest (State boundary line in 3 n.m. out to 1300 m depth). In many respects, the trawl sector data set had the highest utility for this because it largely met these key needs (Table 5.1.4.1). Non-trawl data were useful to corroborate trawl sector information, and provide additional interpretation for a large number of areas, but did not meet the key needs of complete coverage for areas across the fishery region. For this reason they were maintained as a separate set of records. Similarly, no data from the Danish Seine sector were used in the final map database, in part because it was so localised, and in-part because the main area used by the fishery was the subject of a previous study that involved mapping the seabed (Bax and Williams, 1999).

Because seabed information was not available for all areas of the fishery, it was necessary to in-fill some areas: in the jig-saw analogy, to add a few missing pieces. The trawl sector data set was sufficient to delineate 452 fishing grounds, but an additional 64 areas were added to complete coverage for the entire fishery region. These were recorded as 'CSIRO-contributed' areas in the database, and their attributes, such as terrain type, were based on published analysis of the distribution of effort by other fishing sectors from logbooks (e.g. as mapping in the BRS publication Marine Matters), on information provided by fishers from other sectors, and from scientific survey data.

In summary, the combination of trawl-contributed and CSIRO-contributed areas comprise the 'CSIRO-industry map database' (= the project database). Non-trawl and Danish Seine areas were maintained separately in the database.

The project database provided the backdrop on which to overlay additional scientific information at both fishery-wide scales (e.g. logbook data, temperature and current maps) and fine scales or point sources (e.g. acoustic maps and photographs) (Fig. 5.1.6.3). In particular, it formed the background for the analysis of trawl sector logbook data which were recorded at fine-scale (latitude/ longitude) resolution (Table 5.1.4.1). For analysis, each fishing ground becomes a unique area (polygon) in the Geographical Information System (GIS) to which other questionnaire-based attributes are linked in the database.



GENERAL ATTRIBUTES

CONTRIBUTORS DETAILS

TRACKING OF DATA FOR SECURITY

GROUND ATTRIBUTES

- Bottom type
- Boundary definition
- Confidence levels for bottom type and boundaries
- What the bottom looks like (seabed geomorphology)
- What the bottom is made of (substratum)
- Area (sq km)
- Depth range
- Membership of other regions
- Catch (total and individual species)
- Effort (hours/ shots/ vessels)
- $ value (total catch)

LOGBOOK ATTRIBUTES

Figure 5.1.6.3 A diagrammatic summary of the CSIRO – Industry SEF mapping project database and some key fields.

5.1.7 Fishing ground boundaries

An overall summary of boundary types in the two separate sets of records (non-trawl records and project data (Table 5.1.7.1) showed that most boundaries are based on distinct physical features (such as reef edges or canyons) or distinct depths (that are surrogate measures for well-defined biological distributions) In the project data (Table 5.1.7.1 b), these accounted for about two thirds of boundaries in total (~40% physically distinct and ~26% depth distinct). A higher proportion of physically distinct boundaries in the non-trawl data reflects a higher degree of targeting of seabed features; the relatively high proportion of physically indistinct non-trawl boundaries was due to the inclusion of many deliberately 'fuzzy' boundaries around precisely targeted features. These summary data provide an insight into the structured nature of the SESSF seascape and its compartmentalization for fishing.

Table 5.1.7.1 Basis for identifying boundaries around 516 fishing grounds; four separate boundary segments (nominally north, south, east and west) shown separately.

	Boundary segment					
Boundary type	**North**	**South**	**East**	**West**	**Total**	**%**
Physical distinct	219	204	209	192	824	39.9
Physical indistinct	56	33	37	46	172	8.3
Depth distinct	68	103	195	171	537	26.0
Depth indistinct	10	6	22	27	65	3.1
Arbitrary	136	155	48	44	383	18.6
Political	23	14	3	35	75	3.6
Unrecorded	4	1	2	1	8	0.4
Total	516	516	516	516	2064	100

Arbitrary boundary segments, resulting most often from an alignment with another seabed feature or landmark, were more common in the project data compared to non-trawl (19 vs 6%). This is because of the sub-division of large contiguous sediment plains (many 10s km in length) based on trawl duration, i.e. into lengths of 10s km representing single tows, and from the creation of CSIRO 'fill-in' polygons in the project data. Relatively few project data boundaries were based on indistinct features or depths, or political lines, and only 8 segments had unrecorded reasons for their placement. Boundary types were not categorized in the Danish Seine data sets because they were not clearly defined (see section 5.1.4 above).

5.1.8 Fishing ground size

The sizes of SEF fishing grounds, as defined for this project, are highly variable ranging from 0.6 sq km to 13,000 sq km, with the size range of non-trawl grounds small relative to that in the project data set. Both ends of the size distribution in both data sets contain a mix of realistic and anomalous cases, and the vast majority of grounds are relatively small; for example, in non-trawl data 85% are smaller than 100 sq km, and in the project data 75% are less than 200 sq km (Fig. 5.1.8.1).

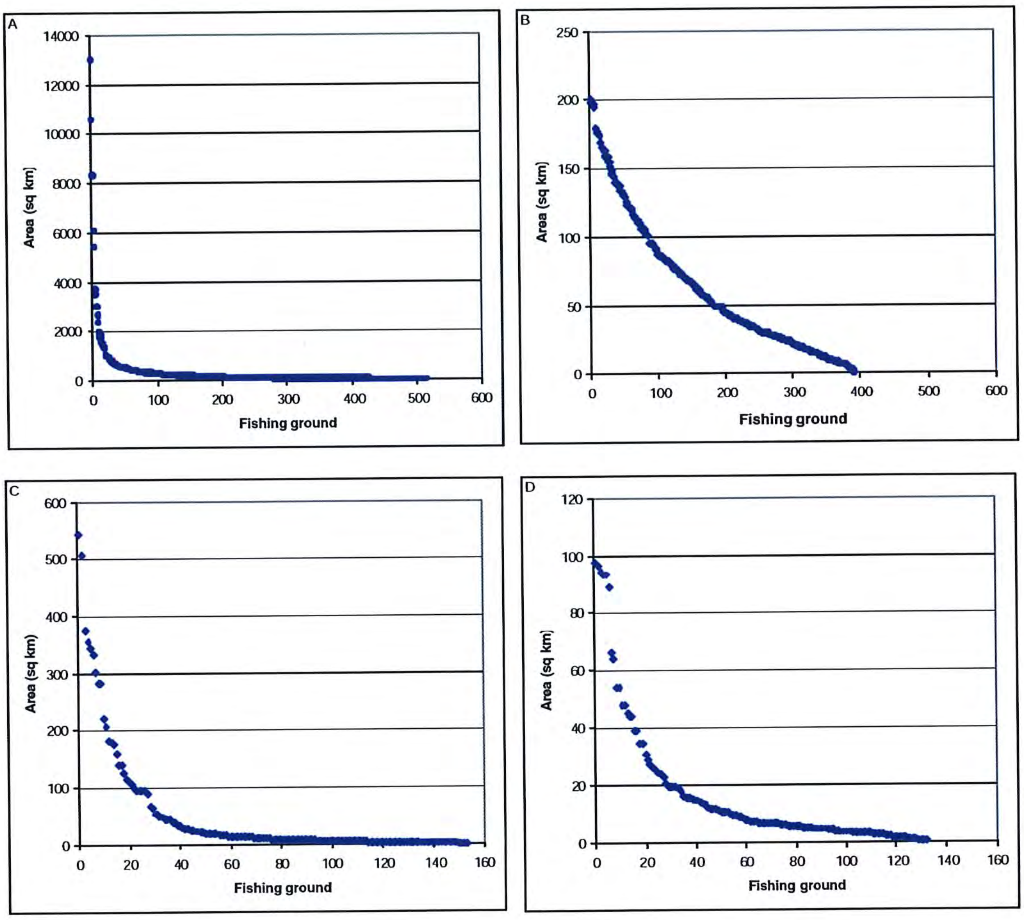


Figure 5.1.8.1 The distribution of fishing ground size (plan area in sq km) for (a) 516 fishing grounds in the project data set; (b) the 392 grounds less than 200 sq km in the project data set; (c) 153 fishing grounds in the non-trawl data set; (d) 132 grounds less than 100 sq km in the non-trawl data . Note: changes in scaling on both axes.

Two classes of grounds account for the largest in non-trawl data: coarsely defined auto-longline grounds that are long corridors of upper slope defined by inner and outer depth boundaries; and relatively small, precise and confidential areas that are aggregated into large polygons and/ or have 'buffer' zones around them. In the project data set, the 49 grounds representing the largest 10% include eight areas of the deep mid-slope (between approximately 500 and 1,300 m depths) and 41 areas on the continental shelf. Of these 49, the majority are poorly known by trawl fishers (being lightly fished, fished only in part or unfished) and their large size is mainly due to a lack of information on which to sub-divide them. However, several others are key fishing grounds and include, for example, three contiguous grounds making up the large continental shelf area off eastern Victoria: the "Twofold Shelf" (5,418 sq km), the "Flat Patch" (1,514 sq km) and "Sand Patch" (1,505 sq km) in the Eden/Smithy's subregion. Collectively, these three massive sediment plains make up a large proportion of the seabed used by the Eden and Lakes Entrance trawl and Danish Seine fleets.

Grounds at the smaller end of the size spectrum are mostly defined features. In non-trawl data, 17 of the 21 grounds less than 3 sq km are physically distinct or indistinct rocky areas, most of which are used for dropline fishing (primarily for blue-eye trevalla). In project data, 20 of the 32 grounds less than 10 sq km are named features of which most are isolated rocky reefs. The remainder are un-named, being either relatively nondescript, or artificially small areas by virtue of an arbitrary or political boundary, e.g. a 3 n.m. State waters boundary creating a small area at the shallow margin of a region of continental shelf.

5.1.9 Seabed terrain types

Within grounds, the first interpretation of the make-up of seabed habitat was by classifying 'Terrains' (four descriptive categories based on estimated proportions of sediment and rocky reef – see Section 4.3.4 for definitions). Non-trawl data cover only about 5% of the SEF, whereas the project data set covers the whole fishery as defined by this study (Table 5.1.9.1, a and b respectively).

Table 5.1.9.1 Terrain types of SEF fishing grounds showing the number of grounds, aggregated plan area (sq km) of each terrain, and percentage of the total fishery area of 141,652 sq km, in (a) the non-trawl data set, and (b) the project data set

a

	Heavy reef	Many reef patches	Few reef patches	Clear sediments	Total
Total grounds	55	59	36	3	153
Total area (sq km)	1,058	4,796	1,383	81	7,318
% of total fishery area	0.7	3.4	1.0	0.1	5.2

b

	Heavy reef	Many reef patches	Few reef patches	Clear sediments	Total
Total grounds	45	150	173	148	516
Total area (sq km)	2,395	68,384	42,974	27,899	141,652
% of total fishery area	1.7	48.3	30.3	19.7	100.0

The project data set shows that most grounds are terrains of 'sediments with few reef patches' (173 grounds in which reef makes up ~5-30% of total ground area). Of the remainder, there are 150 grounds made up by 'sediments with many reef patches' (~30-70% reef) and 148 made up by 'clear sediments' (reef less than 5%). Relatively few (45 grounds) were classed as 'heavy reefs' (homogeneous, contiguous rocky banks).

In terms of area, however, 'sediments with many reef patches' were estimated to make up about half the total area of the SEF seabed. The other half is made up by 'sediments with few reef patches' (~30%) and clear sediments (~20%); the 45 'heavy reefs' make up less than 2% of the area of the seabed.

Summary data for the small area of the fishery covered by non-trawl information are different to the fishery-wide data, and reflect the terrains mostly used for non-trawl fishing. Data show a relatively larger proportion of grounds and areas characterised by rocky bottom (sediments with many reef patches and heavy reef) and few areas of clear sediments.

5.1.10 Seabed form and bottom types

In addition to classifying each ground on the basis of its terrain, we also used a questionnaire to record habitat information in two classes: 'what the bottom looks like' – the presence or absence of feature types (geomorphology), and 'what the bottom is made of' (substratum) – the estimated proportions of substratum types. At the most simple level, an overview of seabed types is provided by occurrence (presence/ absence) of features and bottom type attributes across grounds (Table 5.1.10.1) and (Table 5.1.10.2).

Table 5.1.10.1 The presence or absence of ten primary seabed substratum types ("what the bottom looks like") for each fishing ground in the non-trawl and project data sets.

	Non-trawl data set			Project data set		
Geomorphology	Present	Absent	Total grounds	Present	Absent	Total grounds
Flat	45	108	153	268	248	516
Sloping	52	101	153	158	358	516
Steep	76	77	153	162	354	516
Undulating	27	126	153	127	389	516
Rugged	71	82	153	155	361	516
Bank	35	118	153	73	443	516
Valley	11	142	153	40	476	516
Canyon	38	115	153	69	447	516
Hill	9	144	153	19	497	516
Seamount	3	149	153	2	514	516

Table 5.1.10.2 The presence or absence of ten primary seabed substratum types ("what the bottom is made of") for each fishing ground in the non-trawl and project data sets.

	Non-trawl data set			Project data set		
Substratum type	Present	Absent	Total grounds	Present	Absent	Total grounds
Mud - soft & boggy	8	145	153	165	351	516
Mud - compact	91	62	153	271	245	516
Sand	14	139	153	124	392	516
Gravel	2	151	153	93	423	516
Rubble	22	131	153	22	494	516
Mud boulders	0	153	153	58	458	516
Slabby	48	105	153	169	347	516
Sandstone	7	146	153	8	508	516
Heavy low reef	75	78	153	210	306	516
Heavy high reef	90	63	153	132	384	516
Unknown	0	153	153	55	461	516

Presence/ absence scores for geomorphology ('what the bottom looks like') in the project data set showed a high number of grounds contain areas of flat or sloping bottom (268 and 158 grounds respectively), substantial numbers contain steep, undulating or rugged bottom (127-162), while relatively few (< 73) are, or contain, banks, canyons or valleys. Only 19 have hills, and two are described as containing seamounts. The non-trawl data refer to one additional ground with a seamount(s), and indicate higher relative occurrences of canyons, rugged and steep areas.

Presence/ absence scores for bottom types ('what the bottom is made of') in the project data set showed most grounds (> 50%) contain areas of muddy substrata, with a differentiation between relatively compact and soft types. A high proportion of grounds (> 40%) also contain patches of heavy low reef. Slabby bottom, soft mud, heavy high reef and sandy substrata are present in substantial numbers of grounds (124-169), whereas gravel bottom, mud boulders, rubble and sandstone were reported as relatively uncommon (< 100 or 20% of grounds). Compact muds were also the most commonly reported bottom type in the non-trawl data set, whereas slabby and reef bottoms were reported to be present in relatively high proportions of grounds.

5.1.11 Reconciling terrains and bottom types

For grounds in the project data set, we then examined the information on bottom type (Section 5.2.7) to check that it was consistent with the more coarsely resolved classification of terrains (Section 5.2.6). For this purpose, each ground was classified according to its percentage scores for bottom type independently of the terrain type classification. The five 'hard' consolidated bottom types (mud boulders, sandstone, slabby, low heavy reef and high heavy reef) were aggregated in a 'Reef' class, while five 'soft' sediment types (soft and compact muds, sand, gravel and rubble) were aggregated into a 'Sediment' class. Not all grounds could be compared because some (107) lacked bottom type information (scored either as 'unknown' or as presence/absence). Each of 409 grounds with bottom type information then had two percentage scores for reef and sediment totalling 100% (Table 5.1.11.1).

Table 5.1.11.1 Estimated proportions of substratum types) aggregated into 'Reef' and 'Sediment' for comparison with general classification of fishing grounds into four classes of bottom type for the project data set. Shaded areas indicate Reef: Sediment ratios that are consistent with the general criteria specified to differentiate the four classes of bottom type (<5%, 5-30%, 30-70%, and >70% reef). Note: substratum not estimated for 107 of 516 fishing grounds.

Estimated % substratum		Bottom type class				
Reef	Sediments	Heavy reef	Sediments, many reef patches	Sediments, few reef patches	Clear sediments	Total no. grounds
0	100				117	117
5	95			30	10	40
10	90		2	47	15	64
15	85		1	15		16
20	80		7	20	1	28
25	75		1	4		5
30	70		7	7		14
34	66		1	1		2
40	60		7	2		9
45	55			1		1
50	50		22	10		32
55	45		1			1
60	40	3	16			19
65	35		1			1
67	33		1			1
70	30		10			10
75	25	1	3			4
80	20	1	6			7
90	10	7	4			11
95	5	2				2
100	0	21	3	1		25
Total no. grounds		35	93	138	143	409
Terrain pres/ abs only			31	20	1	52
Terrain unknown		10	26	15	4	55
Total no. grounds		45	150	173	148	516

There was a high degree of agreement between the two data sets on 409 grounds for which bottom type information was provided. Shaded areas in Table 5.1.11.1 indicate Reef: Sediment ratios that are consistent with the general criteria specified to differentiate the four terrains (<5%, 5-30%, 30-70%, and >70% reef). These represent the vast majority of grounds in each class of terrain.

There were, however, a number of bottom type outliers in each class of terrain and it was of interest to understand why they appear to be inconsistent. For example, three grounds estimated to have only 60% reef were put into the heavy reef class (terrain type 1). Each of these was an area of densely scattered reef patches rather than contiguous reef, but being inaccessible to trawling were regarded as 'reefs' by contributors.

In the second class (sediments with many reef patches), three grounds were scored at 100% reef and another 13 at >70% reef. The first three were variously: a dumping ground for old gear and rocks with some trawl shots; an untrawlable area of low reef with intervening sandy gutters; and a poorly known rocky area with a low confidence score (see section below). The other 13 were predominantly shallow (mid-shelf) areas of very mixed, but predominantly rocky bottom types and upper slope grounds with areas of slabs; they also included a deep mid-slope debris field associated with the base of submarine canyon, and a seamount. In general terms, these outliers can be classed as generally rocky bottom with limited or no scope for trawling, estimated only indirectly (e.g. from echosounder readings) or incompletely (e.g. untrawlable areas incompletely explored), but not heavy reef.

Slabby bottom and mud boulders made up most of the 'Reef' in the 21 outlier grounds estimated to be >30% reef but classified in the third class (sediments with few reef patches). Again, in general terms, this appears to be linked to a perception of how accessible a ground is to trawling: grounds are classified as being 'less reefy' where the presence of slabs and mud boulders does not necessarily prevent trawl fishing. However, generalisation is difficult as the 21 grounds range from the shallow shelf to deep slope, and include trawl grounds, others with few trawl tows, and others that remain unfished.

As above, slabby bottom makes up the estimated 10% 'Reef' in the 15 grounds classified as clear sediments (terrain type 4); these are all trawl grounds. The outlier estimated to have 20% 'Reef' is an area with many mud boulders on the deep mid-slope trawled for orange roughy.

5.1.12 Quality assurance

Applying confidence levels to boundary and terrain type data was valuable for estimating the reliability and variation in the quality of the mapping and attribute data provided by fishers. Overall, the categories and terminology used for boundaries and terrain/ bottom types in the questionnaire were found to be familiar to fishers and were used consistently for the vast majority of fishing ground descriptions. The criteria applied to assess confidence were conservative, with a strong emphasis placed on corroboration and validation (Table 4.4.3.1). The highest levels of confidence were allocated only when distinct natural boundaries or unmixed (homogeneous) terrain types were judged to exist in nature, when responses were corroborated, and when a boundary was completely known or a terrain type was validated.

Judged against these criteria, the scores for the project data set comprised of 516 boundary confidence estimates indicated a high quality data set: 230 grounds (45%) were scored as having a high level of confidence, with the majority of the remainder scored as very high or moderate confidence (114 and 153 grounds respectively); low confidence was attributed to only 17 grounds (Table 5.1.12.1).

Table 5.1.12.1 Confidence levels for (a) boundaries and (b) bottom (seabed) types for 516 fishing grounds in 17 subregions of the SEF

(a) Boundaries

	Certain	Very high	High	Moderate	Low	
Region	1	2	3	4	5	Total grounds
Beachport	0	9	40	9	5	63
Portland	0	1	40	10	3	54
Coral Coast	0	0	19	5	0	24
King Island	0	0	4	6	0	10
West Tasmania	0	26	8	12	0	46
SW Tasmania	0	1	6	10	0	17
South Tasmania	0	0	6	26	0	32
Maria	0	4	7	2	0	13
East Tasmania	0	0	2	1	0	3
St Helens	1	0	6	2	0	9
Banks Strait	0	0	5	8	0	13
Babel	0	1	26	10	0	37
Eden/ Smithy's	1	34	15	2	0	52
Eden/Bermagui	0	31	10	9	1	51
Ulladulla	0	0	1	16	2	19
Wollongong	0	7	28	12	3	50
Sydney	0	0	7	13	3	23
Total grounds	2	114	230	153	17	516

(b) Bottom type

Region	1	2	3	4	5	Total grounds
Beachport	0	0	10	53	0	63
Portland	0	0	2	46	6	54
Coral Coast	0	0	1	21	2	24
King Island	0	0	0	8	2	10
West Tasmania	0	0	7	27	12	46
SW Tasmania	0	0	0	12	5	17
South Tasmania	0	0	0	26	6	32
Maria	0	0	0	12	1	13
East Tasmania	0	0	0	3	0	3
St Helens	0	1	0	5	3	9
Banks Strait	0	0	0	5	8	13
Babel	0	0	0	37	0	37
Eden/ Smithy's	0	8	23	21	0	52
Eden/Bermagui	0	0	25	20	6	51
Ulladulla	0	0	0	15	4	19
Wollongong	0	0	6	37	7	50
Sydney	0	0	0	18	5	23
Total grounds	0	9	74	366	67	516

In certain places it was possible to validate and judge the precision of the boundary provided by comparing fishers' information with scientific mapping data. For example, in the case of the outer edge of the Gabo Reef, the accuracy is within approximately 200 m (Fig. 5.1.6.2) – an extremely fine resolution in the context of a regional mapping exercise. In the context of confidence scoring, this ground scored level 2, having a completely known boundary that is indistinct in places that was corroborated by three fishers. Only two ground boundaries were classed as certain: these were two rare examples where scientific swath map data was available to enable complete boundary definition and validation (Big Horseshoe Canyon and St. Helens Hill).

The scores for 516 terrain type confidence levels showed the majority of grounds (366 or 71%) were categorised with a moderate level of confidence, and that relatively few high or very high scores were given (Table 5.1.12.1). This outcome results mostly from circumstances outside the control of contributing fishers: the lack of validation by physical samples from most grounds – recognising that, by intention, trawls do not return samples of substratum and mostly avoid rocky bottom types – and the fact that most grounds are large (10s sq km and larger, see above) with mixed (heterogeneous) bottom types. In total, 83 grounds (16%) were scored with high to very high confidence; these included the nine grounds where there are ground-truthed scientific data (samples and photographs) from the study by Bax and Williams (1999). Only 67 grounds (13%) were scored with low confidence: this group is comprised mainly of canyons (with mixed and/ or unknown terrain types), unfished 'reef' areas, and unfished areas on the shallow continental shelf and deep continental slope.

Table 5.1.12.2 Confidence levels for (a) boundaries and (b) bottom (seabed) types for 153 fishing grounds in 11 subregions of the SEF (non-trawl data set).

	Certain	Very high	High	Moderate	Low	
Subregion	**1**	**2**	**3**	**4**	**5**	**Total grounds**
(a) Boundaries						
						Total
Beachport	0	0	22	1	0	23
King Island	0	0	0	0	1	1
West Tasmania	0	0	10	0	0	10
SW Tasmania	0	0	6	0	0	6
South Tasmania	0	0	13	0	0	13
Maria	0	0	5	0	0	5
East Tasmania	0	0	4	1	0	5
St Helens	0	0	7	6	0	13
Banks Strait	0	0	7	4	2	13
Babel	0	0	7	3	5	15
Eden/ Smithy's	0	0	20	21	8	49
Total grounds	0	0	101	36	16	153

(b) Terrain

	1	2	3	4	5	Total
Beachport	0	0	13	9	1	23
King Island	0	0	0	1	0	1
West Tasmania	0	0	8	1	1	10
SW Tasmania	0	0	2	4	0	6
South Tasmania	0	0	6	7	0	13
Maria	0	0	3	2	0	5
East Tasmania	0	0	3	2	0	5
St Helens	0	0	5	8	0	13
Banks Strait	0	0	5	7	1	13
Babel	0	0	5	9	1	15
Eden/ Smithy's	0	0	6	38	5	49
Total grounds	0	0	56	88	9	153

Two factors resulted in a conservative estimate of the degree of corroboration: interviews that involved two or more contributors providing details together were not judged as providing corroborated data (this happened in several interviews); and no cross-sector corroboration was included. The confidence levels on many grounds would be increased by updating with recently obtained ground-truth data (e.g. Williams et al. in press).

In overview, however, we interpret these terrain type scores as being a moderate to high quality data set in which recorded terrain types provide a good general description of the types and mix of substrata in relatively large, and often complex, seabed areas.

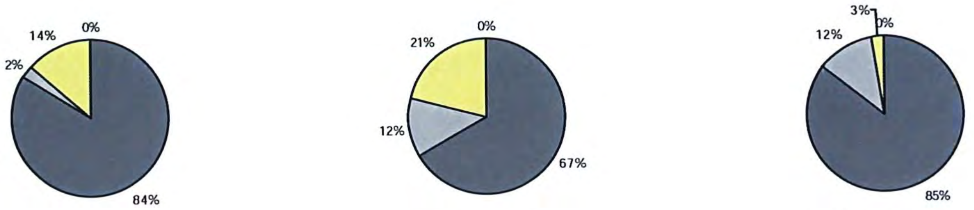
Confidence estimates for the 153 grounds comprising the non-trawl data set were slightly lower for boundaries and higher for terrain types (Table 5.1.13.1.). Boundary scores included none as certain or very high and higher proportions were scored as low. This mainly reflected the lower numbers of contributors (less opportunity for corroboration) and the inclusion of deliberately 'fuzzy' boundaries (Section 5.1.7) around some precise locations. A higher proportion of ground bottom types were scored as high, reflecting the focus on generally smaller areas of more homogeneous (harder/ rocky) bottoms where echo sounder records provided a reliable indication of bottom type. But again, we interpret the data as a moderate to high quality data set, which would be improved with additional corroboration or ground-truthing.

5.1.13 Fishery subregions: ground characteristics

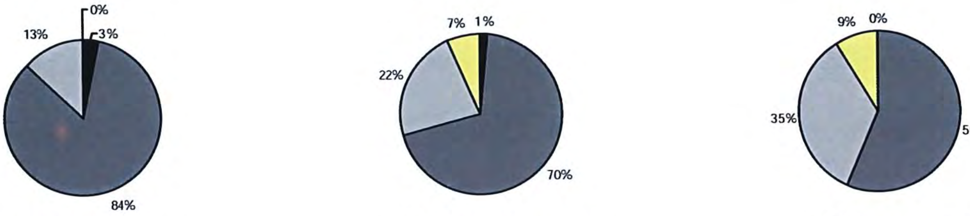
Examination of data from 17 separate fishery subregions show there are distinct differences in the extent of seabed terrain types around the SEF, and that this affects the distributions of fishing effort by each sector at a coarse scale. (The Lakes subregion was excluded due to the paucity of mapping data.) Data overviews of terrain type distributions are presented by subregion (Fig. 5.1.13.1), together with a list of grounds (Tables 5.1.13.1 to 5.1.13.28) from trawl industry contributors and from non-trawl contributors for some subregions.

Each ground is identified in these tables with industry's names where they exist. Unnamed grounds and CSIRO polygons are identified with a standard code name: a prefix which is a unique area (ground) code, followed by descriptors for subregion and depth zone code, e.g. 152 [Beachport, shelf]. The small number of names appearing more than once represent split polygons in cases where large grounds have been sub-divided – most commonly where a long terrace is divided by a canyon. These names carry an additional suffix which differentiates them based on ground size – given in sq km.

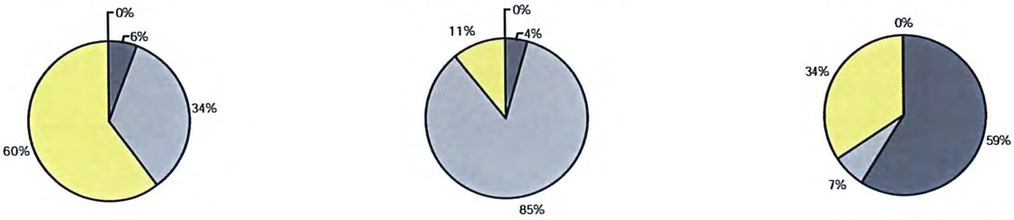
Figure 5.1.13.1 Percentage area of Terrain types for fishery subregions



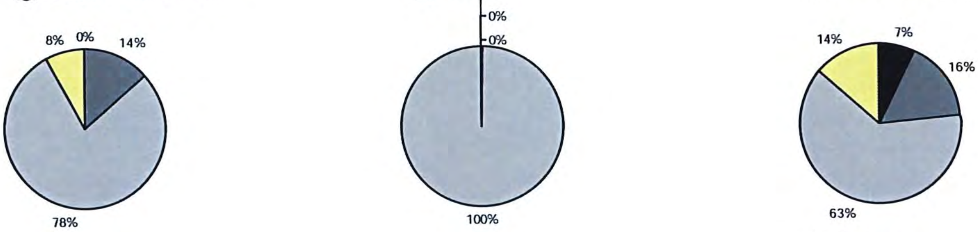
(a) Beachport (b) Portland (c) Coral Coast



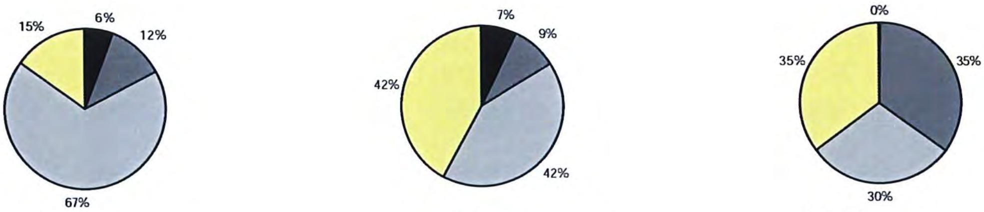
(d) King Island (e) West Tasmania (f) Southwest Tasmania



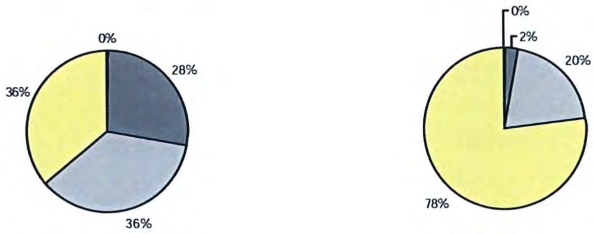
(g) South Tasmania (h) Maria (i) East Tasmania



(j) St Helens (k) Banks Strait (l) Babel



(m) Eden-Smithys (n) Eden-Bermagui (o) Ulladulla



(p) Greenwell Pt - Wollongong (q) Sydney

■ Heavy reefs

▨ Sediments with many reef patches

☐ Sediments with few reef patches

☐ Clear sediments

1. Beachport

Total area: 29,776 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 9,937 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 12,119 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,343 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 594 sq km

Upper continental slope (200-700 m; ~110-380 fm): 2,620 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 3,163 sq km

Table 5.1.13.1 Details of 'trawl grounds' for the Beachport subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Beachport	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Beachport Shelf	3	30	5	55	9942	2
Beachport Shelf	30	55	55	101	12113	2
Beachport Shelf (outer)	55	110	101	201	2157	2
152 [Beachport, shelf]	80	100	146	183	67	4
Western Moe Shot	85	105	156	192	56	4
153 [Beachport, upper-slope]	100	150	183	275	17	3
171 [Beachport, upper-slope]	100	200	183	366	7	1
168 [Beachport, upper-slope]	100	240	183	439	68	2
189 [Beachport, upper-slope]	100	240	183	439	143	2
163 [Beachport, upper-slope]	100	270	183	494	30	2
164 [Beachport, upper-slope]	100	300	183	549	11	1
Eastern Gem (shallow)	120	160	220	293	19	3
Eastern Canyon	120	500	220	915	60	2
Far West Gem	140	190	256	348	54	4
Western Gem	140	200	256	366	32	4
188 [Beachport, upper-slope]	140	200	256	366	10	1
Main Gem	140	210	256	384	60	4
Stargazer Alley	140	230	256	421	38	4
138 [Beachport, upper-slope]	150	300	275	549	9	2
140 [Beachport, upper-slope]	150	350	275	641	15	4
135 [Beachport, upper-slope]	150	370	275	677	10	2
Macca's Canyon Ground	150	370	275	677	15	3
137 [Beachport, upper-slope]	150	370	275	677	30	2
139 [Beachport, upper-slope]	150	370	275	677	34	2
Macca's Canyon	150	700	275	1281	95	3
Short Shot	160	210	293	384	15	4
Eastern Gem (deep)	160	210	293	384	24	4
Inside Soela Shot (shallow)	160	220	293	403	21	3
148 [Beachport, upper-slope]	160	250	293	458	22	1
183 [Beachport, upper-slope]	160	300	293	549	8	1
Portland Shot	180	240	329	439	81	3
186 [Beachport, upper-slope]	200	280	366	512	20	2

Grounds in project data set from Beachport	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Southeast of Harry's Hill	210	240	384	439	10	1
155 [Beachport, upper-slope]	210	300	384	549	16	3
Main Drag	210	300	384	549	154	4
Horseshoe	220	260	403	476	70	4
193 [Beachport, upper-slope]	220	260	403	476	94	2
Inside Soela Ground	220	280	403	512	32	4
Western West Dory Shot	220	290	403	531	26	4
142 [Beachport, upper-slope]	220	700	403	1281	41	2
151 [Beachport, upper-slope]	230	330	421	604	8	3
166 [Beachport, upper-slope]	240	260	439	476	9	2
Harry's Hill	240	260	439	476	12	2
Southwest Shot	240	330	439	604	56	4
182 [Beachport, upper-slope]	240	330	439	604	48	4
Bowl	240	340	439	622	77	3
147 [Beachport, upper-slope]	250	290	458	531	26	2
162 [Beachport, upper-slope]	250	340	458	622	17	3
179 [Beachport, upper-slope]	260	290	476	531	10	1
South Drag	260	320	476	586	73	4
Dory Shot	260	330	476	604	27	4
Canyon Shot	260	330	476	604	53	4
Eastern West Dory Shot	260	340	476	622	39	3
150 [Beachport, upper-slope]	270	350	494	641	42	2
Inside Soela Shot (deep)	280	340	512	622	50	4
156 [Beachport, upper/ mid-slope]	280	500	512	915	22	2
Western West Dory Shot (deep)	290	340	531	622	26	3
178 [Beachport, mid-slope]	300	700	549	1281	2368	4
190 [Beachport, mid-slope]	300	700	549	1281	238	3
176 [Beachport, mid-slope]	320	700	586	1281	560	4
192 [Beachport, mid-slope]	320	700	586	1281	213	4
Beachport Canyon	340	560	622	1025	56	3
Soela Mud Hills	460	600	842	1098	18	3

Table 5.1.13.2 Details of 'non-trawl grounds' for the Beachport subregion with ground name, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from Beachport	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
[1184, Beachport, upper-slope reef]	110	210	201	384	3.1	1
[1199, Beachport, upper-slope reef]	110	210	201	384	7.1	1
[1189, Beachport, upper-slope reef]	120	220	220	403	3.1	1
[1186, Beachport, upper-slope reef]	120	260	220	476	10.3	1
[1187, Beachport, upper-slope reef]	120	260	220	476	6.3	3
[1219, Beachport, upper slope reef]	130	220	238	403	1.3	1
[1182, Beachport, upper-slope reef]	130	220	238	403	4.2	1
Blue Cod Hill	130	220	238	403	4.8	1
[1181, Beachport, upper-slope reef]	130	220	238	403	8.1	1
[1191, Beachport, upper-slope reef]	130	170	238	311	3.5	2
Double shelf	140	165	256	302	3.4	1
North end of canyons (3)	150	210	275	384	2.3	1
North end of canyons (3)	150	210	275	384	3.4	1
[1185, Beachport, upper-slope reef]	150	240	275	439	4.6	1
North end of canyons (1)	150	210	275	384	6.3	1
North end of canyons (2)	150	210	275	384	10.0	1
[1180, Beachport, upper-slope reef]	160	200	293	366	1.9	1
[1190, Beachport, upper-slope reef]	170	180	311	329	4.3	1
[1188, Beachport, upper-slope reef]	170	200	311	366	10.5	3
[1193, Beachport, upper-slope reef]	210	300	384	549	3.2	1
[1192, Beachport, upper-slope reef]	210	300	384	549	5.1	1
[1200, Beachport, upper-slope reef]	240	280	439	512	1.3	2
[1220, Beachport, upper slope reef]	280	300	512	549	0.6	1

2. Portland

Total area: 10,571 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 1,489 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 2,916 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,976 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 1,191 sq km

Upper continental slope (200-700 m; ~110-380 fm): 1,632 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 1,368 sq km

Table 5.1.13.3 Details of 'trawl grounds' for the Portland subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Portland	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Portland Shelf (inside)	3	30	5	55	1488	2
Portland Shelf	30	55	55	101	2855	2
134 [Portland, shelf]	40	100	73	183	154	2
Portland Shelf (outside)	50	110	92	201	1557	2
76 [Portland, shelf]	60	100	110	183	258	3
Portland Shelf	60	110	110	201	326	2
2nd Main Drag (shallow)	65	100	119	183	241	3
Mud Holes (shallow)	65	100	119	183	402	3
Pt Mac grounds (inside)	70	100	128	183	217	3
Canyon End of Jump Over	80	700	146	1281	57	2
Pt Mac Shot (shallow)	100	230	183	421	90	4
Short Shots (inside)	100	230	183	421	73	4
2nd Main Drag	100	270	183	494	138	4
Horseshoe (inside)	100	270	183	494	140	4
1st Main Drag (inside)	100	270	183	494	159	4
Jump Over (inside)	100	270	183	494	149	4
Mud Holes (inside)	100	270	183	494	87	3
765 [Portland, upper-slope]	110	230	201	421	56	3
763 [Portland, upper-slope]	130	190	238	348	70	2
The Jump Over Canyon	150	700	275	1281	17	4
764 [Portland, mid-slope]	190	700	348	1281	145	2
117 [Portland, unnamed canyon]	200	700	366	1281	46	2
Pt Mac Canyon	220	700	403	1281	42	2
Main Drag Canyon	220	700	403	1281	58	2
74 [Portland, unnamed canyon]	220	700	403	1281	33	2
75 [Portland, unnamed canyon]	220	700	403	1281	10	4
Reef with Tammy R Wreck	230	270	421	494	4	1
Short Shot (hard ground)	230	270	421	494	50	2
767 [Portland, upper-slope]	230	270	421	494	69	2
80 [Portland, upper slope]	230	300	421	549	49	2
766 [Portland, mid-slope]	270	300	494	549	13	4
Short Shot	270	320	494	586	25	4
1st Main Drag	270	320	494	586	33	4
Horseshoe	270	320	494	586	31	4
Jump Over	270	320	494	586	24	4
Mud Holes	270	320	494	586	27	4
2nd Main Drag	270	330	494	604	32	3
Pt Mac Shot	300	350	549	641	30	4
768 [Portland, mid-slope]	300	700	549	1281	198	4
1st Main Drag (outside)	320	500	586	915	101	4
Short Shot (outside)	320	500	586	915	51	4
Horseshoe (outside)	320	500	586	915	50	4
Jump Over (outside)	320	500	586	915	67	4
Mud Holes (outside)	320	500	586	915	96	4
2nd Main Drag (outside)	330	500	604	915	61	4
Pt Mac (outside)	350	500	641	915	102	4

Grounds in project data set from Portland	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Tom's Shot	400	700	732	1281	41	2
Pt Mac (deep)	500	700	915	1281	118	4
1st Main Drag (deep)	500	700	915	1281	106	4
Short Shot (deep)	500	700	915	1281	25	4
2nd Main Drag (deep)	500	700	915	1281	73	4
Horseshoe (deep)	500	700	915	1281	65	4
Jump Over (deep)	500	700	915	1281	72	4
Mud Holes (deep)	500	700	915	1281	85	4

3. Coral Coast

Total area: 11,515 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 31 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 6,067sq km

Outer continental shelf (100-150 m; ~55-80 fm): 3,165 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 312 sq km

Upper continental slope (200-700 m; ~110-380 fm): 606 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 1,334 sq km

Table 5.1.13.4 Details of 'trawl grounds' for the Coral Coast subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Coral Coast	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Coral Coast Shelf (inner)	3	30	5	55	20	2
Coral Coast Shelf	30	55	55	101	6067	2
Coral Coast Shelf (outer)	55	110	101	201	3477	2
122 [Coral Coast, upper-slope]	100	260	183	476	164	3
2nd Dory (inside)	100	260	183	476	20	3
1st Dory (inside)	100	270	183	494	59	3
108 [Coral Coast, upper-slope]	100	270	183	494	29	2
3rd Dory Ridge	100	400	183	732	12	3
Twofold Bay Ground (inside)	100	400	183	732	209	2
Criss Cross (inside)	220	400	403	732	36	3
2nd dory	260	320	476	586	16	4
3rd dory	260	320	476	586	34	4
1st Dory	270	320	494	586	29	4
4th Dory	270	350	494	641	12	4
1st Dory (outside)	300	500	549	915	79	3
2nd Dory (inside)	320	500	586	915	51	4
3rd Dory (outside)	320	500	586	915	83	4

Grounds in project data set from Coral Coast	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Twofold Bay Shot	400	550	732	1007	27	4
Criss Cross Shot	400	570	732	1043	49	4
Coral Coast Hills Area	400	600	732	1098	34	3
Tricky Hill Area	400	600	732	1098	48	3
Soela Hill	470	550	860	1007	14	4
Metis Hill Area	500	600	915	1098	26	3
Coral Coast (deep)	500	700	915	1281	911	3

4. King Island

Total area: 4,134 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 814 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 1,036 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,571 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 62 sq km

Upper continental slope (200-700 m; ~110-380 fm): 251 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 399 sq km

Table 5.1.13.5 Details of 'trawl grounds' for the King Island subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from King Island	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
King Island Shelf (shallow)	3	30	5	55	814	2
King Is Shelf (inner)	30	60	55	110	1036	2
King Island Shelf	60	80	110	146	1571	2
King Island shelf (outer)	80	110	146	201	63	3
King Island Shot (inside) (140 sq km)	100	270	183	494	140	1
487 [King Is, unnamed Canyon (N)]	110	700	201	1281	12	2
488 [King Is, unnamed Canyon (S)]	110	700	201	1281	19	2
Bottom King Island Shot	270	350	494	641	66	3
Bottom King Island Shot (outside)	350	450	641	824	176	3
Bottom King Island Shot (deep)	450	700	824	1281	236	3

Table 5.1.13.6 Details of 'non-trawl grounds' for the King Island subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from King Island	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
King Island	180	280	329	512	93.2	3

5. West Tasmania

Total area: 17,073 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 467 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 8,272 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 3,346 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 889 sq km

Upper continental slope (200-700 m; ~110-380 fm): 1,824 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 2,274 sq km

Table 5.1.13.7 Details of 'trawl grounds' for the West Coast Tasmania subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from West Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
King Island Shelf (inside)	3	30	5	55	439	2
Western Tasmania inner shelf (north)	30	60	55	110	8298	2
West Tasmania Shelf	55	80	101	146	739	3
Western Tasmania shelf (north)	60	80	110	146	2620	2
Western Tasmania Shelf (outer N)	80	100	146	183	790	3
West Tasmania Shelf (outer)	80	110	146	201	35	3
Top Shot (inside)	90	110	165	201	31	3
Top Shot (inside) (24 sq km)	90	150	165	275	24	4
2nd Above Ling Hole (inside)	90	200	165	366	80	3
334 [West Tasmania, upper slope]	90	200	165	366	44	2
320 [West Tasmania, shelf]	90	220	165	403	37	3
1 Below "36" Canyon (inside)	100	200	183	366	41	2
1 Below Ling Hole (inside)	100	200	183	366	80	2
1 Above Ling Hole (inside)	100	200	183	366	86	3
Below Strahan Canyon (inside)	100	220	183	403	45	2
Bottom King Island Shot (inside) (58 sq km)	100	270	183	494	58	1

Grounds in project data set from West Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
"17" Canyon	100	700	183	1281	28	3
"26" Canyon	100	700	183	1281	29	3
Kiwi Corner	100	700	183	1281	76	3
"36" Canyon	100	700	183	1281	23	2
The Ling Hole	100	700	183	1281	83	2
308 [West Tasmania, unnamed canyon]	100	700	183	1281	74	1
The Strahan Canyon	100	700	183	1281	30	2
Top Shot	110	250	201	458	126	3
Top Shot (north) (70 sq km)	150	350	275	641	70	4
1 Above Ling Hole	200	450	366	824	319	3
1 Below Ling Hole	200	450	366	824	133	3
1 Below "36" Canyon	200	480	366	878	169	3
2nd Above Ling Hole	200	500	366	915	262	3
306 [West Tasmania, unnamed canyon]	200	700	366	1281	10	1
Canyon South of Kiwi Corner	200	700	366	1281	23	2
Above Strahan Canyon	220	480	403	878	524	3
Top Shot (outside)	250	300	458	549	66	3
337 [West Tasmania, unnamed canyon]	250	700	458	1281	84	2
Top Shot (deep)	300	450	549	824	106	4
North of Ling Hole (outside) (139 sq km)	330	450	604	824	139	3
305 [West Tasmania, unnamed canyon]	400	700	732	1281	7	1
335 [West Tasmania, unnamed canyon]	430	700	787	1281	39	1
336 [West Tasmania, unnamed canyon]	430	700	787	1281	25	1
North of Ling Hole (deep) (144 sq km)	450	700	824	1281	144	3
1 Above Ling Hole (deep)	450	700	824	1281	209	4
2nd Above Ling Hole (deep)	450	700	824	1281	164	4
1 Below Ling Hole (outside)	450	700	824	1281	96	4
340 [mid-slope]	450	700	824	1281	290	4
1 Below "36" Canyon (deep)	480	700	878	1281	177	4
The Penis	550	700	1007	1281	5	3

Table 5.1.13.8 Details of 'non-trawl grounds' for the West Coast Tasmania subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from West Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Central West	180	280	329	512	179.0	2
Upper West	180	280	329	512	544.7	3
NW Patch	190	300	348	549	93.3	3
Strahan Patch	220	300	403	549	5.2	1
South of Kiwi's	220	250	403	458	14.7	2
South of Ling Hole	220	250	403	458	14.9	2
Nth of Kiwi's	220	250	403	458	19.6	2
Strahan Grounds	220	250	403	458	48.1	2
Ling Hole	220	330	403	604	15.4	3
Kiwis Canyon	240	280	439	512	106.3	2

6. Southwest Tasmania

Total area: 4,569 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 0 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 656 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,714 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 398 sq km

Upper continental slope (200-700 m; ~110-380 fm): 721 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 1080 sq km

Table 5.1.13.9 Details of 'trawl grounds' for the Southwest Tasmania subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Southwest Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Southwest Tasmania Shelf (inside)	30	55	55	101	652	2
Southwest Tasmania (shelf) (1714 sq km)	55	80	101	146	1714	2
348 [SW Tasmania, shelf edge]	90	300	165	549	31	2
415 [Southwest Tasmania, upper-slope]	100	280	183	512	84	2
1049 [Southwest Tasmania, upper-slope]	100	280	183	512	19	2
Davey (312 sq km)	100	300	183	549	312	3
414 [Southwest Tasmania, upper-slope]	100	400	183	732	121	2
Point Hibbs Shot	280	350	512	641	37	3
North of Davey	280	440	512	805	42	3
Davey (deep) (448 sq km)	300	700	549	1281	488	3
Pt Hibbs Shot (outside)	350	450	641	824	163	3
399 [Southwest Tasmania, upper-slope]	400	500	732	915	2	1
398 [Southwest Tasmania, unnamed canyon]	400	700	732	1281	19	2
North of Davey (deep)	440	700	805	1281	52	3
Pt Hibbs Shot (deep)	450	700	824	1281	139	3
Above Strahan Canyon (deep)	480	700	878	1281	413	4
SW Tasmania Shelf (outer S) (382 sq km)	550	700	1007	1281	382	3

Table 5.1.13.10 Details of 'non-trawl grounds' for the Southwest Tasmania subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from Southwest Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Lower West	180	280	329	512	283.0	2
Sth Low Rocky	200	300	366	549	3.6	1
Nth Low Rocky	200	300	366	549	7.2	1
Hibbs	200	300	366	549	8.5	2
Davey Canyon (N)	220	300	403	549	3.3	1
Davey Peaks	220	280	403	512	2.9	2

7. South Tasmania

Total area: 11,844 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 0 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 175 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 2,999 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 3,886 sq km

Upper continental slope (200-700 m; ~110-380 fm): 1,999 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 2,784 sq km

Table 5.1.13.11 Details of 'trawl grounds' for the South Tasmania subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from South Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Around Maat	20	60	37	110	106	2
South of Friars	50	60	92	110	207	2
Southwest Tasmania (shelf) (72 sq km)	55	80	101	146	72	2
Southwest Davey (shallow)	60	85	110	156	79	3
Inside 17 Mile Patch	68	85	124	156	1387	4
Pedra to Maatsuyker	68	85	124	156	681	4
SW Tasmania Shelf (outer S) (175 sq km)	80	100	146	183	175	3
30 Mile Patch (shallow)	85	110	156	201	247	4
South of Bruny	85	110	156	201	1003	4
South of SW Cape	85	110	156	201	429	4
Southwest Davey (inside)	85	110	156	201	121	4
17 & 30 Mile Patch (shallow)	85	110	156	201	502	4
Southeast of Tasman (inside)	85	110	156	201	214	2
Pedra - Maatsuyker	85	110	156	201	1845	4
South of Southwest Cape (115 sq km)	90	280	165	512	115	4
South of Southwest Cape (13 sq km)	90	280	165	512	13	4
Davey (40 sq km)	100	300	183	549	40	3
Canyon South of SW Cape	105	320	192	586	39	2
Southeast of Tasman	110	250	201	458	122	3
17 & 30 Mile Patch	110	280	201	512	205	4
30 Mile to Pedra	110	280	201	512	306	4
Pedra to Maatsuyker (outside)	110	280	201	512	325	3
South of Maatsuyker	110	280	201	512	222	4
Southwest Davey	110	280	201	512	45	2
Canyon South of Maat	110	550	201	1007	19	3
Southwest Cape Canyon	110	700	201	1281	68	4
Pedra (deep-slope)	280	700	512	1281	961	3
Southwest Davey (deep)	280	700	512	1281	230	3
South of Bruny (outside)	280	700	512	1281	501	3
Outside 30 mile patch	280	700	512	1281	442	3
Maatsuyker (deep-slope)	280	700	512	1281	864	3

Grounds in project data set from South Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Davey (deep) (303 sq km)	300	700	549	1281	303	3

Table 5.1.13.12 Details of 'non-trawl grounds' for the South Tasmania subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from South Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
South Patch	170	270	311	494	34.6	2
South West Cape	180	280	329	512	141.7	2
17 Mile Patch	195	200	357	366	3.8	1
SE Cape	200	300	366	549	6.1	1
Matt Patch	220	280	403	512	4.4	1
Bird Is Patch	220	300	403	549	4.6	1
Davey Canyon (s)	220	300	403	549	5.5	1
Matt Canyon	220	300	403	549	7.0	1
30 Mile Patch	220	280	403	512	19.5	1
SW Cape Canyon	220	300	403	549	2.2	2
Pedra Patch	220	300	403	549	6.0	2
30 Mile Patch	225	245	412	448	3.1	1
Southeast of Tasman	250	270	458	494	3.3	1

8. Maria

Total area: 1,813 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 0 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 118 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 823 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 103 sq km

Upper continental slope (200-700 m; ~110-380 fm): 316 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 452 sq km

Table 5.1.13.13 Details of 'trawl grounds' for the Maria subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Maria	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Maria	40	100	73	183	633	3
Hippolyte	40	100	73	183	411	3
Hippolyte (outside)	100	270	183	494	64	3
Maria (outside)	100	300	183	549	96	3
Riedle Canyon	100	700	183	1281	29	2
293 [Maria, unnamed canyon]	100	700	183	1281	15	2
295 [Maria, unnamed canyon]	100	700	183	1281	13	2
298 [Maria, unnamed canyon]	100	700	183	1281	20	2
Hippolyte (deep)	270	700	494	1281	276	3
294 [Maria, mid-slope]	300	700	549	1281	37	4
296 [Maria, mid-slope]	300	700	549	1281	25	4
297 [Maria, mid-slope]	300	700	549	1281	58	4
376 [Maria, mid-slope] (68 sq km)	300	700	549	1281	68	4

Table 5.1.13.14 Details of 'non-trawl grounds' for the Maria subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from Maria	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Lower East Tasman - Schouten	180	280	329	512	138.9	2
Riedle Canyon	200	280	366	512	7.5	2
Schouten Patch	220	300	403	549	9.3	2
Top Yellow Bluff	240	250	439	458	1.1	1
Hippolytes Over The Lanterns	240	250	439	458	2.8	2

9. East Tasmania

Total area: 2,222 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 10 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 655 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 607 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 39 sq km

Upper continental slope (200-700 m; ~110-380 fm): 195 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 716 sq km

Table 5.1.13.15 Details of 'trawl grounds' for the East Tasmania subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from East Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
East Tasmania Shelf	30	100	55	183	1312	2
Off Bicheno	100	300	183	549	151	3
375 [Maria, mid-slope] (760 sq km)	300	700	549	1281	760	4

Table 5.1.13.16 Details of 'non-trawl grounds' for the East Tasmania subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from East Tasmania	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Paddys Head (S)	150	300	275	549	11.2	3
Schouten Island Patch	180	200	329	366	1.1	1
Upper East	180	280	329	512	64.4	4
The Nursery	200	240	366	439	1.0	2
Harpooka Patch	220	240	403	439	0.7	2

10. St. Helens

Total area: 2,581 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 15.8 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 467 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,007 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 63 sq km

Upper continental slope (200-700 m; ~110-380 fm): 305 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 724 sq km

Table 5.1.13.17 Details of 'trawl grounds' for the St Helens subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from St Helens	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
St Helens Shelf (inside)	30	30	55	55	482	3
St Helens Grounds (inside) (542 sq km)	40	60	73	110	542	3
St Helens Grounds (522 sq km)	80	100	146	183	522	3
Banks Strait Ground (5 sq km)	90	270	165	494	5	3
St Helens Grounds (outside)	90	500	165	915	331	2
St Helens Grounds North (267 sq km)	100	600	183	1098	267	3
St Helens Hill	350	600	641	1098	22	2
St Helens Grounds (deep)	500	600	915	1098	207	4
St Helens Grounds (very deep) (204 sq km)	600	700	1098	1281	204	3

Table 5.1.13.18 Details of 'non-trawl grounds' for the St Helens subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from St Helens	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Binnalong	120	220	220	403	2.0	3
Binnalong	120	220	220	403	4.8	3
The Plateau	120	220	220	403	19.1	3
Eddystone	150	300	275	549	5.8	1
North West Bank (S)	150	300	275	549	6.9	1
Paddys Head (N)	150	300	275	549	3.2	3
Binnalong Patch	165	200	302	366	0.8	2
North West Bank (S)	180	200	329	366	0.9	1
Eddystone Patch	180	240	329	439	2.6	1
East Flinders	180	280	329	512	96.6	2
Eddystone (S)	220	300	403	549	6.5	2
Eddystone Patch (S)	220	250	403	458	19.5	3
Banks Strait (S)	220	250	403	458	45.2	3

11. Banks Strait

Total area: 2,905 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 969 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 1,005 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 259 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 40 sq km

Upper continental slope (200-700 m; ~110-380 fm): 298 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 334 sq km

Table 5.1.13.19 Details of 'trawl grounds' for the Banks Strait subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Banks Strait	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Banks Strait Shelf (north)	3	50	5	92	587	3
Banks Strait Shelf	3	55	5	101	1392	3
North of St Helens Grounds (inside) (77 sq km)	40	80	73	146	77	3
North of St Helens Grounds (inside) (43 sq km)	40	80	73	146	43	3
Banks Strait	50	110	92	201	49	3
St Helens Grounds (102 sq km)	60	90	110	165	102	3
Banks Strait Ground (101 sq km)	90	270	165	494	101	3
St Helens Grounds North (237 sq km)	100	600	183	1098	237	3
342 [Babel, unnamed canyon]	100	700	183	1281	11	2
Banks Strait (upper-slope)	110	330	201	604	106	3
Banks Strait (mid-slope)	330	450	604	824	40	3
Banks Strait Deep (mid-slope)	450	700	824	1281	102	3
St Helens Grounds (very deep) (43 sq km)	600	700	1098	1281	43	3

Table 5.1.13.20 Details of 'non-trawl grounds' for the Banks Strait subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from Banks Strait	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Gull Ground (shallow) (S)	50	100	92	183	97.9	1
Gull Ground (deep) (S)	100	250	183	458	22.5	3
North West Bank (N)	150	300	275	549	3.5	1
North West Bank	150	300	275	549	3.5	1
Gull	150	250	275	458	20.9	2
North West Bank (N)	180	200	329	366	1.3	1
Banks	180	280	329	512	124.0	2
Barren Patch	220	300	403	549	5.7	1
Eddystone (N)	220	300	403	549	1.6	2
Banks Patch	220	300	403	549	6.4	2
Cape Barren (S)	220	240	403	439	26.1	2
Eddystone Patch (N)	220	250	403	458	5.3	3
Banks Strait (N)	220	250	403	458	113.7	3

12. Babel

Total area: 9,637 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 3,602 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 2,452 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,348 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 149 sq km

Upper continental slope (200-700 m; ~110-380 fm): 1,074 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 1,012 sq km

Table 5.1.13.21 Details of 'trawl grounds' for the Babel subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Babel	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Babel (inshore)	3	30	5	55	3687	3
Babel Ground (inside)	25	50	46	92	492	3
Graveyard (inside) (1008 sq km)	25	58	46	106	1008	4
Northeast Babel Reef	25	100	46	183	623	1
Babel Ground	50	85	92	156	592	3
Cape Barren Grounds (inside)	52	66	95	121	727	2
Graveyard (158 sq km)	58	68	106	124	158	2
Babel Fault	62	66	113	121	30	2
Northeast Babel Reef (south)	66	80	121	146	56	1
Cape Barren Grounds	68	72	124	132	111	4
Cape Barren Grounds (outside)	72	150	132	275	75	3
Babel Ground (outside)	72	150	132	275	48	3
South of Babel Horseshoe (edge)	80	150	146	275	16	3
Finger South	100	150	183	275	177	2
Babel Deepwater (inside)	100	150	183	275	86	2
218 [Babel, unnamed canyon]	100	700	183	1281	19	2
Middle Ground - Hole Shot Canyon	100	700	183	1281	64	2
Babel Deepwater - Hole Shot Canyon	100	700	183	1281	28	2
Babel Horseshoe	100	700	183	1281	122	2
Babel Deepwater	150	240	275	439	110	4
Hole Shot (middle)	150	300	275	549	24	4
Middle Ground	150	300	275	549	33	4
One Above	150	300	275	549	34	4
Babel Ground (outside 150)	150	450	275	824	195	3
South of Babel Horseshoe (outside)	150	450	275	824	81	3
Cape Barren Ground (outside150)	150	450	275	824	166	3
Babel Deepwater (outside)	240	450	439	824	94	2
Hole Shot	300	500	549	915	87	3
Middle Ground (outside)	300	500	549	915	19	3
One Above (outside)	300	500	549	915	49	3
Cape Barren Ground (deep)	450	700	824	1281	114	3
Babel Ground (deep)	450	700	824	1281	177	3
South of Babel Horseshoe (deep)	450	700	824	1281	38	2
Babel Deepwater (deep)	450	700	824	1281	34	2
One Above (deep)	500	650	915	1190	30	3
Middle Ground (deep)	500	700	915	1281	76	3
Hole Shot (deep)	500	700	915	1281	143	3

Table 5.1.13.22 Details of 'non-trawl grounds' for the Babel subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from Babel	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Babel Ground	37	70	68	128	355.9	2
Gull Ground (shallow) (N)	50	100	92	183	345.1	1
Graveyard	50	200	92	366	183.1	2
First Finger (S)	60	200	110	366	6.6	1
Babel	100	300	183	549	159.0	2
Gull Ground (deep) (N)	100	250	183	458	44.3	3
Nth of Babel	150	250	275	458	44.1	2
Babel	150	300	275	549	176.7	2
Babel Patch	180	280	329	512	5.8	1
40 01 (The Wall)	180	280	329	512	10.5	2
North Babel Canyon	180	280	329	512	27.4	2
Babel	180	280	329	512	221.3	2
Cape Barren (N)	220	240	403	439	18.1	2
Babel	230	240	421	439	24.4	3
Pot Boil	234	240	428	439	54.3	2

13. Eden-Smithy's

Total area: 18,142 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 796 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 5,807 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 4,670 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 1,170 sq km

Upper continental slope (200-700 m; ~110-380 fm): 3,921 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 1,777 sq km

Table 5.1.13.23 Details of ‘trawl grounds’ for the Eden-Smithys subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Eden-Smithys	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Twofold Shelf	3	50	5	92	5418	3
NZ Star Banks	8	70	15	128	248	1
Graveyard (inside) (1010 sq km)	25	58	46	106	1010	4
Mallacouta Inshore	26	44	48	81	61	3
Airstrip	42	56	77	102	277	4
Flat Patch	42	90	77	165	1514	3
Mowarry Reef	48	52	88	95	22	2
The Gutters	48	68	88	124	282	4
Smithy's	48	90	88	165	337	4
Rigs Inshore	50	100	92	183	516	4
Cumberland Reef	51	56	93	102	40	2
The Inside Reef	56	62	102	113	83	1
Gabo Reef	56	76	102	139	276	1
Gabo Extension	56	76	102	139	52	1
Graveyard (7 sq km)	58	68	106	124	7	2
260 [Eden/Smithy's shelf-edge]	64	140	117	256	45	2
10x10 Reef	65	100	119	183	8	1
The Outside Reef	66	72	121	132	140	1
Sand Patch	68	86	124	157	1505	3
Outside the Reef (431 sq km)	68	100	124	183	431	3
Horseshoe Canyon	80	400	146	732	300	2
Bottom of Flower Patch Reef	95	110	174	201	36	2
211[Eden/Smithy's shelf-edge]	100	140	183	256	6	2
214 [Eden/Smithy's upper-slope]	100	140	183	256	26	1
Second Howe (shelf-break)	100	150	183	275	165	3
Cape Ground	100	150	183	275	75	3
First Howe (shelf-break)	100	150	183	275	137	3
East of Eden (shelf-break) (16 sq km)	100	150	183	275	16	3
Top of Flower Patch Reef	100	165	183	302	25	2
West-side of Horseshoe	100	180	183	329	92	2
Rigs (deep)	100	220	183	403	376	3
Pedra	100	300	183	549	129	4
Smithy's Corner	100	300	183	549	86	2
Little Horseshoe Canyon	110	320	201	586	37	1
Second Howe Ground Reef	140	190	256	348	115	2
Eden Deep	150	260	275	476	108	2
Second Howe Ground	150	300	275	549	565	3
First Howe Ground	150	320	275	586	198	3
Gabo Canyon	170	310	311	567	28	1
First Howe Canyon	175	310	320	567	66	2
Everard Deep Water	180	300	329	549	195	4
The No 2	180	300	329	549	67	2
The No 1	180	360	329	659	331	3
Eden Deep (outside) (117 sq km)	210	700	384	1281	117	1
257 [Eden/Smithy's deep upper-	220	300	403	549	324	2

Grounds in project data set from Eden-Smithys	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
slope]						
First Howe (outside)	300	500	549	915	93	3
First Howe (deep)	300	700	549	1281	111	2
237 [Eden/Smithy's mid-slope]	300	700	549	1281	346	2
Horseshoe (deep)	300	700	549	1281	333	2
West of Horseshoe (deep)	300	700	549	1281	479	3
278 [Smithy's Corner mid-slope]	300	700	549	1281	571	3
248 [Eden/Smithy's mid-slope]	320	700	586	1281	324	3

Table 5.1.13.24 Details of 'non-trawl grounds' for the Eden-Smithys subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in non-trawl data set from Eden-Smithy's	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Trumpeter Reef	24	63	44	115	334.5	2
The Paddock	40	48	73	88	48.0	3
SE Reef	50	60	92	110	89.1	2
6-hour Bank and 8-mile Reef	50	65	92	119	208.3	2
Gabo Reef	56	70	102	128	301.6	1
First Finger (N)	60	200	110	366	9.4	1
10 x 10 Reef	60	180	110	329	53.7	2
Smithy's Corner	60	250	110	458	376.1	2
West Bank	65	260	119	476	4.7	1
Little Horseshoe Snotty Shot (inside)	65	210	119	384	38.9	1
Eden Smithy's (shelf)	65	70	119	128	5.6	2
15 mile snotty shot	65	70	119	128	9.1	2
Big Horseshoe West	65	260	119	476	19.4	2
Eden Smithy's (shelf)	65	270	119	494	26.0	2
Eden Smithy's (shelf)	65	270	119	494	66.4	2
Eden Smithy's (shelf)	65	270	119	494	4.6	3
Eden Smithy's (shelf)	65	110	119	201	13.5	3
Smithy's Snotty Ground	70	120	128	220	15.4	2
Big Horseshoe	70	500	128	915	281.3	2
10x10	70	120	128	220	6.9	3
Eden Smithy's (slope)	74	115	135	210	4.0	2
Little Horseshoe	85	260	156	476	110.8	2
Eden Smithy's (shelf)	85	100	156	183	6.6	3
Eden Smithy's (shelf)	90	110	165	201	34.4	2
Middle Bight	90	260	165	476	505.8	2
Eden Smithy's (shelf)	90	110	165	201	3.0	3
Eden Smithy's (slope)	100	330	183	604	10.9	1
Eden Smithy's (slope)	100	190	183	348	9.0	3
Eden Smithy's (slope)	110	150	201	275	12.9	2
Big Horseshoe canyon base	110	270	201	494	12.3	3
Eden Smithy's (slope)	140	270	256	494	15.1	2
Eden Smithy's (slope)	140	190	256	348	1.1	3
Eden Smithy's (slope)	140	190	256	348	1.6	3
Eden Smithy's (slope)	150	440	275	805	29.3	2
Mud Bank	150	270	275	494	5.1	4
Eden Smithy's (slope)	160	220	293	403	6.0	1
East Bank at Big Horseshoe	160	270	293	494	39.3	2
Eden Smithy's (slope)	160	330	293	604	11.4	3
Smithy's	160	330	293	604	30.8	3
Black Hole	170	170	311	311	24.2	3
Doggy Spit	180	250	329	458	94.1	3
Eden Smithy's (slope)	190	330	348	604	14.0	1
Little Horseshoe Ling Hole	210	320	384	586	16.3	3
Little Horseshoe	210	300	384	549	11.9	4
Eden Smithy's (slope)	220	270	403	494	15.5	1
Eden Smithy's (slope)	220	330	403	604	2.4	3

Eden Smithy's (slope)	220	300	403	549	6.8	3
Eden Smithy's (slope)	220	350	403	641	11.9	3
Eden Smithy's (slope)	270	330	494	604	5.2	1

14. Eden-Bermagui

Total area: 3,265 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 0 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 684 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,434 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 293 sq km

Upper continental slope (200-700 m; ~110-380 fm): 553 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 300 sq km

Table 5.1.13.25 Details of 'trawl grounds' for the Eden-Bermagui subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Eden-Bermagui	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
Eden to Bermagui Shelf (inner)	3	55	5	101	272	3
Trevally Hole	25	58	46	106	16	3
4 Mile Reef	33	35	60	64	3	1
East of Eden	36	55	66	101	285	4
6 Mile Reef	38	42	70	77	10	1
North of Montague	38	58	70	106	49	3
50's Ground South of Bunga	40	58	73	106	309	3
50's "out the front"	43	58	79	106	105	4
12 x12 Reef	55	68	101	124	80	2
Eden to Bermagui Shelf	55	70	101	128	110	3
Patches North of Montague	56	59	102	108	12	1
Bunga Reef	58	62	106	113	10	1
Tarthra Reef	58	62	106	113	6	2
Large Flathead Ground	58	62	106	113	29	4
Inside 12 Mile	58	73	106	134	122	4
North of 12X12 Reef	60	70	110	128	17	2
Kali Ground	60	70	110	128	179	4
Northeast of Montague	60	100	110	183	147	4
Moe Hole	65	75	119	137	15	2
12 Mile Reef (top end)	68	76	124	139	43	1
Outside the Reef (126 sq km)	68	100	124	183	126	3
12 Mile Reef (bottom end)	70	75	128	137	26	1
589 [Eden, unnamed reef]	70	100	128	183	28	2
Eden to Bermagui Shelf (outer)	70	100	128	183	68	4
Southeast Ground (on the edge)	70	100	128	183	200	4

Grounds in project data set from Eden-Bermagui	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Outside the Moe Hole	70	100	128	183	30	3
The Edge (out the front)	78	100	143	183	85	4
Northeast Montague (on the edge)	80	120	146	220	12	2
Tuross Reef	80	130	146	238	12	2
Reef Northeast of Montague	85	120	156	220	7	2
Inside The Kink	85	120	156	220	12	2
East of Eden (shelf-break) (27 sq km)	100	150	183	275	27	3
The Front Shot	100	200	183	366	71	4
Southeast Ground	100	200	183	366	86	3
Bottom-end of Montague Shot	100	250	183	458	8	2
Eden to Bermagui (upper-slope)	100	260	183	476	38	3
South of Tarthra Canyon	100	450	183	824	35	2
Graveyard	120	200	220	366	27	3
Tarthra Canyon	160	280	293	512	19	1
The Kink	170	700	311	1281	35	3
Bottom of Front Shot Reef	180	235	329	430	3	1
Bunga Canyon	180	600	329	1098	6	3
Graveyard (deep)	200	500	366	915	62	4
Front Shot (deep)	200	500	366	915	83	3
Southeast Ground (deep)	200	500	366	915	87	3
Eden Deep (outside) (92 sq km)	210	700	384	1281	92	1
The Southeast Hole	225	300	412	549	7	1
Eden to Bermagui (mid-slope)	260	700	476	1281	37	2
Off Montague (deep)	500	700	915	1281	28	3
South of Montague (deep)	500	700	915	1281	23	3
North of Eden (mid slope)	500	700	915	1281	31	2

15. Ulladulla

Total area: 2,983 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 0 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 216 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,537 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 361 sq km

Upper continental slope (200-700 m; ~110-380 fm): 416 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 453 sq km

Table 5.1.13.26 Details of 'trawl grounds' for the Ulladulla subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Ulladulla	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
North of Montague inner-shelf	3	60	5	110	16	3
[Shelf South of Jervis Bay]	3	90	5	165	160	3
The Snapper Ground	40	48	73	88	27	3
Batemans Bay (in close)	40	48	73	88	82	4
[Ulludulla inside reef]	40	55	73	101	134	2
Moruya Reef	48	55	88	101	6	1
Burrawurra (in close)	50	79	92	145	211	4
55 [Ulladulla, shelf]	55	65	101	119	209	4
56 [Ulladulla, shelf]	55	65	101	119	39	2
52 [Ulladulla, shelf]	61	65	112	119	48	2
51 [Ulladulla, shelf]	65	68	119	124	14	2
Barnetts Patch Reef	65	77	119	141	440	2
South East of the 70's	74	100	135	183	259	2
Burrawurra	80	100	146	183	406	4
Edge (outside)	100	150	183	275	133	4
63 [Ulludulla, unnamed canyon]	100	700	183	1281	62	2
Southeast (deep)	150	380	275	695	445	3
Plateau Canyon	180	700	329	1281	48	2
65 [Ulladulla, mid-slope]	380	700	695	1281	229	3

16. Greenwell Point - Wollongong

Total area: 4,284 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 0 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 585 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,539 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 388 sq km

Upper continental slope (200-700 m; ~110-380 fm): 927 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 845 sq km

Table 5.1.13.27 Details of 'trawl grounds' for the Greenwell Point - Wollongong subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Greenwell Point - Wollongong	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km^2)	Terrain Type
South of Jervis Bay Reef	3	70	5	128	48	2
Shelf Southeast of Jervis Bay	3	90	5	165	43	3
Reef at Northern-end Shitters Ditch	3	100	5	183	82	2
Golden Rivet	20	40	37	73	120	4
Top of Golden Rivet	20	40	37	73	1	4
Bulli Reef	20	55	37	101	297	2
North of The Mud	20	60	37	110	24	2
517 [Wollongong, shelf]	24	30	44	55	8	2
Joseph Young Banks	25	60	46	110	123	2
Geroa Reef	26	40	48	73	23	2
The Mud	45	60	82	110	57	4
Hill 60 Reef	50	60	92	110	5	1
Drumsticks	50	78	92	143	96	3
Bulli Ground	55	110	101	201	423	3
JB Reef	60	70	110	128	41	2
Jervis Bay Ground	60	70	110	128	25	4
Shitters Ditch	60	80	110	146	134	4
60's East	60	80	110	146	113	3
Wollongong Ground	65	80	119	146	232	3
Wagon Wheel Patch	67	68	123	124	13	2
497 [Wollongong, shelf]	70	72	128	132	7	3
508 [Wollongong,shelf]	70	75	128	137	1	1
518 [Wollongong, shelf]	70	75	128	137	8	2
Wollongong Coral	72	72	132	132	18	3
Port Kembla Reef	72	76	132	139	5	1
500 [Wollongong,shelf]	73	77	134	141	2	1
Les's Ground	78	100	143	183	116	2
Southeast of Jervis Bay	80	100	146	183	40	3
591 [Woolongong, unnamed reef]	80	100	146	183	44	2
521 [Wollongong, shelf]	80	100	146	183	85	2
Kiama Ground	80	280	146	512	158	2
Beecroft Canyon	80	700	146	1281	17	2
Wollongong (outside)	90	110	165	201	164	4
505 [Wollongong, upper slope]	100	180	183	329	76	2
South of Shoalhaven (upper-slope)	100	330	183	604	56	3
526 [Wollongong, upper-slope]	100	400	183	732	38	3
Shoalhaven Shelf	100	400	183	732	224	3
Long Nose Canyon	100	700	183	1281	20	2
Wollongong Shelf	110	220	201	403	173	4
Shelf North of The Hole	110	240	201	439	71	4
534 [Wollongong, unnamed canyon]	160	700	293	1281	3	2
Outside The Hole	200	700	366	1281	121	3
South of The Hole	220	280	403	512	38	4

Grounds in project data set from Greenwell Point - Wollongong	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
North of The Hole	220	280	403	512	10	4
North of The Hole	240	260	439	476	3	1
South End	240	280	439	512	7	4
North of The Hole (deep)	280	700	512	1281	49	4
Wollongong (deep)	280	700	512	1281	197	4
South of Shoalhaven (deep)	330	700	604	1281	131	3
Shoalhaven (deep)	400	700	732	1281	486	4

17. Sydney

Total area: 4,495 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 0 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 300 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 1,507 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 493 sq km

Upper continental slope (200-700 m; ~110-380 fm): 1,209 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 987 sq km

Table 5.1.13.28 Details of 'trawl grounds' for the Sydney subregion with ground names, depths (fathoms and meters) for the inner and outer margins, ground area (square kilometres) and Terrain type

Grounds in project data set from Sydney	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
Narabeen Waters	3	70	5	128	447	3
Sydney Waters	3	70	5	128	112	4
Botany (inside coral)	3	70	5	128	215	4
Coral outside Palm Beach	70	90	128	165	199	3
549 [Sydney, shelf]	70	90	128	165	104	3
Coral Outside Botany	70	90	128	165	155	3
The Peak	72	76	132	139	17	2
Stingray Bottom (north)	90	110	165	201	543	4
Stingray Bottom	90	110	165	201	202	4
Stingray Bottom	90	110	165	201	297	4
548 [Sydney, unnamed canyon]	110	650	201	1190	57	2
Northeast of Sydney	120	220	220	403	198	4
East of Sydney (inside)	120	300	220	549	316	4
ESE Sydney before canyons	130	355	238	650	132	4
ESE Sydney after canyons	130	355	238	650	169	4
Northeast of Sydney (outside)	220	300	403	549	96	4
Brown's Mountains	250	310	458	567	17	1
South of Dumping Ground	300	325	549	595	32	2

Grounds in project data set from Sydney	Depth min (fm)	Depth max (fm)	Depth min (m)	Depth max (m)	Area (km²)	Terrain Type
East of Sydney	300	325	549	595	45	4
Northeast of Sydney (deep)	300	550	549	1007	241	4
East of Sydney (deep)	325	700	595	1281	459	4
560 [Sydney, mid-slope]	325	700	595	1281	269	4
539 [Sydney, mid-slope]	550	650	1007	1190	130	4

18. Lakes

Total area: 20,840 sq km

Inner continental shelf (3 nm-50 m; ~3 nm-27 fm): 5,212 sq km

Mid- continental shelf (50-100 m; ~27-55 fm): 0 sq km

Outer continental shelf (100-150 m; ~55-80 fm): 0 sq km

Continental shelf-break (150-200 m; ~80-110 fm): 0 sq km

Upper continental slope (200-700 m; ~110-380 fm): 0 sq km

Mid- continental slope (700-1300 m; ~380-700 fm): 0 sq km

No grounds mapped.

5.1.14 Grounds as habitats at larger scales (depth zones and features)

As well as classifying grounds as habitats at the levels of 'terrains' and 'bottom (Section 5.1.9 and 10), we also classified each ground into habitats at coarser (higher) levels using the habitat classification scheme being used for Regional Marine Planning in Australia (for details of scheme see Section 5.4.6).

Scientific bathymetry data were added to maps of fishing grounds and each ground placed in a primary 'Depth Zone' based on the depth distribution of the 1 km cells within it. Most grounds (468) fell clearly in one of the four zones, while 48 grounds with wide depth ranges (mostly canyons) spanned the upper and mid-slope and were placed in a fifth zone. The depth zones (which approximately represent 'sub-biomes' – see Section 5.4.6 – but are constrained analytically by available bathymetry and map resolution to 50 m intervals) were classified as follows:

- Shallow shelf is the region out to 100 m incorporating the inner and mid-regions of the continental shelf (0-50 m and 50-100 m respectively).

- Deep shelf is the region out to 200 m incorporating the outer shelf and shelf break (100-150 m and 150-200 m respectively).
- Upper slope is the upper zone of the continental slope in 200-700 m.
- Mid-slope is the mid- zone of the continental slope in 700 m out to the deep limit of the study area in 1300 m.
- Upper/mid slope is the entire slope.

Grounds were also classified into 'Features' using the relevant standard geological terminology from the scheme used to describe the geomorphic features of Australia's continental margin (Harris et al., 2004) – plains, terraces, scarps, rocky banks, canyons, hills and fans. Because we applied the terms to areas at smaller scales than in the national scheme, one exception was needed: the term 'shelf' was not used because here the shelf is subdivided into other features. All grounds were classified as features despite many being small (see Section 5.1.8). It was difficult to establish a minimum size for features because some such as distinct rocky banks and hills were only a few sq km in size. The feature types were classified on the following basis:

- Plains may be clear sediments or a mix of sediments and scattered rocky reef patches (broken ground); they are typically flat or sloping, but rarely steep. Large plains containing high proportions of rocky reef may account for considerable areas of rocky areas in addition to features classified as 'rocky banks'.
- Rocky banks are large contiguous rocky reefs, and in some cases plains or scarps with extensive rocky areas called 'reefs' by fishers.
- Terraces are flat to sloping areas, often long and narrow, with a steep ascending boundary on one side and a steep descending boundary on the opposite side. Most occur on the slope, although some are found at the shelf edge.
- Scarps, or escarpments, are elongate and steeply sloping, and separate more gently sloping areas. These make up much of the upper slope, and are frequently characterised by the presence of outcrop and are incised by small tributary canyons, often called gutters or gullies by fishers.
- Canyons are relatively narrow, deep sided depressions that most often have their 'heads' at the shelf break and extend down the slope to abyssal depths.

- Hills are small isolated elevations, and include all the features commonly called seamounts.

- Fans are fan-like depositional features normally sloping away from the outer termination of a canyon.

Analysis of industry's data using the habitat classification framework provides a synoptic regional view of habitat types, distributions and quantities at scales consistent with those being used for Regional Marine Planning and for MPA design. Tabulated results for crosses of some habitat levels (features and bottom types within depth zones and fishery subregions) provide a number of insightful summaries.

The numbers and plan area (sq km) of features by depth zone shows several strong associations (Table 5.1.14.1). Plains comprise virtually all the shelf, which makes up nearly 73% of the study area. The inner shelf is comprised of relatively few, relatively large areas – which in part is a reflection of their poor discrimination in the western half of the fishery due to lack of use by the offshore fishing sectors. Terraces and scarps (escarpments) make up most of the continental slope; the presence of numerous, relatively small features (terraces and scarps) on the upper slope compared to the mid-slope reflects both their importance to the fishery (many developed grounds) and the topographic complexity of that depth zone. Other features – rocky banks, canyons, hills and fans – cover relatively small areas and are scarce.

The numbers and plan area (sq km) of features by fishery subregion (Table 5.1.14.2) shows strong subregional differences in the distributions and areas of features, and the relative scarcity of particular features in many subregions. A starting point is to recognise the major difference between the "west" (Beachport to South Tasmania) and "east" (Maria to Sydney). The west is characterised by the presence of massive plains of mixed sediments and rocky reef (mostly terrains of sediments with many reef patches) on the relatively wide continental shelf (see Fig. 5.3.1.2g,h). In contrast, the east has a generally relatively narrow shelf with large areas of terrains of clear sediment or sediments with few reef patches, but most of the region's continental shelf rocky banks situated between Babel and Wollongong. The west has a broadly similar sized continental slope to the east but differs by having virtually all the area containing hills (although the vast majority are scattered in two large areas of mid-slope in South Tasmania), nearly three times more upper slope terrace, and less than half the upper slope scarp.

Table 5.1.14.1 Estimated extent of seabed habitat in the SEF at the scale of Features within primary Depth Zones: (a) plan area (sq km); (b) numbers of individual features.

				Features				
(a)	**Plain**	**Terrace**	**Scarp**	**Rocky bank**	**Canyon**	**Hill**	**Fan**	**Total SEF**
Shallow shelf	60,034			465				60,499
Deep shelf	39,458	841	14	1,890	71	246		42,520
Upper slope	187	7,222	6,334	248	763	17		14,771
Slope (upper/ mid)		1,832	1,988		1,478			5,298
Mid-slope		10,510	5,328		697	1,983	335	18,853
Total SEF	99,679	20,405	13,664	2,603	3,009	2,246	335	141,941

(b)	Plain	Terrace	Scarp	Rocky bank	Canyon	Hill	Fan	Total SEF
Shallow shelf	33			6				39
Deep shelf	88	10	1	32	1	1		133
Upper slope	2	84	86	11	13	1		197
Slope (upper/ mid)		13	4		23			40
Mid-slope		46	31		19	9	1	106
Total SEF	123	153	122	49	56	11	1	515

Table 5.1.14.2 Estimated extent of seabed habitat in the SEF at the scale of Features in each fishery subregion: (a) plan area (sq km), showing the sub-totals for "west" (Beachport to South Tasmania), and "east" (Maria to Sydney); (b) numbers of individual features

(a)

Subregion name	Plain	Terrace	Scarp	Rocky bank	Canyon	Hill	Fan	Total SEF
Beachport	24,298	4,702	561	22	217	16	--	29,816
Portland	7,102	2,855	170	5	475	--	--	10,607
Coral Coast	9,573	1,316	508	--	--	120	--	11,517
King Island	3,428	477	208	--	31	--	--	4,144
West Tasmania	13,012	2,975	561	--	534	6	--	17,088
SW Tasmania	2,755	1,308	612	--	19	--	--	4,694
South Tasmania	6,886	1,593	1,483	--	126	1,820	--	11,908
Maria	1,045	--	622	--	81	--	--	1,748
East Tasmania	1,312	--	916	--	--	--	--	2,228
St Helens	1,549	5	1,010	--	--	21	--	2,585
Banks Strait	2,253	--	623	--	12	--	--	2,888
Babel	6,787	608	1,294	715	230	--	--	9,634
Eden/ Smithys	11,346	1,341	3,047	842	1,003	246	335	18,160
Eden/ Bermagui	2,124	264	472	298	71	--	--	3,229
Ulladulla	2,042	137	671	6	109	--	--	2,965
Wollongong	1,868	769	906	696	44	--	--	4,283
Sydney	2,299	2,055	--	19	57	17	--	4,447
Total "West"	67,054	15,226	4,103	27	1,402	1,962	0	89,774
% SEF	67	74	30	1	47	87	0	
Total "East"	32,625	5,179	9,561	2,576	1,607	284	335	52,167
% SEF	33	25	70	99	53	13	100	
Total SEF	99,402	20,682	13,664	2,603	3,009	2,246	335	141,941
% SEF	70.0	14.6	9.6	1.8	2.1	1.6	0.2	

(b)

Subregion name	Plain	Terrace	Scarp	Rocky bank	Canyon	Hill	Fan	Total SEF
Beachport	4	33	19	2	4	1		63
Portland	8	33	3	1	9			54
Coral Coast	3	10	7			4		24
King Island	3	3	2		2			10
West Tasmania	5	19	8		13	1		46
SW Tasmania	3	6	7		1			17
South Tasmania	12	9	6		3	2		32
Maria	2		7		4			13
East Tasmania	1		2					3
St Helens	3	1	4			1		9
Banks Strait	6		6		1			13
Babel	7	10	13	3	4			37
Eden/ Smithys	10	4	18	13	5	1	1	52
Eden/ Bermagui	16	5	12	14	4			51
Ulladulla	13	1	2	1	2			19
Wollongong	18	8	6	14	3			49
Sydney	10	10		1	1	1		23
Total SEF	123	153	122	49	56	11	1	515

The plan area (sq km) of each bottom type was estimated by multiplying its estimated percentage in each ground by the total plan area of the ground and then summing across grounds. Unfortunately, however, a full synoptic view is not possible because large areas of bottom types were scored either as present/absent or as 'unknown'. Most are the large (1000s sq km) plains of the western continental shelf (Beachport to SW Tasmania) that are unfished by the offshore fleet because they are too rugged to trawl and do not support the species targeted by the non-trawl sector. Considerable additional effort involving the inshore fishery sectors (especially rock lobster fishers) would be needed to map the substructure of these areas in a manner consistent with the offshore areas. Large unknown areas are also made up by complex, rugged bottom types such as canyons, the large sediment plain in eastern Bass Strait used by the Danish Seine sector (mostly sands), and large deep areas of the mid-slope (mostly muddy terraces).

In spite of these data gaps, plan area of bottom type shows several strong associations with depth zone (Table 5.1.14.3). Relatively coarse sediments – sands and gravels – are associated with the continental shelf, with muds making up most bottom types on the continental slope. Slabby and heavy reef bottom habitats that provide key fishery habitat for several key species are concentrated on the deep shelf and upper slope, while mud boulders are mostly bottom type habitats of the continental slope and concentrated on the mid-slope. Bottom types are unevenly distributed across subregions (Table 5.1.14.4). For example, relatively large areas of slabby bottom and heavy reef occur in the Babel and

Eden/Smithys subregions, associated with the massive deep shelf and upper slope escarpments of Bass Canyon. Relatively high fractions of other subregions are composed of muds (e.g. Sydney) and sands (South Tasmania).

Table 5.1.14.3 Estimated extent of seabed habitat in the SEF (sq km) at the scale of Bottom Types within Depth Zones

Bottom Type	Shallow shelf	Deep shelf	Upper slope	Slope (upper/ mid)	Mid-slope	Total SEF
Mud - soft & boggy	199	1,327	1,824	869	5,161	9,379
Mud - compact	170	3,961	7,912	1,002	8,805	21,849
Gritty Mud	30	83	491	0	0	604
Sand	3,616	11,754	911	0	0	16,280
Gravel	140	4,189	856	0	0	5,184
Sandstone	112	119	2	0	0	233
Rubble	8	41	33	9	34	126
Slabby	183	940	1,111	122	381	2,737
Mud boulders	0	41	195	57	384	678
Heavy low reef	335	1,573	960	262	379	3,509
Heavy high reef	552	1,508	387	223	206	2,876
Unknown	55,156	16,984	1,662	1,182	3,503	78,487
Total	60,499	42,520	16,343	3,726	18,853	141,941

Table 5.1.14.4 Estimated extent of seabed habitat in the SEF (sq km) at the scale of Bottom Types within fishery subregions

Bottom Type	Beachport	Portland	Coral Coast	King Island	West Tasmania	SW Tasmania	South Tasmania	Maria	East Tasmania	St Helens	Banks Strait	Babel	Eden/ Smithys	Eden/ Bermagui	Ulladulla	Wollongong	Sydney	Total SEF
Mud - soft & boggy	574	783	53	0	1,062	793	923	161	768	8	45	682	1,177	343	933	647	429	9,379
Mud - compact	3,999	2,587	1,632	414	2,289	603	2,707	321	141	297	45	570	588	231	1,092	696	3,638	21,849
Gritty Mud	40	0	0	0	12	0	409	0	0	0	0	0	108	5	0	30	0	604
Sand	145	326	0	82	244	0	5,866	0	0	246	526	2,140	4,601	1,351	0	754	0	16,280
Gravel	284	0	0	20	317	62	619	730	0	246	99	55	2,095	235	0	423	0	5,184
Sandstone	9	0	0	0	0	0	0	0	0	0	0	166	43	13	0	2	0	233
Rubble	1	0	0	0	0	1	0	0	0	0	0	82	24	10	0	8	0	126
Slabby	110	118	108	3	75	56	110	12	0	33	0	727	591	89	225	253	229	2,737
Mud boulders	58	0	85	0	0	7	156	41	0	1	0	231	65	4	0	29	0	678
Heavy low reef	76	142	43	0	270	119	248	60	7	70	74	706	1,040	136	264	245	10	3,509
Heavy high reef	118	116	24	24	59	46	217	0	0	0	0	546	985	118	184	354	86	2,876
Unknown	24,403	6,536	9,573	3,601	12,760	3,007	654	422	1,312	1,685	2,100	3,728	6,843	695	268	843	57	78,487
Total	29,816	10,607	11,517	4,144	17,088	4,694	11,908	1,748	2,228	2,585	2,888	9,634	18,160	3,229	2,965	4,283	4,447	141,941

5.1.15 Industry data: summary

Industry's information on the seabed habitats that make up fishing grounds was successfully collected in a systematic way and there was strong co-operation by operators in all major southeast ports. This has resulted in a mapping database that includes information from the complete offshore fishing area within the boundaries of the traditional SEF fishery (excluding offshore platforms such as Cascade and South Tasman Rise). This complete coverage means that we can provide summaries of information by categories including depth, bottom type, fishing ground for 17 fishery subregions (no detail recorded for 'Lakes').

There was enough overlapping coverage (provided by more than one operator for an area) to corroborate a large fraction of the information provided and generate a moderate to high quality data set for bottom types and boundaries over the often complex area of seabed used by the offshore fishery. In areas where validation with swath acoustic was possible, the quality of industry's data was shown to be extremely precise (Fig. 5.1.6.2). The database provides the means to understand the physical structure of this "working landscape" at fishing ground scales of 10s to 100s of km. Maps developed from these data provide a backdrop on which to overlay additional information at both fishery-wide scales (e.g. logbook data, temperature and currents) and fine scales or point sources (e.g. acoustic maps and photographs).

What is the project mapping database? The product of this project can be visualised as a completed 516-piece jig-saw puzzle of the SEF fishery region, with each fishing ground representing one piece. The spatial information forms a computer-based electronic map which is linked to a database that stores industry's information on habitats, as well as other information, such as catches and effort for each individual ground estimated from logbooks. This information is easily retrieved – either for individual grounds or many grounds, such as all those from one region of the fishery. Most pieces of the puzzle were made using trawl sector information; missing pieces were made from other data sources, including cross-reference to non-trawl information. At this stage, however, 153 individual non-trawl grounds have not been integrated as new or overlapping pieces in the fishery-scale puzzle. There are several reasons for this (Sections 5.1.4; 5.1.12); primarily, non-trawl grounds are relatively small in size and represent precise and confidential fishing locations.

Industry's mapping information consists of names, boundaries (and therefore the spatial extent) for seabed areas representing fishing grounds. Grounds could be consistently defined as "areas of the seabed characterised by a mix of biological and geological features relevant to fishing that are targeted or avoided" because most ground boundaries are based on distinct physical features, such as reef edges, canyons or distinct depths. There were also 'arbitrary' boundaries, resulting most often from an alignment with another seabed feature or landmark, but these were consistently recognised. Although the size range of recorded grounds was from 0.6 sq km to 13,000 sq km, with the size range of non-trawl grounds small relative to that in the whole project data set. Within this range, the majority of grounds are relatively small: in non-trawl data 85% are smaller than 100 sq km, and in the project data 75% are less than 200 sq km.

Information on habitats for each ground was recorded at two levels. Firstly, a simple, 4-category classification of terrain, and secondly, a more detailed description in terms of 'what the bottom looks like' – the presence or absence of feature types (geomorphology) and 'what the bottom is made of' – the estimated proportions of bottom types (substratum). Terrain type information was recorded in a consistent way with bottom types. At industry's request, this information is presented here mostly as tabulated summaries, but it can all be mapped at a range of resolutions for specific purposes, such as to examine the distribution of grounds within a subregion, or the characteristics of an individual ground. Finer scale logbook or scientific data (photographs or acoustic maps) can provide detailed information for whole grounds, or parts of grounds, and this is illustrated in the final section (5.4).

The overall make-up of the SEF seabed in terms of terrain types (estimated from the project data set) is about half 'sediments with many reef patches', ~30% 'sediments with few reef patches', and ~20% clear sediment. Although there are 45 grounds classified as 'heavy reef', they make up less than 2% of the total area.

Each ground was also classified using the habitat classification scheme being used for Regional Marine Planning into primary 'Depth Zones' and 'Features'. This shows a range of general patterns in the extent of seabed habitats (depth zones, features, terrains and bottom types), and distinct differences between fishery subregions.

Overall, plains of mixed sediment and reef patches comprise virtually all the shelf, which makes up nearly 73% of the study area. Terraces and scarps (escarpments) make up most of the continental slope; the presence of numerous, relatively small features (terraces and scarps) on the upper slope compared to the mid-slope reflects both their importance to the fishery (many developed grounds) and the topographic complexity of that depth zone.

Other features – rocky banks, canyons, hills and fans – form relatively small areas and are relatively scarce. Slabby and heavy reef bottom habitats that provide key fishery habitat for several key species are concentrated on the deep shelf and upper slope, while mud boulders are concentrated on the mid-slope. Relatively large areas of slabby bottom and heavy reef occur in the Babel and Eden/Smithys subregions, associated with the massive deep shelf and upper slope escarpments of Bass Canyon.

Of interest are considerable "east-west" differences: Beachport to South Tasmania vs Maria to Sydney. In the west, the relatively wide continental shelf is a series of massive plains of mixed sediments and rocky reef (mostly terrains of sediments with many reef patches). In contrast, the east has a generally relatively narrow shelf with large areas of terrains of clear sediment or sediments with few reef patches, but most of the region's continental shelf rocky banks are situated between Babel and Wollongong. The west has a broadly similar sized continental slope to the east but differs by having virtually all the area containing hills (although the vast majority are scattered in two large areas of mid-slope in South Tasmania), nearly three times more upper slope terrace, and less than half the upper slope scarp.

Communicating the aims and progress of the project was done effectively through face-to-face meetings with working fishers during port visits and with a variety of industry and other stakeholders at SETFIA, SENTA and meetings with other groups and individuals during the data collection phase of the project (the project Steering Committee, AFMA, FRDC, NOO, DEH, WWF, SETFEAG, and the Fisheries Minister). Generating maps from the information provided by fishers required several iterations. Each iteration improved our understanding of how fishers understand the habitat they fish, and passed scientific information to fishers including, hopefully, a broader perspective on how individual grounds and subregions relate to the fishery as a whole. Flyers and mini-posters with photographs and example maps were effective in visually demonstrating how industry data could be contributed without compromising commercially sensitive information, and were used frequently. They were good focal points for discussing the role of habitat for sustaining fishery production, and for the more sensitive issues of the ways in which habitats are vulnerable to certain types of fishing impact. Documents and images were widely distributed and posted on the project website – which had 5,755 visits at the time of writing. One of the important, but rather intangible, outcomes of this project was to put habitat management issues on industry's radar at a grass-roots level.

However, despite the fact that communication had been open and effective, and that data security was preserved as agreed (no electronic or paper map product was shown or distributed without prior direct approval of the contributing fisher), the project suffered from several episodes of rumours to the contrary. Much of this coincided with activity to implement Marine Protected Areas in Commonwealth waters of the South East Region, when many of the initial Broad Areas of Interest defined for MPAs coincided with key fishing areas. It was difficult to manage the perception that these outcomes were not linked to this project, despite assurances there had been no 'leaking' of industry data.

Project data were contributed to MPA implementation by providing some general information confirming the presence of rocky upper slope habitat in the Zeehan candidate area (MPA1); this was provided through SETFIA and ASIC (no raw contributor data or any form of map was included) and helped in boundary setting for that MPA. There is scope for the project data to have a larger and positive impact for the fishery by informing the spatial management of fishing effort and fishery habitat being planned by AFMA, and project data have been provided, with individual contributor and SETFIA endorsement, to a series of workshops in June 2006 for this purpose.

5.2 Logbook data

5.2.1 The utility of trawl and non-trawl data

SEF1 logbook data for the years 1996 to 2001 were processed to use in conjunction with maps of fishing grounds (see Section 4.5.1). Trawl and non-trawl data differ greatly in a range of spatial characteristics (Section 5.1.4) and we had expected different approaches would be needed to analyse the two data sets. With the data processed it became evident that there was considerably more scope to analyse the trawl data, and this is reflected in the results presented in the following sections.

The primary difference was that, during the period considered (1996-2001), non-trawl data were too coarsely resolved in logbooks (half-degree or ~50 km grid cell resolution) to match confidently to fishing ground polygons. However, in addition we had difficulty with consistently matching gear types to catch records and locations. More generally, way-point data tended to mark exact fishing positions rather than boundaries of areas or seabed types resulting in multiple localised maps that showed fishing positions rather than fishing areas. These reasons, in combination with the relatively unstable spatial distribution of non-trawl activity and relatively few operators (Table 5.1.4.1), meant that few detailed analyses were possible.

Non-trawl data added considerably to interpretation of the project data set through cross-referencing to trawl data, but has been treated separately to the electronic project GIS mapping data set. Certain components could be added as stand-alone polygons, or used to modify existing polygons where they provide new information, but amalgamation would need to be done selectively and would need to be updated to reflect the large-scale expansion of auto-longline effort that has occurred since the project data was collected.

5.2.2 Matching trawl logbook data with fishing ground polygons

The distribution of trawling effort recorded in SEF1 logbooks was analysed, after erroneous data were removed, with respect to fishery subregion, major depth zone, terrain type and fishing ground. Data were pooled in 1 km grid cells, and only cells containing > 0.5 hours effort in any year were included in the analysis. Grid cells were then overlaid on fishing ground polygons to match logbook data to individual fishing grounds, i.e. logbook data then became attributed to individual fishing grounds in the database.

Overlays were first examined for differences in plan area estimates (sq km) between the 516 fishing ground polygons and their corresponding groups of 1 km grid cells (Fig. 5.2.2.1). Differences between individual polygon and grid areas were small, ranging from plus 11 to minus 16 sq km per fishing ground. In total, the grid estimate was 290 sq km greater (141,941 vs 141,651 sq km) due in part to the extension of cells beyond the outer and inner margins of the study area at 3 n.m. and 1300 m depth, and one large discrepancy (127 sq km in ground 469,West Tasmania inner shelf, north) due to a change in the placement of a complex State 3 n.m. boundary that formed the inner fishing ground boundary; this latter source had no bearing on subsequent results because it received no trawl or non-trawl fishing effort. The revised grid area excluding area inside State waters was 141,818 sq km.

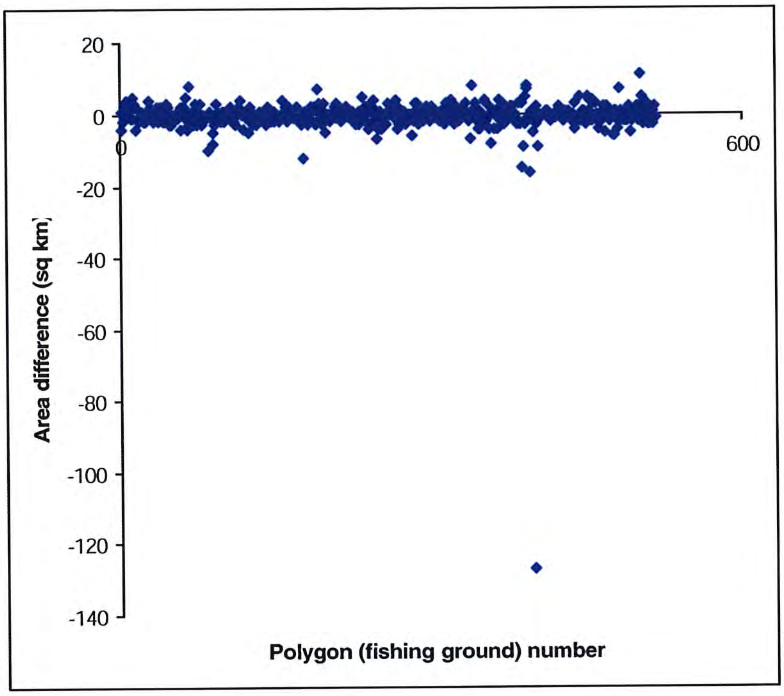


Figure 5.2.2.1 Difference in plan area estimates (sq km) between map polygon and corresponding 1km grid cell overlay for each of 516 fishing grounds (range, 11 to -16 sq km). Note: single large difference (127 sq km) in ground 469 (Western Tasmania inner shelf, north) due to error in placement of State 3 n.m. boundary

In summary, the very small differences, 0.2% of the total study area and < 0.5% for any ground, showed there was a good spatial match between the polygons and the logbook data that were being attributed to them.

Overlay of grid cells on the mosaic of fishing ground polygons also enabled reflection of effort 'smeared' over untrawlable bottom by the straight-line interpolation process used to locate the trawl lines across cells in the 1 km grid (Section 4.5.1). Effort was reflected from 118 grounds classified as untrawlable (Table 5.2.2.1) resulting in the distribution of data over a subset of 381 grounds of which only 364 had effort recorded between 1996 and 2001. The 17 trawlable grounds without trawl effort are comprised of nine areas on the deep mid-slope, seven on the mid-shelf, and two canyons.

Table 5.2.2.1 Classification of fishing grounds into untrawled (effort reflected) and trawled (effort not reflected) for spatial analysis of effort data from SEF1 logbook. Totals of grounds showing (a) general use for trawling, and (b) Terrain

(a)

Use for trawling	Effort reflected	Effort not reflected	Total grounds
Untrawlable	118	0	118
Not trawled	2	27	29
Trawled in part: no information	0	2	2
Trawled in part: few shots	14	112	126
Trawled	0	238	238
Unknown	1	2	3
Total grounds	135	381	516

(b)

Terrain	Effort reflected	Effort not reflected	Total grounds
Heavy reef	45	0	45
Many reef patches	88	62	150
Few reef patches	2	171	173
Clear sediments	0	148	148
Total grounds	135	381	516

5.2.3 Types and areas of seabed used for fishing

We used two methods to examine the types and areas of seabed used by each industry sector in the fishery area (3 n.m. State boundary to the 1300 m depth contour). The first method used industry data in isolation to estimate the proportions of terrains used; this is a very conservative estimate from an industry point of view because not all the area of any ground used for fishing is actually fished. The second method, possible only for trawl sector data, provides an absolute estimate of area fished (sq km) based on fishery logbook records. This estimate is also conservative, but from the opposite point of view: it estimates the area trawled in any one year but does not consider the non-overlapping trawled areas between years.

Trawling

There was a clear relationship between the type of seabed and its use for trawl fishing. The vast majority (132 of 148) of grounds made up by clear sediments are trawled (Table

5.2.3.1 a). In addition, most grounds made up by sediments with few reef patches are trawled (97 of 173) or trawled in part (activity distributed along one to few trawl shots) (59 of 173). Most grounds made up by sediments with many reef patches were described as untrawlable (74 of 150 grounds), or fished along few trawl shots (57 of 150); a further seven were untrawled and nine trawled. There was virtually no trawling on heavy reef bottom types (43 of 45 grounds); 2 of 45 grounds were reported to have some trawl shots.

Table 5.2.3.1 The Terrain of 516 SEF fishing grounds showing (a) the number of grounds of each Terrain used for trawl fishing; (b) the plan area (sq km) of each Terrain used for trawl fishing

(a)

Use for trawling	Heavy reef	Many reef patches	Few reef patches	Clear sediments	Total grounds	% total grounds
Untrawlable	43	74	1		118	22.87
Not trawled		7	15	7	29	5.62
Fished in part: no information		1	1		2	0.39
Fished in part: few shots	2	57	59	8	126	24.42
Trawled		9	97	132	238	46.12
Unknown		2		1	3	0.58
Total grounds	45	150	173	148	516	100

(b)

Use for trawling	Heavy reef	Many reef patches	Few reef patches	Clear sediments	Total area	% total area
Untrawlable	2,119	61,112	571		63,802	45.04
Not trawled		1,327	7,857	1,910	11,094	7.83
Fished in part: no information		50	16		66	0.05
Fished in part: few shots	276	4,833	9,407	3,017	17,533	12.38
Trawled		980	25,123	22,860	48,963	34.57
Unknown		82		112	194	0.14
Area (sq km)	2,395	68,384	42,974	27,899	141,652	--
% of total fishery area	1.7	48.3	30.3	19.7	100	100

Over half the fishery area (53%) was estimated to be untrawlable (~45%) or not trawled (~8%) (Table 5.2.3.1). Trawl grounds made up about 35% of the total fishery area, with an additional 12% of total area described as being 'trawled in part' (usually along one to a few trawl shots).

In overview, a high proportion of grounds (about 71%) experience some trawl activity, but these grounds make up less than half the total SEF fishery area (about 47%). Activity on trawl grounds is highly variable in its distribution and regularity – ranging from regular wide-ranging activity by many vessels to occasional activity along a restricted set of tow lines (Section 5.2.9).

Absolute estimates of trawled areas (in sq km) were not attempted using industry data alone because the data provided was not at a sufficiently fine resolution. Data are at the resolution of fishing grounds not trawl tows, and trackplotter data showed some, but not all trawl shots. Quantitative estimates could be made using effort data reported in the SEF1 logbook. However, as noted in Section 4.5.1, this method is prone to overestimation, firstly because trawl tows that curve around untrawlable features are extrapolated as straight lines; and secondly because vessel position, rather than the position of gear on the seabed, is recorded and this extends the estimated trawl area at one or both ends of the tow. Both biases serve to increase the area of seabed trawled and mask untrawlable areas, e.g. reefs, in maps of effort. So estimates using logbook data incorporated industry's bottom type data to 'reflect' effort off untrawlable areas.

Effort was reflected from 135 grounds: 118 classified as untrawlable, 14 in which there is very little opportunity to trawl, and 3 that were not trawled or unknown. Effort was reflected into adjacent trawlable areas (Section 4.5.1) that comprised 238 trawl grounds, 112 that are trawled in part and 27 that are not trawled but classified as trawlable (Table 5.2.2.1). All heavy reef bottom types were reflected, as were the majority (88 of 150 grounds) made of sediments with many reef patches); virtually all sediments with few reef patches and all clear sediments remained unreflected (Table 5.2.2.1 B).

The total area trawled in each of the years from 1996 to 2001 is shown in following sections: by depth zone in Section 5.2.4 and by fishery subregion Section 5.2.5. In overview, we estimate the area trawled in 2001 was 26,469 sq km or about 19% of the SEF region as defined here (3 n.m. to 1,300 m depth contour). However, finer scale information is needed to understand and interpret what this means for sustainable use of habitats and for conserving biodiversity, and it is this context we explore in the following sections.

Non-trawl fishing

The spatial resolution of non-trawl data is a mix of precisely recorded fishing positions on features such as reefs and canyons, and imprecisely defined areas where 'buffers zones' deliberately mask precise fishing locations. In addition, there are many small-scale or part-time non-trawl fishers using areas that we have no information for. As a consequence, it is difficult to provide an estimate of the area used for fishing. A conservative (over) estimate from the non-trawl database including all mapped areas is about 5% of the total fishery area (Table 5.1.9.1). This is highly variable between subregions: for example, our data mapped non-trawl grounds in only 11 subregions, with concentrations in three – Eden/Smithys, Babel and West Tasmania (Table 5.2.3.2).

However, as noted elsewhere, the rapid increase and spatial expansion of auto-longline effort since the project data collection concluded will have substantially increased this estimate.

Table 5.2.3.2 The Terrain of 153 SEF fishing grounds in the non-trawl data set showing (a) the number of grounds of each Terrain used for non-trawl fishing; (b) the plan area (sq km) of each Terrain used for non-trawl fishing

(a)

	Heavy reef	Many reef patches	Few reef patches	Clear sediments	Total grounds
Beachport	19	2	2		23
King Island			1		1
West Tasmania	1	6	3		10
SW Tasmania	3	3			6
South Tasmania	9	4			13
Maria	1	4			5
East Tasmania	1	2	1	1	5
St Helens	4	3	6		13
Banks Strait	5	5	3		13
Babel	3	10	2		15
Eden/ Smithy's	9	20	18	2	49
Total grounds	55	59	36	3	153

(b)

	Heavy reef	Many reef patches	Few reef patches	Clear sediments	Total area
Beachport	87	5	17		109
King Island			93		93
West Tasmania	5	383	653		1,041
SW Tasmania	14	294			309
South Tasmania	57	184			242
Maria	1	158			160
East Tasmania	1	2	11	64	78
St Helens	16	104	94		214
Banks Strait	112	179	141		432
Babel	357	1,250	69		1,676
Eden/ Smithy's	406	2,236	305	17	2,964
Total area	1,058	4,796	1,383	81	7,318
% of total fishery area (141,652 sq km)	0.75	3.39	0.98	0.06	5.17

Danish Seine fishing

Few data were collected from the Danish Seine sector for the reasons outlined in Section 5.1.6. The spatial extent of this fishery was documented from logbook data by Larcombe et al. (2002) and the habitats of the extensive continental shelf sediment plain off Lakes Entrance used by the major part of the fleet were detailed by Bax and Williams (1999).

5.2.4 Patterns of trawl effort distribution related to depth

The area of seabed trawled across the entire fishery was higher in 2001 than 1996: the annual 'footprint' showed a small decrease of 410 sq km from 1996 to 1998 then an increase of 3,124 sq km by 2001 to give a net increase over the six year period of 2,714 sq km (Table 5.2.4.1; Fig 5.2.4.1 a). Trawled area increased in all depth zones except for the shallowest (inside 50 m depth) where virtually no effort was recorded (Table 5.2.4.1).

Table 5.2.4.1 Plan area (sq km) of seabed trawled in primary depth zones of the SEF based on grid-cell estimates from SEF1 logbook data. Estimates include only cells with >0.5 hours of effort per year, and show areas trawled in six years to 2001, and change between 1996 and 2001. Note: estimated net changes compare counts of grid cells with effort, not their spatial overlap between years.

			Depth zone					
Year	3nm-50m	50-100m	100-150m	150-200m	200-700m	700-1300m	Total	Net Change
1996	1	1752	7521	2474	8679	3328	23755	--
1997		1469	7202	2605	8891	3424	23591	-164
1998		1686	7172	2363	8853	3271	23345	-246
1999	1	1916	7451	2568	9164	3227	24327	982
2000		1922	7403	2630	9694	3455	25104	777
2001	1	1953	7816	2884	10091	3724	26469	1365
Net change in area trawled (sq km) (1996 to 2001)	0	201	295	410	1412	396	2714	2714
Total area of depth zone	18086	43552	30817	10468	18854	20041	141818	--
Percentage trawled 1996	0.0	4.0	24.4	23.6	46.0	16.6	16.8	--
Percentage trawled 1997	0.0	3.4	23.4	24.9	47.2	17.1	16.6	-0.12
Percentage trawled 1998	0.0	3.9	23.3	22.6	47.0	16.3	16.5	-0.17
Percentage trawled 1999	0.0	4.4	24.2	24.5	48.6	16.1	17.2	0.69
Percentage trawled 2000	0.0	4.4	24.0	25.1	51.4	17.2	17.7	0.55
Percentage trawled 2001	0.0	4.5	25.4	27.6	53.5	18.6	18.7	0.96
% net change in area trawled (1996 to 2001)	0.0	0.5	1.0	3.9	7.5	2.0	1.9	1.9

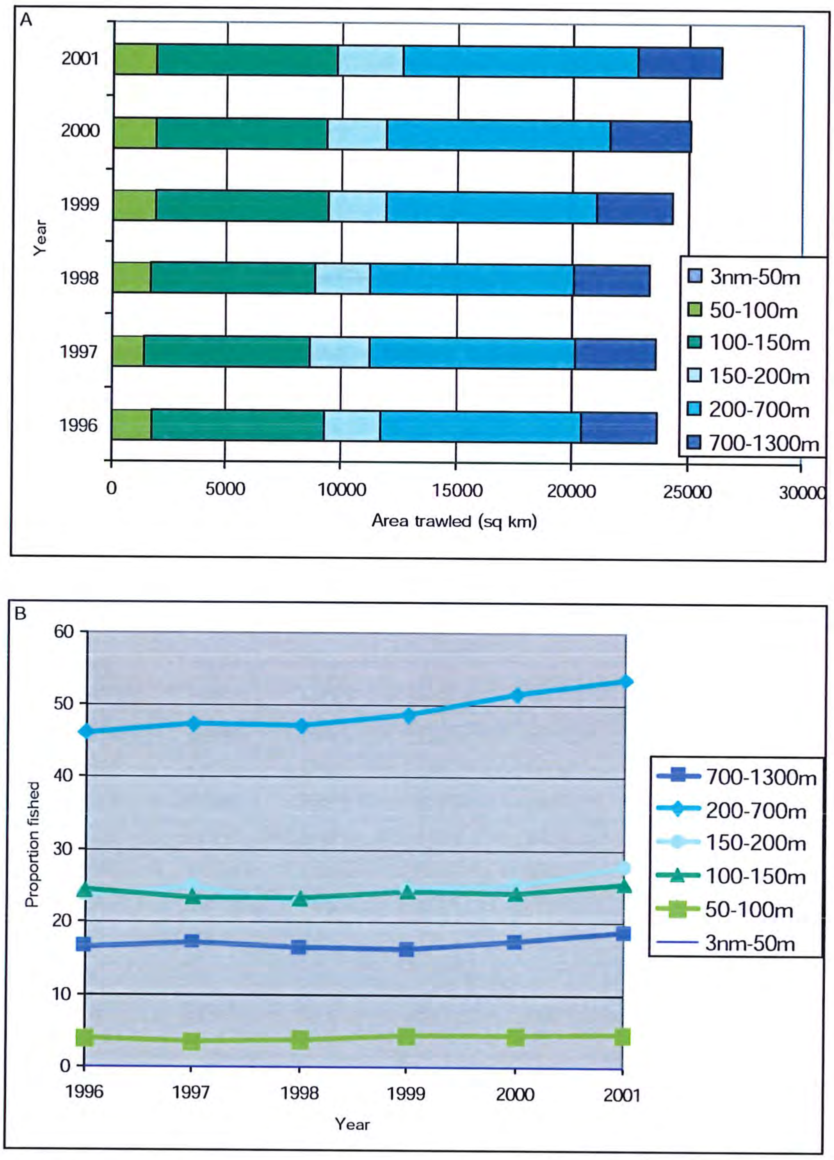


Figure 5.2.4.1 (a) Plan area (sq km) and (b) proportions of seabed trawled in primary depth zones of the SEF between 1996 and 2001 based on grid-cell estimates from SEF 1 logbook data. Estimates include only cells with >0.5 hours of effort. Note: estimated net changes compare counts of grid cells with effort, not their spatial overlap between years

The degree of change varied substantially between depth zones, and there was inter-annual variation within depth zones – including some years when the trawled area decreased (Fig. 5.2.4.1 b). Between 1996 and 2001, the proportional increases were small (< 2%) on the mid-shelf and mid-slope, but 3.9% on the deep shelf, and 7.5% on the upper slope. This increase of 2,714 sq km, or more than 11%, from 1996 to 2001 is a conservative (minimal) estimate because only the area trawled in any one year is estimated; the overlap of cells between years (whether the same areas are used every year) is not estimated.

There is a second source of conservatism, where expansions and contractions within the same individual fishing ground (which are summed to provide the aggregate estimate) have the effect of 'cancelling out'. This is investigated in the last part of this section. The true increase in area trawled (omitting the areas where effort contracted), is 4,758 sq km (see following Section 5.2.8).

5.2.5 Patterns of trawl effort distribution related to fishery subregion

Subregional patterns in effort distribution were underpinned by estimates of the total plan area of seabed in each region, and estimates of the areas that are untrawlable and trawlable (Table 5.2.5.1). In this context, trawlable area is derived from the aggregation of grounds that are trawled, in whole or in part; untrawlable means trawling is not considered possible. Logbook effort was summed across the grounds making up each fishery subregion to provide an aggregated estimate of the number of 1 km grid cells fished in each year between 1996 and 2001 (Table 5.2.5.1).

There are large differences in the size of fishery subregions (Fig 5.2.5.1 a) that stem in large part from the way they have been defined – primarily as the areas used historically by parts of the fishing fleet based in major ports. However, another important component is the relative size of the continental shelf which is relatively massive in subregions such as Beachport, West Tasmania and Eden/Smithys. The relative size differences are an important part of the context for interpreting patterns related to the substructure within subregions such as depth zones, seabed types and patterns of use.

There are also large differences in the estimated proportions of trawlable and untrawlable grounds within subregions (Fig. 5.2.5.1 b). This indicates the subregions to the west of Tasmania have the largest proportions of untrawlable seabed, and contain the vast majority of the region's untrawlable seabed. In these subregions, untrawlable bottom is primarily made up by very extensive areas of patchy reef on the continental shelf, with relatively small contributions from rough bottom on the upper slope, and several (~19) substantial canyon features (and see following sections). Southern Tasmania and all eastern seaboard subregions with the exclusion of Babel are made up mostly by grounds that are trawlable. The relatively large areas of untrawlable seabed in Babel and Eden/Smithys, are made up by several large reef platforms on the shelf together with extensive rough areas on the upper and mid-slope, much of it associated with canyons.

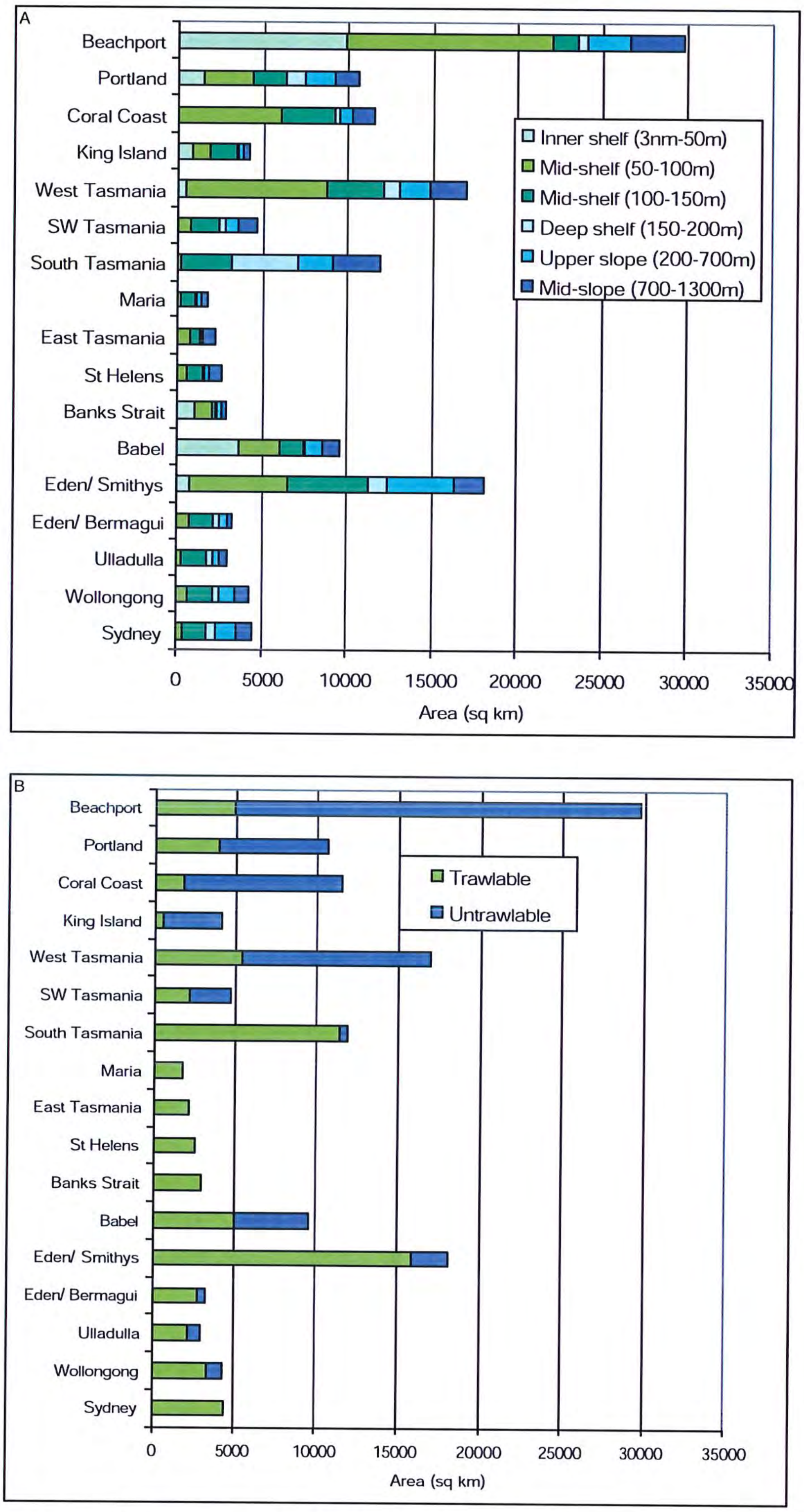


Figure 5.2.5.1 Estimated plan areas (sq km) of (a) fishery subregions of the SEF showing major depth zones, and (b) trawlable and untrawlable fishing grounds in fishery subregions. Note, trawlable means some, but not necessarily all, of a ground is trawlable or trawled; untrawlable means trawling is not considered possible

Two patterns in effort distribution were examined for each subregion: the overall difference in area of seabed trawled between 1996 and 2001 (the sum of expansion and contraction in individual grounds), and the net difference in trawlable area used for trawl fishing over the same period expressed as a percentage (Fig. 5.2.5.2 a and b). There were strong similarities in the two plots: most (14 of 17) subregions showed increases in area trawled over this period with only three subregions (South Tasmania, Eden/Bermagui and Ulladulla) showing decreases. The largest area increases were in Western Tasmania, SW Tasmania and Babel. Relatively large increases also occurred in the western subregions of Portland and Coral Coast, and together these five subregions also showed the largest increases in % terms (~9-18%), together with the relatively small Maria subregion (13%). Effort distribution (in total area and % trawlable) increased steadily during this 6-year period in Western Tasmania, SW Tasmania and Babel, whereas in Portland, Coral Coast and Maria, effort levels fluctuated between years but increased markedly between 2000 and 2001 (Table 5.2.5.1). Effort decreases in South Tasmania, Eden/Bermagui and Ulladulla) were also characterised by interannual fluctuations, but marked decreases occurring early in this period – particularly between 1996 and 1997.

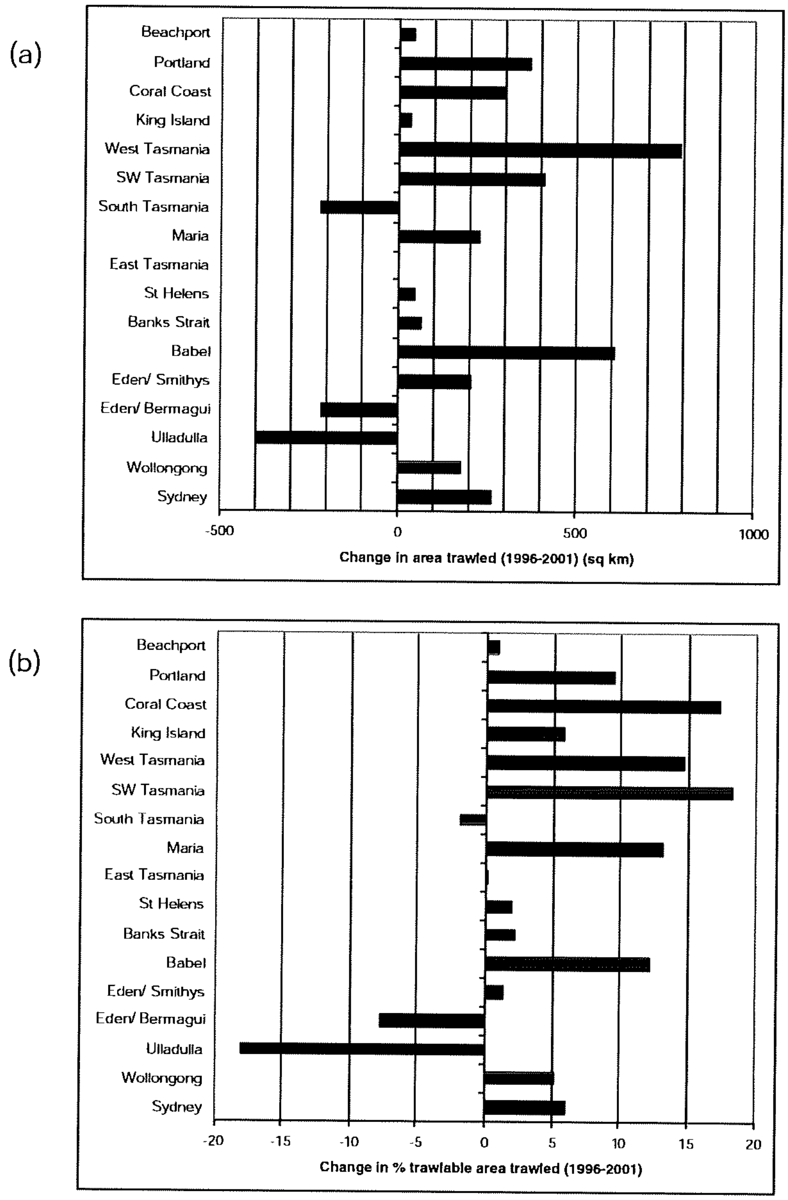


Figure 5.2.5.2 Net change in (a) plan area (sq km) of seabed trawled and (b) % change in trawlable area trawled in fishery subregions of the SEF: comparison of effort in 2001 with 1996 using 1 km grid-cells derived from SEF1 logbook data.. Estimates include only cells with >0.5 hours of effort. Note: estimated changes compare counts of grid cells with effort, not their spatial overlap between years.

5.2.6 Patterns of trawl effort distribution related to depth within subregion

Data were further subdivided by depth within subregion to examine patterns in areas of seabed trawled not evident when depth zones and subregion were examined independently. There was considerable variation in depth-related patterns between subregions and groups of subregions (Tables 5.2.6.1 and 5.2.6.2).

Table 5.2.6.2 Summary of plan areas of seabed trawled (sq km) in primary depth zones in fishery subregions of the SEF based on grid-cell estimates from SEF1 logbook data. Estimates include only cells with >0.5 hours of effort, and show areas trawled in 1996 and 2001, net change between 1996 and 2001, and pattern of net effort change by subregion for both the entire seabed and the fraction classified as trawlable (see Section 5.3). Note: estimated changes compare counts of grid cells with effort, not their spatial overlap.

Subregion by depth zone by year	Depth	Beachport	Portland	Coral Coast	King Island	West Tasmania	SW Tasmania	South Tasmania	Maria	East Tasmania	St Helens	Banks Strait	Babel	Eden/ Smithys	Eden/ Bermagui	Ulladulla	Wollongong	Sydney	All SEF
Total area in subregion depth zone	Inner shelf (3nm-50m)	9951	1476	21	817	471	0	0	0	8	18	961	3589	774	0	0	0	0	18086
	Mid-shelf (50-100m)	12128	2917	6083	1040	8284	655	179	119	660	467	1001	2497	5768	678	207	582	287	43552
	Outer shelf (100-150m)	1470	1863	3156	1571	3347	1715	3008	822	604	1011	253	1308	4703	1429	1531	1537	1489	30817
	Shelf break (150-200m)	557	1239	313	65	892	401	3877	105	41	60	47	153	1174	303	362	389	490	10468
	Upper slope (200-700m)	2532	1732	614	249	1848	696	2034	270	191	308	294	1073	3948	520	415	927	1204	18855
	Mid-slope (700-1300m)	3179	1379	1330	402	2133	1225	2809	431	722	721	332	1013	1792	298	450	848	977	20041
	Total subregion area (all depths)	29816	10606	11517	4144	16975	4692	11907	1747	2226	2585	2888	9633	18159	3228	2965	4283	4447	141818
***Trawlable* area in subregion depth zone**	Inner shelf (3nm-50m)	0	0	0	0	0	0	0	0	8	18	961	11	774	0	0	0	0	1772
	Mid-shelf (50-100m)	0	13	0	0	0	0	19	119	660	467	1001	2056	5701	667	188	183	287	11361
	Outer shelf (100-150m)	3	469	0	0	734	0	2782	822	604	1011	253	987	4025	1212	964	1147	1470	16483
	Shelf break (150-200m)	95	730	0	65	869	396	3876	105	41	60	47	127	966	279	299	365	490	8810
	Upper slope (200-700m)	1663	1449	459	107	1725	651	1987	270	191	308	294	951	3089	443	368	847	1160	15962
	Mid-slope (700-1300m)	3150	1304	1275	402	2010	1204	2809	431	722	721	332	895	1315	160	390	841	947	18908
	Total trawlable subregion area (all depths)	4911	3965	1734	574	5338	2251	11473	1747	2226	2585	2888	5027	15870	2761	2209	3383	4354	73296
% of *trawlable* area in subregion depth zone	Inner shelf (3nm-50m)	0.0	0.0	0.0	0.0	0.0	--	--	--	100.0	100.0	100.0	0.3	100.0	--	--	--	--	9.8
	Mid-shelf (50-100m)	0.0	0.4	0.0	0.0	0.0	0.0	10.6	100.0	100.0	100.0	100.0	82.3	98.8	98.4	90.8	31.4	100.0	26.1
	Outer shelf (100-150m)	0.2	25.2	0.0	0.0	21.9	0.0	92.5	100.0	100.0	100.0	100.0	75.5	85.6	84.8	63.0	74.6	98.7	53.5
	Shelf break (150-200m)	17.1	58.9	0.0	100.0	97.4	98.8	100.0	100.0	100.0	100.0	100.0	83.0	82.3	92.1	82.6	93.8	100.0	84.2
	Upper slope (200-700m)	65.7	83.7	74.8	43.0	93.3	93.5	97.7	100.0	100.0	100.0	100.0	88.6	78.2	85.2	88.7	91.4	96.3	84.7
	Mid-slope (700-1300m)	99.1	94.6	95.9	100.0	94.2	98.3	100.0	100.0	100.0	100.0	100.0	88.4	73.4	53.7	86.7	99.2	96.9	94.3
	Total % trawlable subregion area (all depths)	16.5	37.4	15.1	13.9	31.4	48.0	96.4	100.0	100.0	100.0	100.0	52.2	87.4	85.5	74.5	79.0	97.9	51.7
% of depth zone trawled 1996	Inner shelf (3nm-50m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
	Mid-shelf (50-100m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	2.9	12.3	97.9	80.7	20.6	4.9	4.0
	Outer shelf (100-150m)	0.0	2.5	0.0	0.0	0.0	0.0	15.3	64.8	6.1	21.4	12.6	7.0	75.5	82.1	56.9	27.9	5.4	24.4
	Shelf break (150-200m)	1.1	25.5	0.0	3.1	5.9	7.2	7.0	61.0	31.7	20.0	27.7	13.1	79.9	87.8	79.8	33.9	10.0	23.6
	Upper slope (200-700m)	48.8	76.0	22.5	34.9	65.9	33.0	8.2	48.5	11.5	9.7	10.9	22.6	54.4	73.8	74.7	63.8	33.2	46.0
	Mid-slope (700-1300m)	14.7	17.2	12.2	47.5	48.6	12.7	6.6	3.0	30.6	19.4	2.1	12.2	11.2	4.0	22.4	3.4	4.6	16.6
% of depth zone trawled 2001	Inner shelf (3nm-50m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mid-shelf (50-100m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.2	5.3	0.2	1.3	3.9	12.7	97.6	70.0	21.3	41.1	4.5
	Outer shelf (100-150m)	0.2	4.0	0.0	0.0	0.0	0.0	9.4	78.1	14.7	29.2	21.3	43.4	78.4	71.0	36.3	26.5	9.5	25.4
	Shelf break (150-200m)	14.5	36.6	0.0	18.5	32.1	23.2	6.4	56.2	43.9	20.0	21.3	32.0	80.4	72.9	69.1	28.0	7.8	27.6
	Upper slope (200-700m)	50.2	79.3	37.0	36.5	83.8	59.1	12.1	78.1	19.4	15.3	23.8	29.7	58.7	72.5	77.3	77.9	41.6	53.5
	Mid-slope (700-1300m)	12.5	27.8	28.0	52.2	59.2	26.0	3.0	9.3	16.5	13.0	0.3	12.2	4.1	3.7	14.7	13.6	5.4	18.6
% of *trawlable* depth zone trawled 1996	Inner shelf (3nm-50m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
	Mid-shelf (50-100m)	0.0	7.7	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	3.6	12.4	99.6	88.8	65.6	4.9	15.4
	Outer shelf (100-150m)	0.0	9.8	0.0	0.0	0.0	0.0	16.5	64.8	6.1	21.4	12.6	9.3	88.3	96.8	90.4	37.4	5.4	45.6
	Shelf break (150-200m)	6.3	43.3	0.0	3.1	6.1	7.3	7.0	61.0	31.7	20.0	27.7	15.7	97.1	95.3	96.7	36.2	10.0	28.1
	Upper slope (200-700m)	74.3	90.9	30.1	81.3	70.6	35.3	8.4	48.5	11.5	9.7	10.9	25.4	69.5	86.7	84.2	69.8	34.5	54.4
	Mid-slope (700-1300m)	14.8	18.2	12.7	47.5	51.6	13.0	6.6	3.0	30.6	19.4	2.1	13.9	15.3	7.5	25.9	3.4	4.8	17.6
% of *trawlable* depth zone trawled 2001	Inner shelf (3nm-50m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	0.0	0.0	0.0	0.0	0.1
	Mid-shelf (50-100m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.2	5.3	0.2	1.3	4.8	12.9	99.3	77.1	67.8	41.1	17.2
	Outer shelf (100-150m)	100.0	16.0	0.0	0.0	0.1	0.0	10.2	78.1	14.7	29.2	21.3	57.5	91.6	83.7	57.7	35.5	9.6	47.4
	Shelf break (150-200m)	85.3	62.2	0.0	18.5	32.9	23.5	6.4	56.2	43.9	20.0	21.3	38.6	97.7	79.2	83.6	29.9	7.8	32.7
	Upper slope (200-700m)	76.4	94.8	49.5	85.0	89.7	63.1	12.4	78.1	19.4	15.3	23.8	33.5	75.0	85.1	87.2	85.2	43.2	63.2
	Mid-slope (700-1300m)	12.6	29.4	29.2	52.2	62.8	26.4	3.0	9.3	16.5	13.0	0.3	13.9	5.6	6.9	16.9	13.7	5.6	19.7
% net change in depth zone trawled (1996-2001)	Inner shelf (3nm-50m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0
	Mid-shelf (50-100m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	5.3	0.2	1.3	1.0	0.4	-0.3	-10.6	0.7	36.2	0.5
	Outer shelf (100-150m)	0.2	1.6	0.0	0.0	0.0	0.0	-5.8	13.3	8.6	7.8	8.7	36.4	2.8	-11.1	-20.6	-1.4	4.1	1.0
	Shelf break (150-200m)	13.5	11.1	0.0	15.4	26.1	16.0	-0.6	-4.8	12.2	0.0	-6.4	19.0	0.5	-14.9	-10.8	-5.9	-2.2	3.9
	Upper slope (200-700m)	1.4	3.2	14.5	1.6	17.9	26.0	4.0	29.6	7.9	5.5	12.9	7.2	4.3	-1.3	2.7	14.1	8.4	7.5
	Mid-slope (700-1300m)	-2.2	10.7	15.8	4.7	10.6	13.2	-3.6	6.3	-14.1	-6.4	-1.8	0.0	-7.1	-0.3	-7.8	10.1	0.8	2.0
% net change in *trawlable* depth zone trawled (1996-2001)	Inner shelf (3nm-50m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	-0.1	0.0	0.0	0.0	0.0	0.0
	Mid-shelf (50-100m)	0.0	-7.7	0.0	0.0	0.0	0.0	0.0	16.0	5.3	0.2	1.3	1.2	0.4	-0.3	-11.7	2.2	36.2	1.8
	Outer shelf (100-150m)	100.0	6.2	0.0	0.0	0.1	0.0	-6.3	13.3	8.6	7.8	8.7	48.2	3.3	-13.1	-32.7	-1.9	4.1	1.8
	Shelf break (150-200m)	78.9	18.9	0.0	15.4	26.8	16.2	-0.6	-4.8	12.2	0.0	-6.4	22.8	0.6	-16.1	-13.0	-6.3	-2.2	4.7
	Upper slope (200-700m)	2.2	3.9	19.4	3.7	19.2	27.8	4.1	29.6	7.9	5.5	12.9	8.1	5.5	-1.6	3.0	15.5	8.7	8.8
	Mid-slope (700-1300m)	-2.2	11.3	16.5	4.7	11.2	13.5	-3.6	6.3	-14.1	-6.4	-1.8	0.0	-9.7	-0.6	-9.0	10.2	0.8	2.1

Table 5.2.6.1 Data showing plan areas (sq km) of seabed trawled in primary depth zones in fishery subregions of the SEF based on grid-cell estimates from SEF1 logbook data. Estimates include only cells with >0.5 hours of effort. Note: estimated changes compare counts of grid cells with effort, not their spatial overlap between years.

Subregion by depth zone by year	Depth zone	Beachport	Portland	Coral Coast	King Island	West Tasmania	SW Tasmania	South Tasmania	Maria	East Tasmania	St Helens	Banks Strait	Babel	Eden/ Smithys	Eden/ Bermagui	Ulladulla	Wollongong	Sydney	All SEF
1996	Inner shelf (3nm-50m)													1					1
	Mid-shelf (50-100m)		1						5				73	708	664	167	120	14	1752
	Outer shelf (100-150m)		46					459	533	37	216	32	92	3553	1173	871	429	80	7521
	Shelf break (150-200m)	6	316		2	53	29	272	64	13	12	13	20	938	266	289	132	49	2474
	Upper slope (200-700m)	1235	1317	138	87	1217	230	166	131	22	30	32	242	2147	384	310	591	400	8679
	Mid-slope (700-1300m)	466	237	162	191	1037	156	186	13	221	140	7	124	201	12	101	29	45	3328
	Total	1707	1917	300	280	2307	415	1083	746	293	398	84	551	7548	2499	1738	1301	588	23755
1997	Inner shelf (3nm-50m)																		0
	Mid-shelf (50-100m)								7	20	9		47	486	640	151	70	39	1469
	Outer shelf (100-150m)		48					353	496	19	237	55	358	3503	1086	612	402	33	7202
	Shelf break (150-200m)	17	368			74	48	210	56	14	12	18	56	938	247	280	160	107	2605
	Upper slope (200-700m)	1243	1344	114	101	1281	252	226	150	23	76	52	210	2026	391	294	612	496	8891
	Mid-slope (700-1300m)	414	293	268	206	1103	236	145	24	161	100	9	135	162	15	60	29	64	3424
	Total	1674	2053	382	307	2458	536	934	733	237	434	134	806	7115	2379	1397	1273	739	23591
1998	Inner shelf (3nm-50m)																		0
	Mid-shelf (50-100m)								8	1	1	4	109	609	632	158	117	47	1686
	Outer shelf (100-150m)		17					287	424	28	203	60	424	3559	1033	599	443	95	7172
	Shelf break (150-200m)	6	275			75	42	183	49	14	9	15	58	931	216	282	131	77	2363
	Upper slope (200-700m)	1176	1340	126	93	1295	273	149	123	14	65	38	316	2095	365	283	619	483	8853
	Mid-slope (700-1300m)	428	333	192	181	1177	209	110	18	113	74	7	133	72	11	57	50	106	3271
	Total	1610	1965	318	274	2547	524	729	622	170	352	124	1040	7266	2257	1379	1360	808	23345
1999	Inner shelf (3nm-50m)												1						1
	Mid-shelf (50-100m)		5						4		2		151	741	624	157	130	102	1916
	Outer shelf (100-150m)		53			7		260	507	58	311	53	553	3513	991	563	413	169	7451
	Shelf break (150-200m)	25	306		1	145	72	206	47	17	7	15	53	937	220	279	160	78	2568
	Upper slope (200-700m)	1139	1335	146	86	1453	262	166	134	28	51	47	312	2265	370	303	575	492	9164
	Mid-slope (700-1300m)	329	354	244	162	1221	236	146	10	89	80	6	165	74	13	25	8	65	3227
	Total	1493	2053	390	249	2826	570	778	702	192	451	121	1235	7530	2218	1327	1286	906	24327
2000	Inner shelf (3nm-50m)												1						1
	Mid-shelf (50-100m)		1						1		16	30	157	663	666	150	129	109	1922
	Outer shelf (100-150m)		29			1		176	386	112	264	69	605	3337	1134	580	504	206	7403
	Shelf break (150-200m)	23	318		13	181	87	166	46	17	26	13	63	940	257	287	124	69	2630
	Upper slope (200-700m)	1192	1334	178	85	1483	329	256	149	38	101	60	371	2183	398	320	700	517	9694
	Mid-slope (700-1300m)	309	333	319	192	1168	295	129	9	138	107	7	123	82	13	66	56	109	3455
	Total	1524	2015	497	290	2833	711	727	591	305	514	179	1319	7205	2468	1403	1513	1010	25105
2001	Inner shelf (3nm-50m)												1						1
	Mid-shelf (50-100m)								24	35	1	13	98	733	662	145	124	118	1953
	Outer shelf (100-150m)	3	75			1		284	642	89	295	54	568	3687	1014	556	407	141	7816
	Shelf break (150-200m)	81	454		12	286	93	248	59	18	12	10	49	944	221	250	109	38	2884
	Upper slope (200-700m)	1271	1373	227	91	1548	411	247	211	37	47	70	319	2318	377	321	722	501	10091
	Mid-slope (700-1300m)	397	384	372	210	1263	318	84	40	119	94	1	124	73	11	66	115	53	3724
	Total	1752	2286	599	313	3098	822	863	976	298	449	148	1159	7755	2285	1338	1477	851	26469
Net change: 1996 to 2001	Inner shelf (3nm-50m)	0	0	0	0	0	0	0	0	0	0	0	1	-1	0	0	0	0	0
	Mid-shelf (50-100m)	0	-1	0	0	0	0	0	19	35	1	13	25	25	-2	-22	4	104	201
	Outer shelf (100-150m)	3	29	0	0	1	0	-175	109	52	79	22	476	134	-159	-315	-22	61	295
	Shelf break (150-200m)	75	138	0	10	233	64	-24	-5	5	0	-3	29	6	-45	-39	-23	-11	410
	Upper slope (200-700m)	36	56	89	4	331	181	81	80	15	17	38	77	171	-7	11	131	101	1412
	Mid-slope (700-1300m)	-69	147	210	19	226	162	-102	27	-102	-46	-6	0	-128	-1	-35	86	8	396
	Total	45	369	299	33	791	407	-220	230	5	51	64	608	207	-214	-400	176	263	2714

There was a widespread increase in net area of seabed trawled in the depth zone showing the greatest increase between 1996 and 2001: the upper slope in 200-700 m (Fig. 5.2.6.1). All subregions showed increases in this zone except Eden/Bermagui, with the largest increases off West, SW and South Tasmania, and in Eden/Smithys. Increases off SW and West Tasmania were steady upward trends, whereas Eden/Smithys fluctuated over the six year period (Table 5.2.6.1).

In the other depth zone showing a relatively large overall increase in trawled area, the deep shelf (150-200 m), increases were mostly in the western seaboard: SW Tasmania, West Tasmania, Portland and Beachport. The increases were steady off Tasmania over the six year period, but recent (and relatively rapid) in Portland and Beachport between 2000 and 2001. This change in Portland was accompanied by a smaller scale, but equally rapid increase on the outer mid-shelf (100-150 m). During this period, trawled area declined in the deep shelf zone in the NSW subregions (Table 5.2.6.1).

The largest decline overall, in the Ulladulla subregion, stemmed mostly from reduced trawled area on the outer mid-shelf (100-150 m) early in this period. Elsewhere, the outer mid-shelf zone experienced expanded effort in several subregions but particularly Babel, Eden/Smithys and Maria. In Babel the increase was steady over the period: it fluctuated in the relatively massive Eden/Smithy subregion, and the relatively small Maria subregion. With the exception of Portland, increases on the shallow mid-shelf (100-150 m) were confined to the eastern seaboard with the largest increase off Sydney, consistent with the dominance of scattered reef patches over most of the continental shelf of the western seaboard (and see below).

Patterns were most variable in the deepest zone, the mid-slope (700-1300 m), with several increases and decreases of trawled seabed > 100 sq km. These are thought to reflect changes of effort moved away from targeting orange roughy concentrations towards less targeted fishing for other mid-slope species such as species of oreo dory and deepwater dogsharks. The net increase over all subregions of ~400 sq km was due to increases on the western seaboard between SW Tasmania to Portland, where steadily expanded effort covered an additional ~760 sq km in 2001 compared to 1996. Declines were in the traditional orange roughy fishery subregions off Beachport, southern and eastern Tasmania, as well as off Eden/Smithys, but the patterns were different and unstable over the six year period.

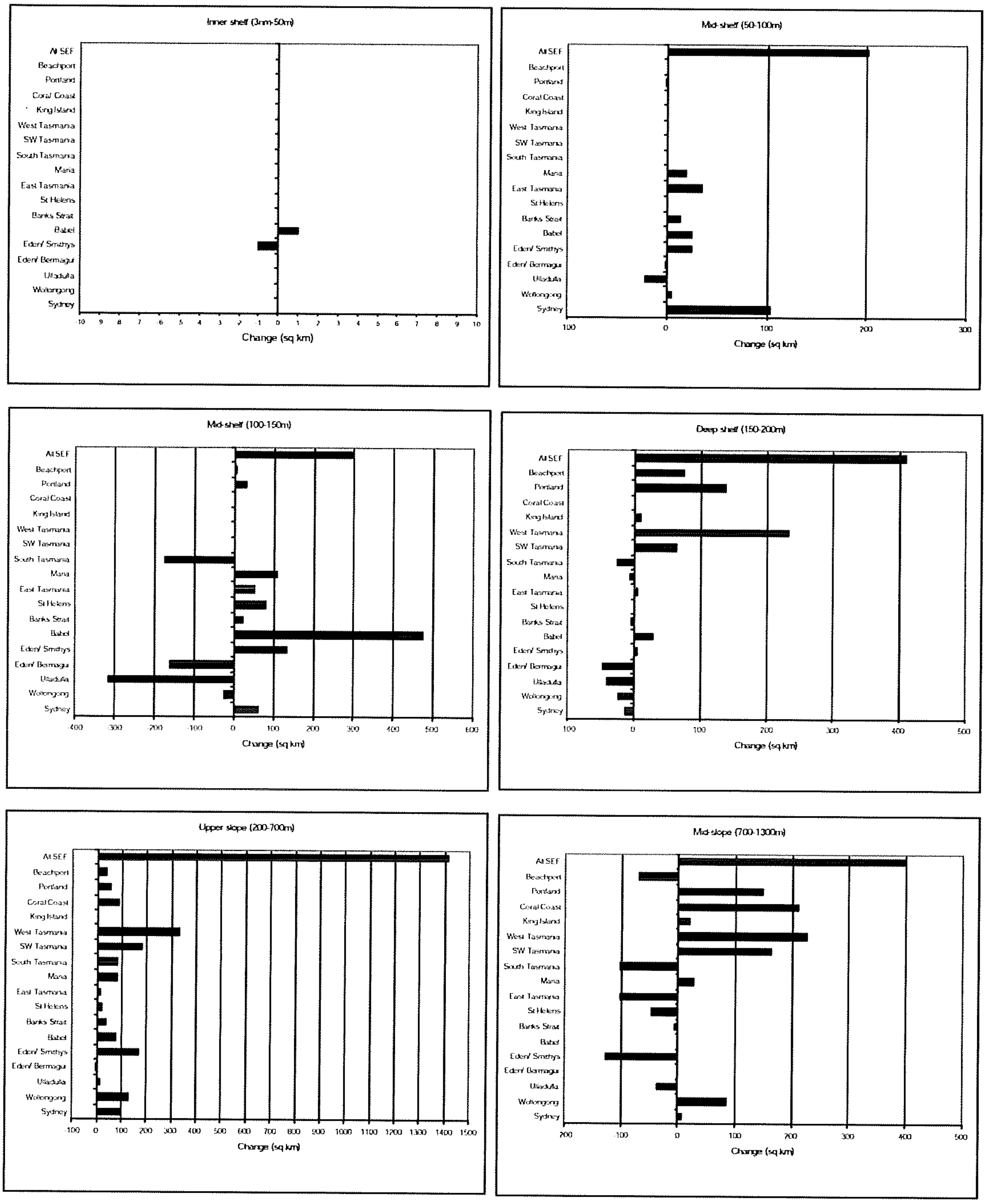


Figure 5.2.6.1 Change in plan area (sq km) of seabed trawled in six primary depth zones in fishery subregions of the SEF based on grid-cell estimates from SEF1 logbook data. Estimates include only cells with >0.5 hours of effort. Note: estimated changes compare counts of grid cells with effort, not their spatial overlap between years.

5.2.7 Patterns of trawl effort distribution related to seabed type

Data were also further subdivided by seabed type within subregion and depth zone to examine patterns in areas of seabed trawled. For context, we have already estimated the overall make of terrain types in the fishery (Table 5.2.3.1) is mostly 'sediments with many reef patches' (grounds with ~30-70% reef) and 'sediments with few reef patches' (~5-30% reef); these types make up 48 and 30% respectively. The remainder is 20% 'clear sediments' (no reef) and 2% 'heavy reef' (>70% reef).

Predictably then, the dominance of mixed sediment and reef patches is evident in most fishery subregions – all except Sydney and South Tasmania which are mostly clear sediments (Fig. 5.2.7.1; Fig. 5.2.7.2). However, there were considerable differences among the other subregions, and a distinction between the western seaboard mostly made up of sediments with many reef patches, and the eastern seaboard (with the exception of East Tasmania and Ulladulla) mostly made up of sediments with fewer reef patches. This regional-scale difference is attributable to the dominance of scattered reef patches over most of the relatively wide continental shelf of the western seaboard. One further east-west difference is in the distribution of large contiguous ('heavy') reefs which were reported mostly in Babel, Eden/Smithys and Eden/Bermagui.

Distinct patterns were also evident in the distribution of seabed terrain types by depth zone (Fig. 5.2.7.2). The overall trend is for relatively large proportions of rocky bottom (heavy reef and many reef patches) in shallower depths (inner and mid-shelf); these depth zones also have relatively large plan areas and therefore account for the majority of the rocky bottom in the fishery. Accordingly, relatively higher proportions of sediments with few reef patches as well as clear sediments are found on the deep shelf and continental slope. The large contiguous heavy reefs, such as the 276 sq km Gabo Reef (Fig. 5.1.6.2), are found mostly on the mid-shelf, although a large reef area was also reported off King Island on the upper slope.

Changes in area trawled were also estimated for each terrain type in each subregion based on aggregation of all component grounds (Table 5.2.7.1; Fig. 5.2.7.3).

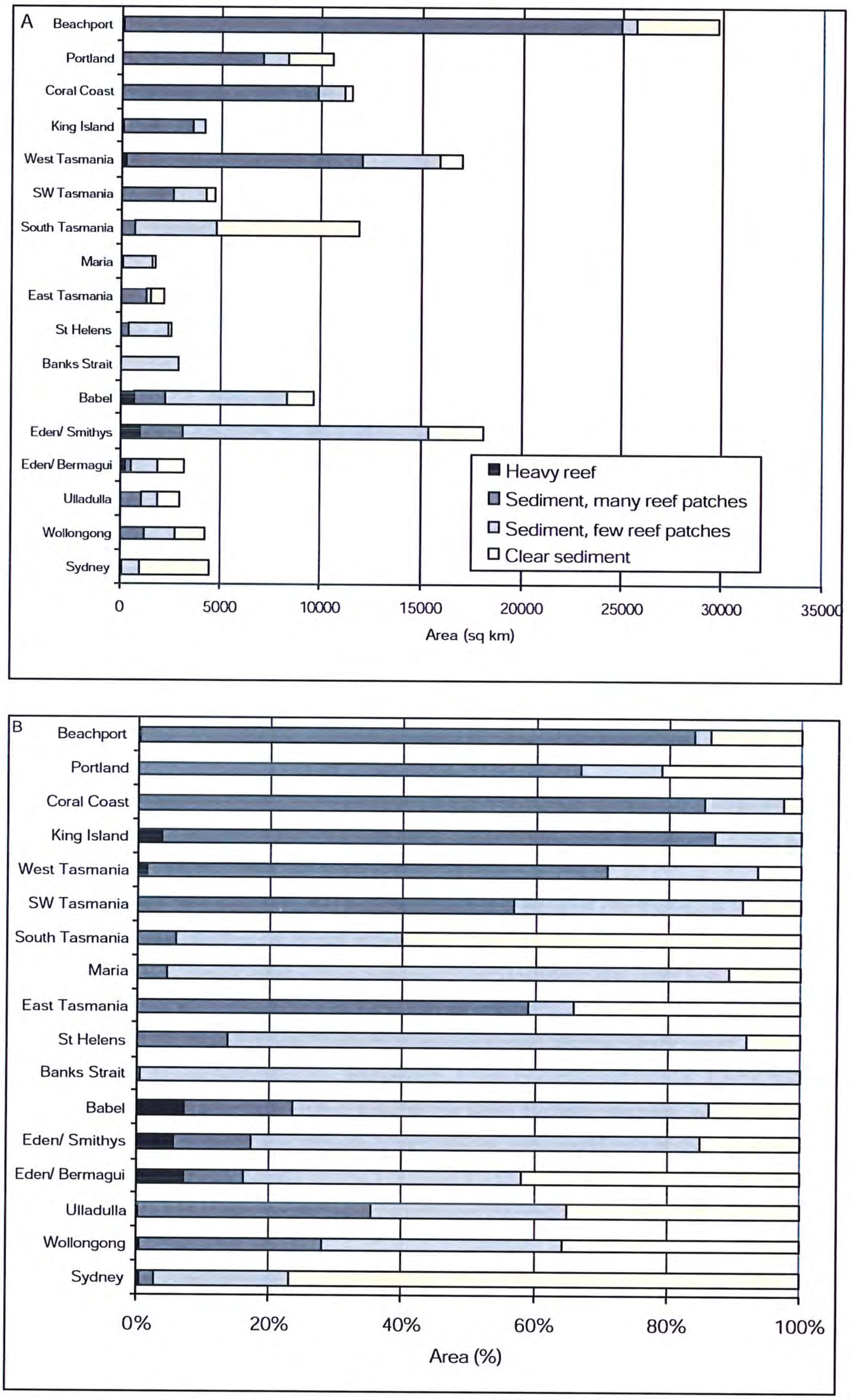


Figure 5.2.7.1 Estimated seabed terrains in fishery subregions of the SEF based on all 516 grounds: (a) polygon plan areas (sq km) and (b) normalized percentage

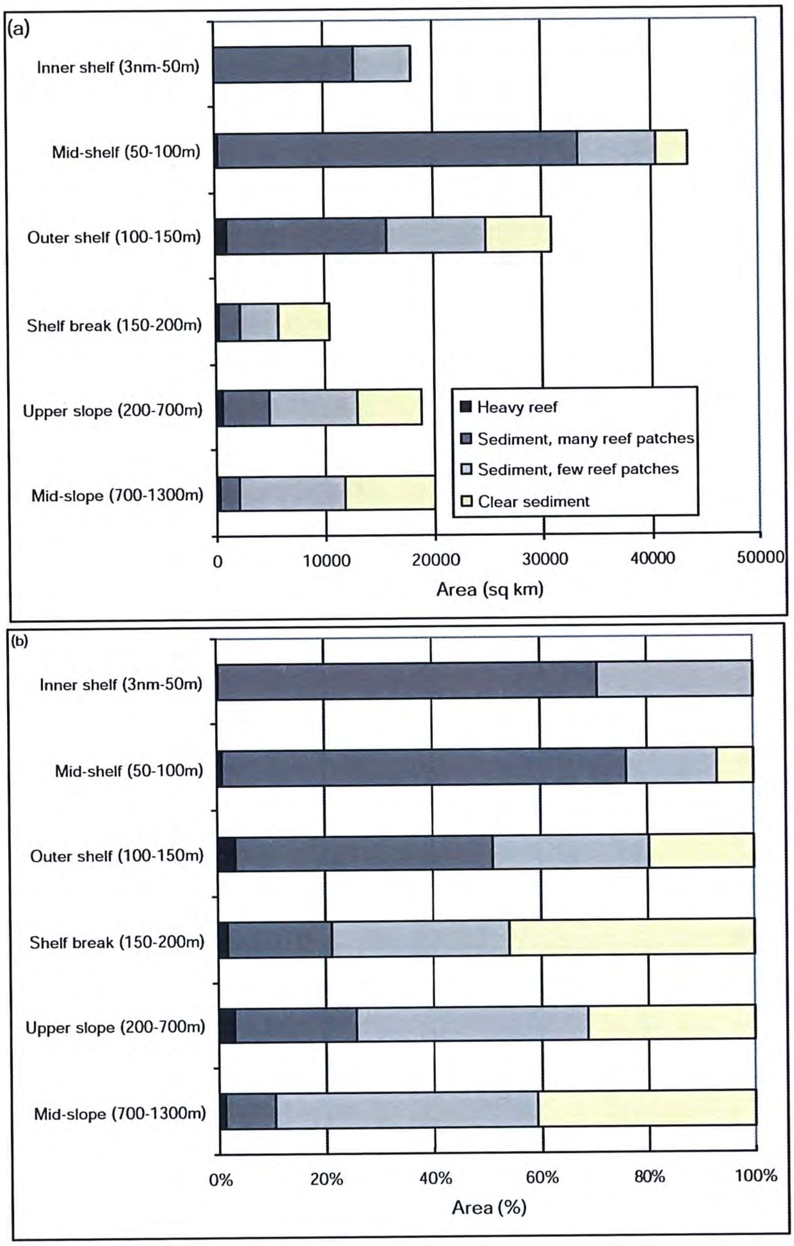


Figure 5.2.7.2 Estimated seabed terrains in depth zones of the SEF based on all 516 grounds: (a) grid cell plan areas (sq km) and (b) normalized percentage

Table 5.2.7.1 Estimated changes in net plan area trawled (sq km) on different seabed terrain types in fishery subregions of the SEF using grid-cell estimates from SEF1 logbook data overlaid on the 364 grounds with trawl effort. Estimates include only cells with >0.5 hours of effort. Note: estimated changes compare counts of grid cells with effort, not their spatial overlap between years

Subregion	Heavy Reef	Sediment, many reef patches	Sediment, few reef patches	Clear sediment	Total
Beachport	0	-14	-24	83	45
Portland	0	63	162	144	369
Coral Coast	0	21	176	102	299
King Island	0	0	33	0	33
West Tasmania	0	109	541	140	790
SW Tasmania	0	50	298	60	408
South Tasmania	0	-35	-84	-101	-220
Maria	0	15	178	37	230
East Tasmania	0	92	16	-103	5
St Helens	0	1	59	-9	51
Banks Strait	0	-1	65	0	64
Babel	0	145	405	58	608
Eden/ Smithys	0	33	43	131	207
Eden/ Bermagui	0	0	-76	-138	-214
Ulladulla	0	-69	-52	-279	-400
Wollongong	0	-8	-4	188	176
Sydney	0	0	118	145	263
Total net change		402	1854	458	2714

With all estimates of effort change across a number of aggregated grounds (for example in the previous subregional and depth zone summaries), the contractions in some individual grounds (negative changes) negate expansions in others (positive changes). This is the case here where grounds are summed within the four terrain types. However, as some subregion x terrain type aggregations have net (overall) contractions while others have net expansions, the data summaries show a combination of –ve and +ve components. This explains the differences in appearance of Fig 5.2.7.3 to the straight subregional plot (Fig. 5.2.5.2) despite the total net change in area trawled being the same (2714 sq km).

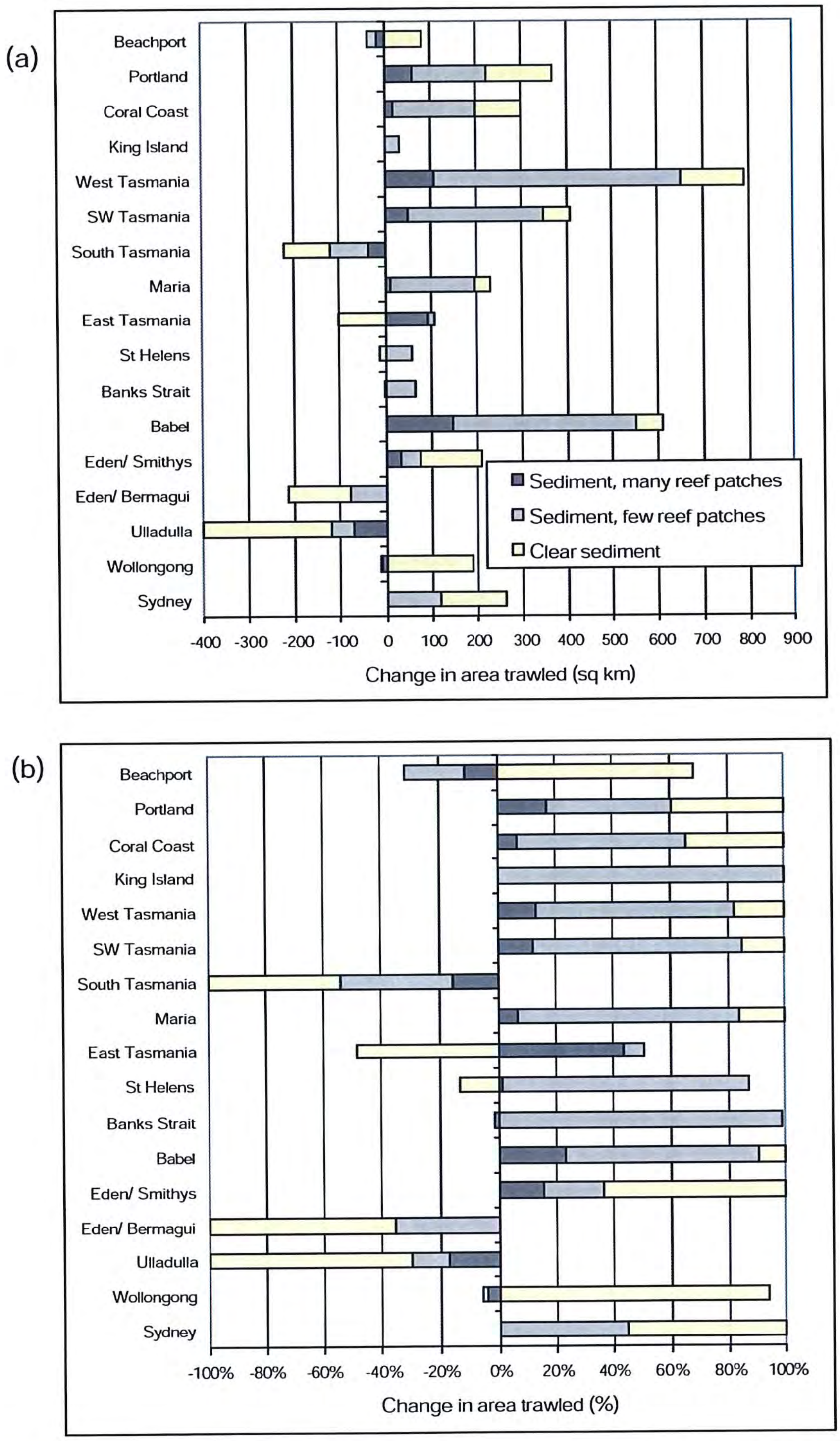


Figure 5.2.7.3 Estimated changes in (a) plan area trawled (sq km) and (b) % change on different terrains in fishery subregions of the SEF using grid-cell estimates from SEF1 logbook data overlaid on the 364 grounds with trawl effort. Estimates include only cells with >0.5 hours of effort. Note: estimated changes compare counts of grid cells with effort, not their spatial overlap between years.

There were expansions and contractions of trawl distribution on all three trawled terrain types, and these were highly variable between subregions. Most net increase in trawled area between 1996 and 2001 occurred on 'sediment with few reef patches', with relatively large increases in West Tasmania (541 sq km), Babel (405 sq km) and SW Tasmania (298 sq km). Relatively little 'sediment with many reef patches' showed a net expansion, although increases of around 100 sq km occurred in West Tasmania, East Tasmania and Babel. In subregions showing overall trawl effort contraction (South Tasmania, Eden/Bermagui and Ulladulla), there was contraction on all terrain types. Beachport showed a move off sediments with reef to clear sediments, while changes in East Tasmania were from clear sediments to sediments with reef patches.

5.2.8 Patterns of trawl effort distribution related to grounds

Because overall (net) area changes, for example across subregions, were based on simple summation of changes within individual grounds, the contraction of effort distribution in some grounds had the effect of negating the expansion in others. Finally, then we re-examine the overall patterns in subregions, depth zones and seabed types when the contractions and expansions in individual grounds are also considered (Table 5.2.8.1).

Table 5.2.8.1 Expansion and contraction in plan area (sq km) of seabed trawled in the SEF by subregion and habitat units: (a) Subregion, (b) Depth Zone, (c) Feature, (d) Terrain: estimates are based on comparing effort in 2001 with 1996 using 1 km grid-cells derived from SEF1 logbook data and aggregating data from individual fishing ground polygons. Estimates include only cells with >0.5 hours of effort. Note: estimated changes compare counts of grid cells with effort, not their spatial overlap

(a)

Subregion	(Combined or 'net' change)	Contraction	Expansion
Sydney	263	-70	333
Wollongong	176	-201	377
Ulladulla	-400	-404	4
Eden/ Bermagui	-220	-242	22
Eden/ Smithys	176	-229	405
Babel	645	-49	694
Banks Strait	64	-9	73
St Helens	51	-31	82
East Tasmania	5	-103	108
Maria	230	-24	254
South Tasmania	-220	-405	185
SW Tasmania	350	-30	380
West Tasmania	848	-5	853
King Island	33		33
Coral Coast	299	-1	300
Portland	369	-9	378
Beachport	45	-232	277
SEF total	2714	-2044	4758

(b)

Depth Zone	(Combined or 'net' change)	Contraction	Expansion
Shallow shelf	68	-95	163
Deep shelf	869	-1063	1932
Upper slope	1263	-148	1411
*Slope (upper/ mid)	180	-180	360
Mid-slope	334	-558	892
SEF total	2714	-2044	4758

* typically canyons, and wide areas combining upper and mid- continental slope

(c)

Feature	(Combined or 'net' change)	Contraction	Expansion
Plain	718	-1175	1893
Terrace	1393	-370	1763
Scarp	447	-409	856
Rocky bank	12	0	12
Canyon	164	-24	188
Hill	-20	-66	46
Fan	0	0	0
SEF total	2714	-2044	4758

(d)

Terrain	(Combined or 'net' change)	Contraction	Expansion
Heavy reef	0	0	0
Sediment, many reef patches	402	-188	590
Sediment, few reef patches	1854	-750	2604
Clear sediment	458	-1106	1564
SEF total	2714	-2044	4758

In the 364 individual grounds that have trawlable areas within them, changes in trawled area in 2001 compared to 1996 varied between large contractions (-70%) and large expansions (+90%) (Fig. 5.2.8.1). In total, trawling expanded in 202 grounds, contracted in 106 grounds, while 56 grounds showed no net change.

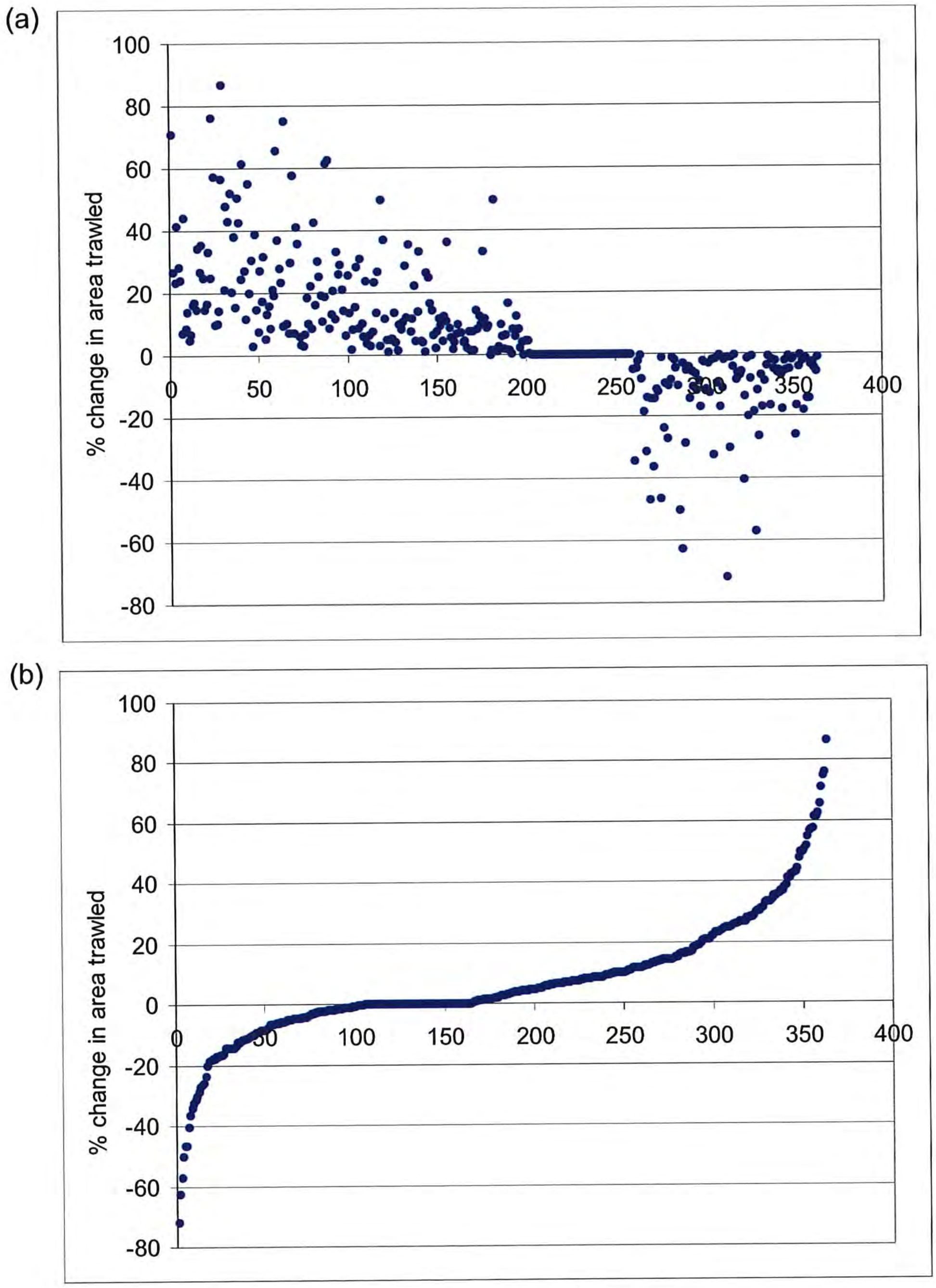


Figure 5.2.8.1 Change in plan area (sq km) trawled in 364 individual fishing grounds comparing 2001 with 1996; change shown as a % of ground size: (a) ordered by ground number; (b) ordered by % change

Analysis of contraction and expansion across subregions (Fig. 5.2.8.2) showed that the overall pattern of trawl distribution closely matched the net distributions (Fig. 5.2.5.2) except for subregions with substantial contraction and expansion (Beachport, South Tasmania and Eden/Smithys and Wollongong). In these cases, the extent of the trawled area changes were increased, and in the case of South Tasmania a net contraction concealed an expansion of ~200 sq km.

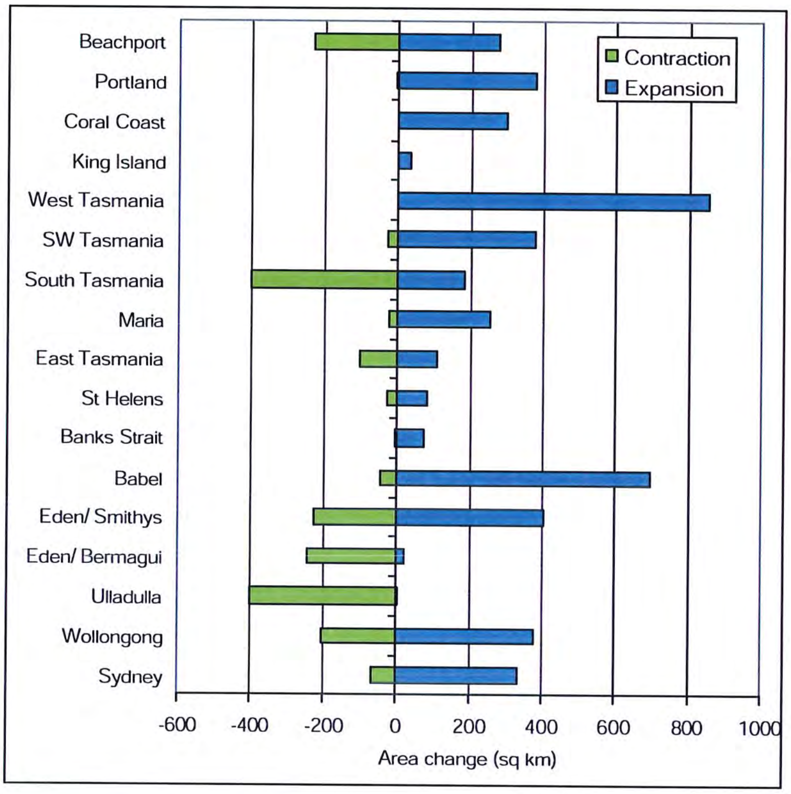


Figure 5.2.8.2 Expansion and contraction in plan area (sq km) of seabed trawled in fishery subregions of the SEF: comparison of effort in 2001 with 1996 using 1 km grid-cells derived from SEF1 logbook data. Estimates include only cells with >0.5 hours of effort. Note: estimated changes compare counts of grid cells with effort, not their spatial overlap between years.

An overview of the 'ground-based' pattern for terrain type shows the expansion and contraction for the entire fishery (Fig. 5.2.8.3 a).

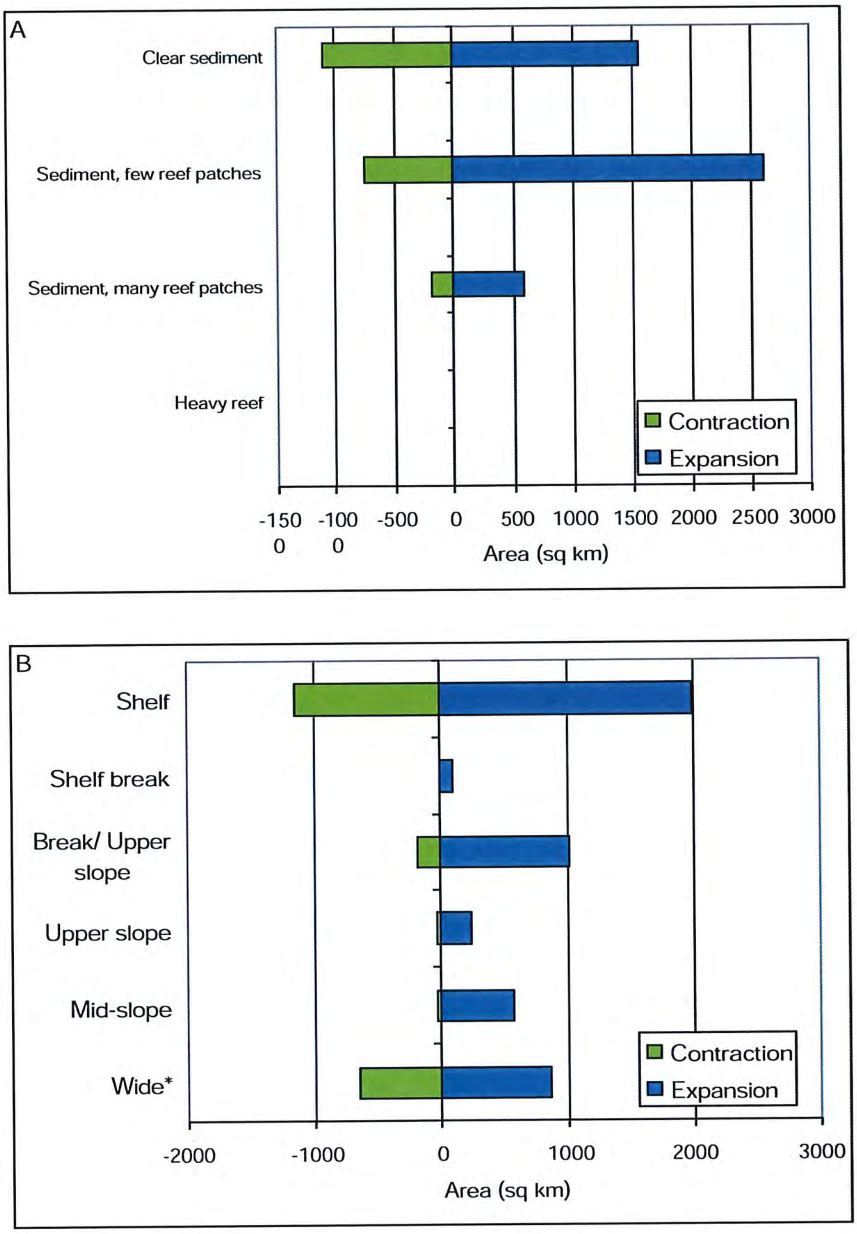


Figure 5.2.8.3 Expansion and contraction in plan area (sq km) of seabed trawled in the SEF (a) by bottom type and (b) by general depth zone (biome): estimates are based on comparing effort in 2001 with 1996 using 1 km grid-cells derived from SEF1 logbook data and aggregating data from individual fishing ground polygons. Estimates include only cells with >0.5 hours of effort. Note: estimated changes compare counts of grid cells with effort, not their spatial overlap between years.

An overview of the pattern with depth was more difficult to provide from aggregating grounds because many individual grounds extended over a broad depth range, for example in canyons. For this purpose we placed each ground into one of five depth zone categories (Section 5.1.14). These were the shallow shelf, deep shelf, upper slope and mid-slope and an 'overlap' category for grounds spanning the upper and mid-slope (e.g.

several canyons). The pattern of contraction and expansion adds considerably to the overall depth summary (Fig. 5.2.4.1) by showing that all depth ranges have large effort contractions as well as large expansions (Fig. 5.2.8.3 b).

Two examples show the underlying patterns in individual grounds. Firstly, a comparison of area trawled in 2001 with 1996 in 336 individual fishing grounds shows the contraction and expansion before grounds are aggregated (Fig. 5.2.8.4 a). (For the purposes of providing a suitably scaled plot we have excluded the two grounds with greatest areas of trawl effort - Sand Patch with 1,431 sq km trawled and Flat Patch with 1,359 sq km trawled in Eden/ Smithys.)

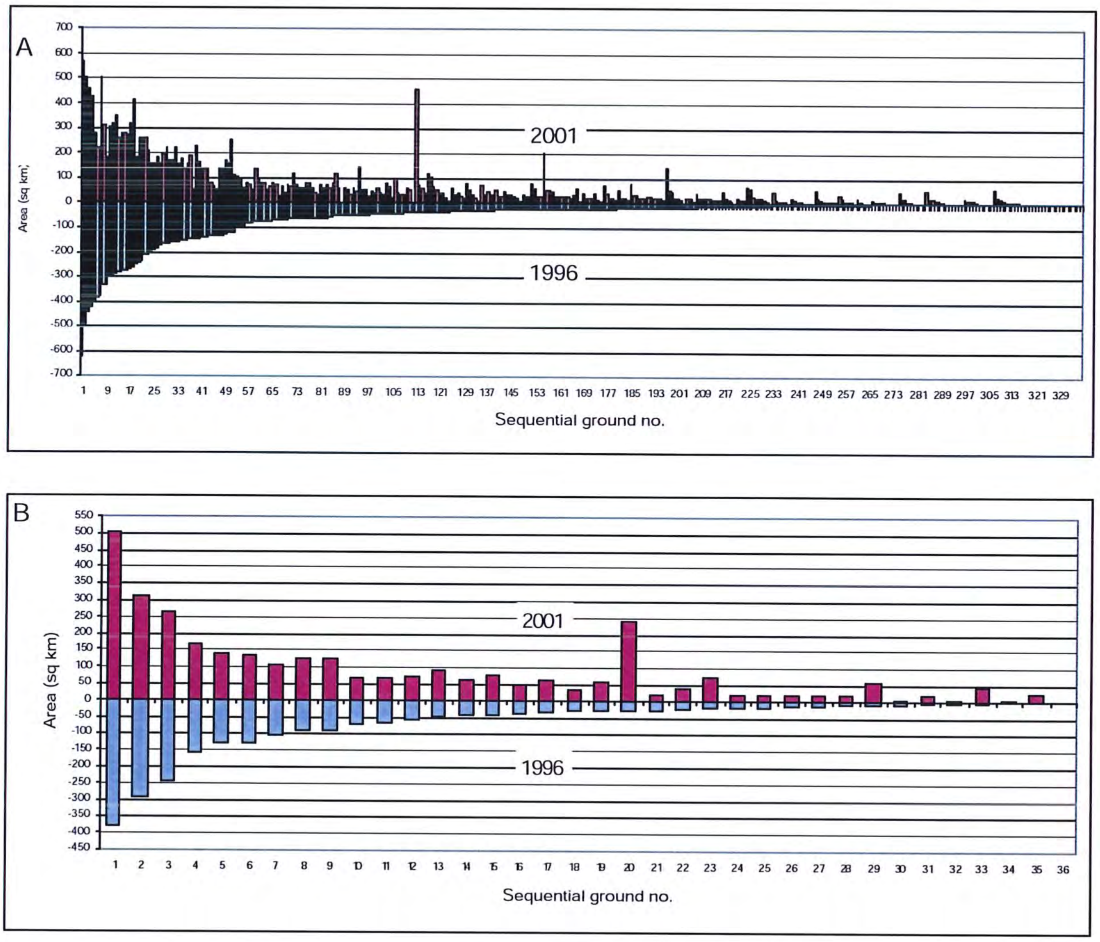


Figure 5.2.8.4 Comparison of plan area (sq km) trawled in 2001 with 1996 in individual fishing grounds: (a) all 336 grounds with trawl effort in 2001 (but with the two largest grounds - Sand Patch (1431 sq km trawled) and Flat Patch (1359 sq km trawled) in Eden/ Smithys excluded), and (b) all 36 grounds in West Tasmania. Note: both ordered by 1996 trawled area

A 'zoom' into the West Tasmania subregion, that has the largest overall change, shows the changes in 36 individual grounds (Fig. 5.2.8.4 b). Summary statistics comparing 1996 with 2001 show an expansion in 34 grounds, and minor contraction in two (Table 5.2.8.3).

Percentage expansion per ground (change/ ground area x 100) is highly variable, between 0 and 66%, with an average increase of 19%; there was no relationship with ground size. The maximum area used for trawling within a ground in any year in this period varied inter-annually (data not shown) but was generally high, averaging 72% and being between 90 and 100% in 15 of the prime grounds. In contrast, a maximum of only 1% (~7 sq km) was trawled in the second largest ground (West Tasmania Shelf; 734 sq km).

Percentage expansion was highest at the shelf-break and upper slope, where the seven of the 10 highest values were recorded (Table 5.2.8.3, grounds 35, 31, 23, 29, 33, 22 and 8 in order of greatest expansion). Changes in shelf grounds were variable, ranging from zero on the West Tasmania Shelf ground to the highest area overall: the 212 sq km (27%) expansion in the large West Tasmania Shelf (outer N) ground. There were no distinct patterns in changing use in the mid-slope and wide grounds, with each group having a broad range of expansions and contractions, and maximum annual use. Of interest among the wide grounds were the group of eight canyons (grounds 12, 14, 15, 24, 25, 26, 27 and 28). As mapped (truncated at 1,300 m depth) these are relatively small grounds (averaging ~50 sq km), but they have a consistently high maximum annual trawl use (average of 80% of total area); change in area use were variable, ranging from zero change between 1996 and 2001 to a 39% expansion in the 82 sq km Ling Hole.

Table 5.2.8.3 Characteristics and effort distribution statistics of individual West Tasmanian fishing grounds: changes in area trawled per ground shown as area-standardised percentages for the difference between 2001 and 1996 and the maximum annual area trawled in this period.

Sequential ground no. (above)	Area name	Plan area (sq km)	Terrain	Trawled area 1996	Trawled area 2001	Change in area 1996-2001 (sq km)	Change trawl area 1996-2001 / ground area (%)	Max. annual trawl area/ ground area (%)
1	Above Strahan Canyon	516	3	377	502	125	24.2	97.3
2	1 Above Ling Hole	318	3	296	315	19	6.0	99.7
3	2nd Above Ling Hole	264	3	245	263	18	6.8	99.6
4	1 Below "36" Canyon	168	3	161	168	7	4.2	100.0
5	North of Ling Hole (outside) (139 sq km)	139	3	132	139	7	5.0	100.0
6	1 Below Ling Hole	134	3	128	134	6	4.5	100.0
7	Top Shot (deep)	105	4	105	105	0	0.0	100.0
8	Top Shot	126	3	92	126	34	27.0	100.0
9	340 [mid-slope]	289	4	92	126	34	11.8	57.8
10	Top Shot (outside)	68	3	68	68	0	0.0	100.0
11	Top Shot (north) (70 sq km)	70	4	66	69	3	4.3	100.0
12	Kiwi Corner	77	3	60	71	11	14.3	92.2
13	1 Above Ling Hole (deep)	210	4	48	92	44	21.0	43.8
14	337 [West Tasmania, unnamed canyon]	85	2	45	61	16	18.8	88.2
15	The Ling Hole	82	2	44	76	32	39.0	92.7
16	1 Below "36" Canyon (deep)	176	4	38	49	11	6.3	33.0
17	1 Below Ling Hole (outside)	92	4	34	63	29	31.5	68.5
18	Top Shot (inside)	31	3	28	31	3	9.7	100.0
19	2nd Above Ling Hole (deep)	166	4	26	59	33	19.9	35.5
20	Western Tasmania Shelf (outer N)	789	3	25	237	212	26.9	30.0
21	North of Ling Hole (deep) (144 sq km)	143	3	25	22	-3	-2.1	24.5
22	1 Below "36" Canyon (inside)	40	2	21	38	17	42.5	95.0
23	1 Above Ling Hole (inside)	89	3	20	71	51	57.3	79.8
24	Canyon South of Kiwi Corner	22	2	19	19	0	0.0	95.5
25	"36" Canyon	24	2	18	18	0	0.0	79.2
26	The Strahan Canyon	30	2	17	17	0	0.0	66.7
27	"17" Canyon	30	3	14	19	5	16.7	63.3
28	"26" Canyon	27	3	12	18	6	22.2	66.7
29	1 Below Ling Hole (inside)	81	2	11	57	46	56.8	71.6
30	Below Strahan Canyon (inside)	44	2	7	5	-2	-4.5	29.5
31	Top Shot (inside) (24 sq km)	24	4	6	21	15	62.5	87.5
32	West Tasmania Shelf (outer)	24	3	4	5	1	4.2	20.8
33	2nd Above Ling Hole (inside)	79	3	3	44	41	51.9	55.7
34	The Penis	6	3	2	3	1	16.7	66.7
35	320 [West Tasmania, shelf]	38	3	0	25	25	65.8	65.8
36	West Tasmania Shelf	734	3	0	1	1	0.1	1.0

5.2.9 Trawl catch and catch value

Many further types of analysis are possible with the combined map of fishing grounds and logbook data but remain outside the scope of this project. Here we provide a few selected examples of how catch data at the level of fishing grounds may be used to consider spatial patterns in the fishery. One application of these approaches is an initial valuation of grounds in the context of loss (and prospective gain) from the introduction of MPAs, and identifying candidate areas for fishery closures. However, we make it clear that 'valuing' individual fishing grounds is a complex process that needs to take into account additional factors such as grounds that are important for particular species, and grounds that are important as part of a group fished in rotation over multi-year cycles.

Plots of total catch (all retained species) against the total catch value (see Section 4.5.2) for each of the 374 trawl grounds show these two attributes are strongly correlated (Fig. 5.2.9.1). This is slightly surprising given the wide range of market prices per species and the wide range of total catches of each species. The result is important because it shows that it is not necessary to undertake the computationally intensive analysis for calculating catch value – at least at the unit of fishing ground.

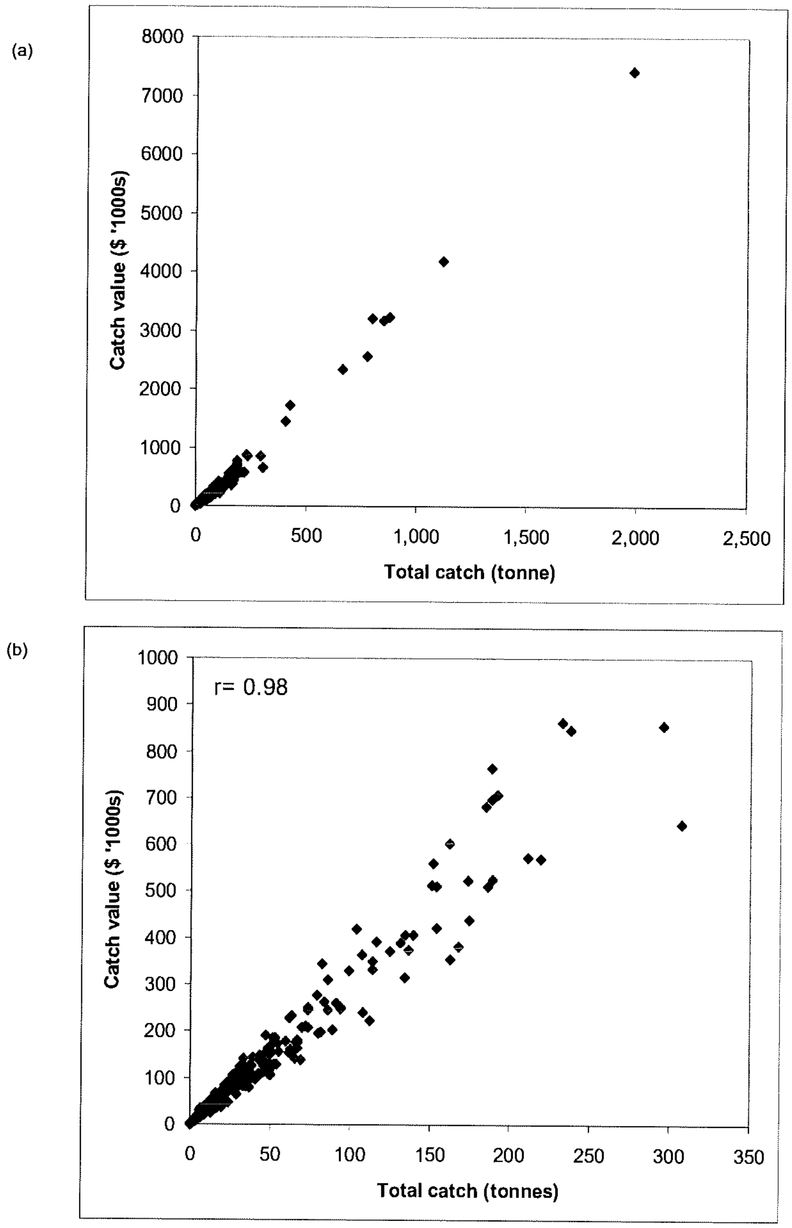


Figure 5.2.9.1 The 2001 total trawl catch (tonne) per fishing ground in relation to catch value (1000s $): (a) all 374 grounds; (b) with 10 most valuable grounds removed for clarity.

The numbers of vessels using fishing grounds is an alternative way of examining patterns of effort distribution. Here we show simply the static (2001) picture of number of vessels vs fishing grounds area and fishing ground catch value (Fig. 5.2.9.2 a and b, respectively). In 2001 there was no relationship between vessel numbers and ground size, with small grounds (< 100 sq km) variously fished by between one and 20 vessels, and large grounds (> 500 sq km) fished by between three and 23 vessels. The most vessels fishing one ground was 24, while only 19 vessels fished the largest ground (Twofold Shelf). A total of 47 grounds were fished by less than five vessels.

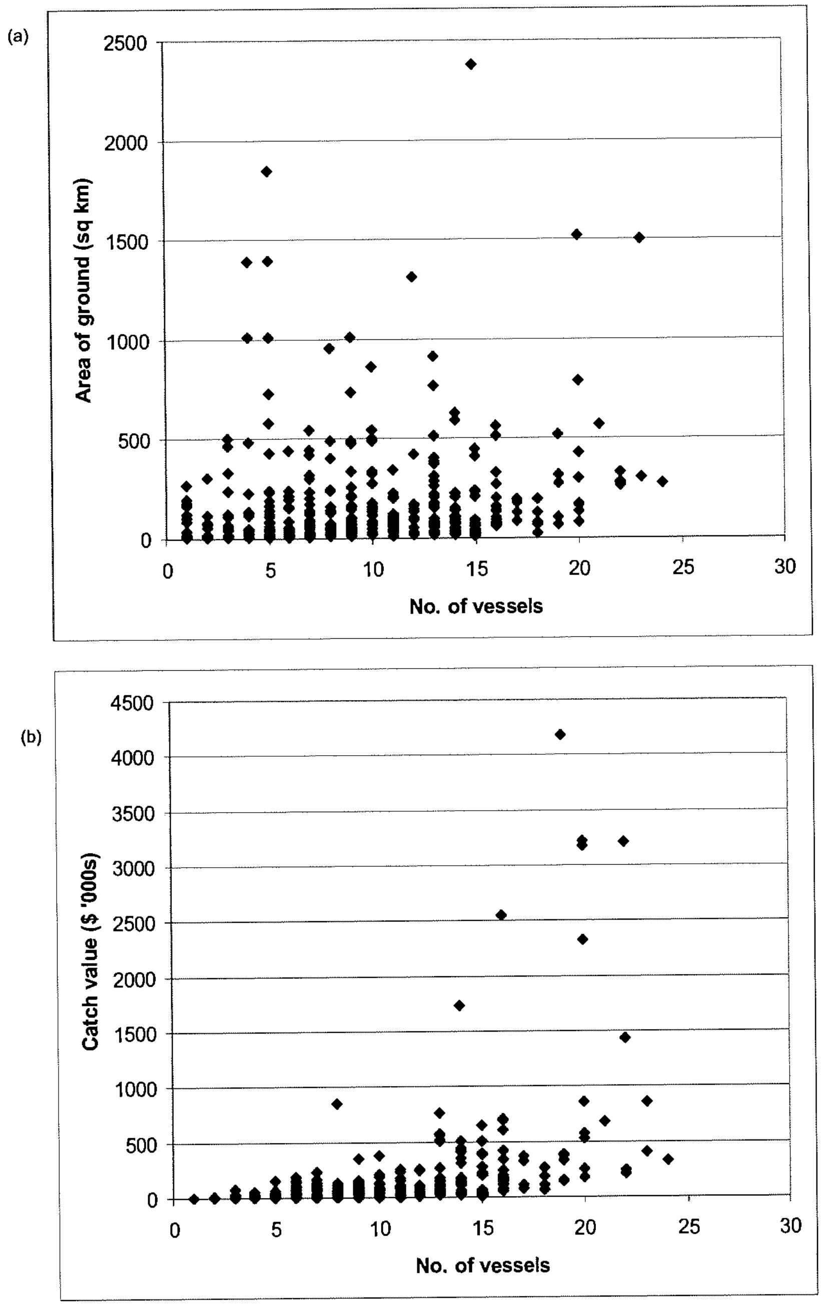


Figure 5.2.9.2 Characteristics of 374 fishing grounds in relation to the number of vessels fishing in 2001: (a), fishing ground area (with the single largest ground removed for clarity - the 5,418 sq km Twofold Shelf with 19 vessels fishing); (b), total trawl catch value ($ '000s) per fishing ground (with the single largest catch value removed for clarity - $7,416,000 at Kiwi's Corner (=Pieman Canyon) with 16 vessels fishing)

The number of vessels per ground was only weakly correlated with catch value per ground (Fig. 5.2.9.2 b). The nine grounds with catch value > $1,000,000 (orange roughy and blue grenadier grounds in the West Tasmania and St. Helens subregions) are fished by large numbers of vessels (14 to 22), but not most vessels. Grounds supporting most vessels

(23 to 25) are in the Eden/Smithys and Eden-Bermagui subregions; these grounds are relatively small with relatively high catch value (~$200-400,000 in 2001) and demonstrate another key valuation to be placed on grounds – proximity to major ports.

Notwithstanding the limitation of using static catch values, values for only one sector, and the effect of quota holdings on where vessels fish, an approach to prioritising areas for any type of closure is to examine the relationship between area (sq km) and catch value. Plots showing this relationship for the 374 trawl grounds can be divided by the median size and median value into four quadrants representing relatively high and low value and relatively large and small size (Fig. 5.2.9.3). In these plots, the relatively large, relatively low value grounds in the lower right quadrant could provide a starting point for identifying trade-offs between good prospective conservation gains (large area) and low loss to fishers (low catch value).

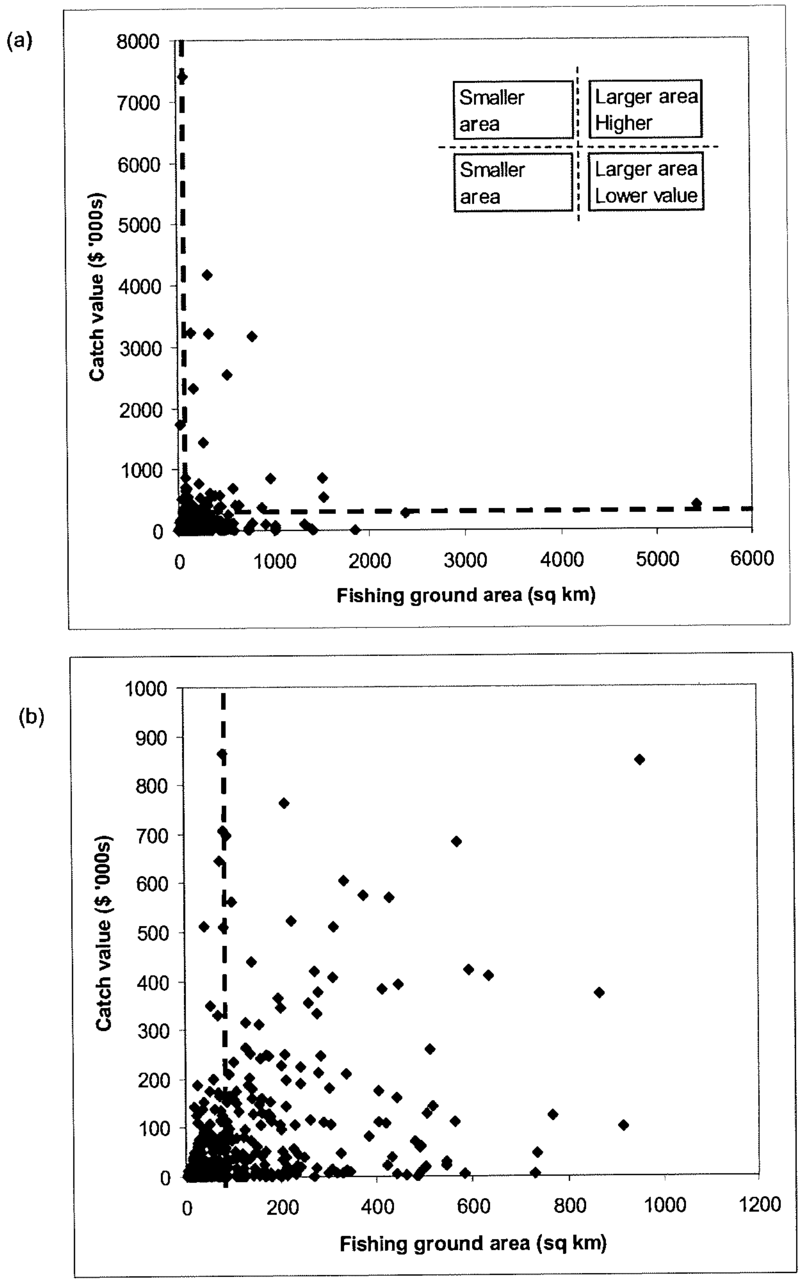


Figure 5.2.9.3 The 2001 total trawl catch value (1000s $) per fishing ground in relation to ground size (sq km): (a) all 374 grounds; (b) with 20 grounds removed for clarity (11 most valuable + 9 largest). Dashed lines represent median ground size and median ground value (A, 85 sq km and $35,000; B, 81 sq km and $33,000)

5.2.10 Fishing grounds, habitats and CPUE

There is no explicit use of fishing ground or habitat data for calculating CPUE as an index of abundance for SESSF species because data with this spatial precision has not previously been available. An alternative 'standardised' CPUE for some species (e.g. pink ling) uses data from a subset of operators, recognising that an improved index may be obtained by considering a smaller number of operators fishing in a similar way from year to year. Implicit in the assumed consistency is that, to a large extent, fishing occurs in the same places.

However, CPUE is vulnerable to overestimating species relative abundances if the targeting of relatively productive habitats increases. Such a situation is possible if species are concentrated in particular habitats at particular times, and those habitats are increasingly fished – opened up for the first time, used more often, or used by more fishers. Systematic and sequential targeted fish-downs of localised areas within grounds, or of entire grounds may be a management concern for some species, so here we address the question, 'is there a relationship between habitat types (bottom types) and catch rates?'

The 2001 trawl CPUE, based on catch (kg of all species combined) and effort (hours), was standardised for each bottom type at the level of subregion in two ways (Fig. 5.2.10.1). Firstly by dividing CPUE by the total area (sq km) of each bottom type in each subregion (Fig. 5.2.10.1 a), and secondly by dividing CPUE by the area of each bottom type fished (sq km) in each subregion (Fig. 5.2.10.1 b). A very similar pattern is shown by both plots, with two key points for consideration here. First is that there are extremely high relative catch rates in the Banks Strait and St Helens subregions, presumably driven by orange roughy catches. Second, is that in most other subregions there is a considerably higher catch rate on the most structured bottom type (sediments with many reef patches) than either sediments with few reef patches or clear sediments.

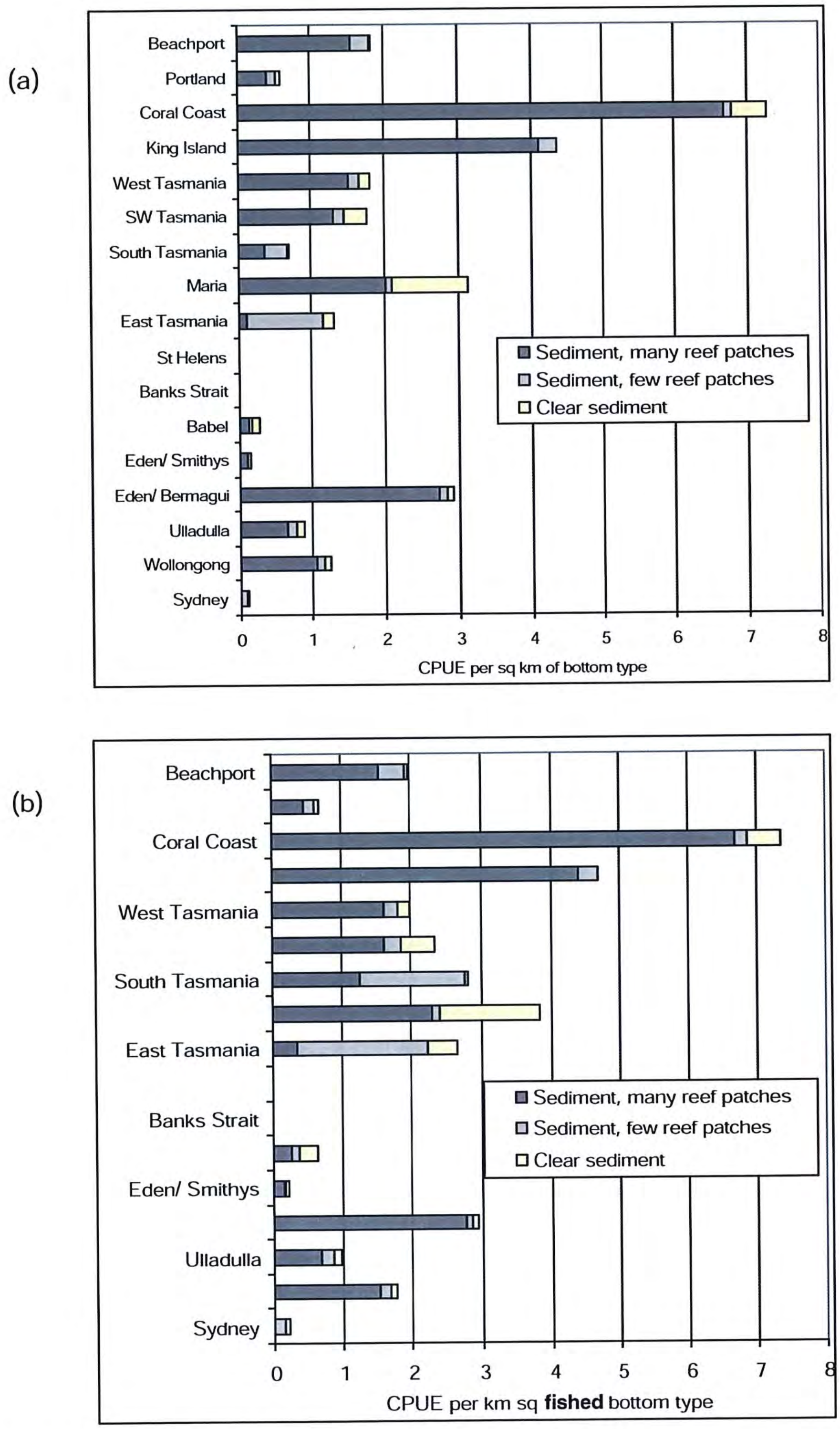


Figure 5.2.10.1 The 2001 CPUE (kg hr) on each terrain by subregion (a) standardised by the total area of each bottom type per subregion (sq km), (b) standardised by the fished area (sq km) of each terrain per subregion (> 0.5 hr of trawl fishing effort). Note: for clarity, both figures exclude the relatively very high rates at Banks Strait and St Helens (a: 33 and 63 respectively; b: 57 and 208 respectively), both presumably attributable to targeted orange roughy catches

This is a coarse-scale result: there is no differentiation between species, and no account of where the bottom types are in relation to depth zone or what they are in terms of geomorphic features, e.g. canyons. However, higher catch rates on structured bottom, in combination with the (conservative) estimate of expanded use of structured bottom types in some subregions (Section 5.2.6), indicate that information on habitat use is relevant to tracking CPUE.

These findings are consistent with data showing increased fish density on hard bottom (e.g. pink ling, Williams et al., in press), the anecdotal reports from many fishers of increased targeting of 'hard bottom', and the ability of the fleet to achieve more precise targeting through the rapid adoption of advanced navigational technology. However, any effect on CPUE from expanded use of structured bottom types occurring from trawl fishing is likely to be considerably lower, at least for species with strong 'hard-bottom' affinities, than with some non-trawl fishing methods. Ironically, data for these methods – especially autolongline and trap – were not amenable to analysis during this project for the reasons provided earlier (Section 5.2.1).

5.2.11 Logbook data: summary

A key goal for the project was to estimate the areas and types of seabed used by the trawl and non-trawl industry sectors. We first used industry data in isolation to estimate the proportions of seabed (terrain) types used; this was based on whether each defined fishing ground was recorded as being used or not. This overestimates the proportion of seabed fished because it assumes that any ground fished in part is fished in full. Second, we used corrected fishery logbook records to estimate the area fished (sq km) in each individual year. This approach underestimates the cumulative area fished because the fleet moves on from areas fished in previous years. Only trawl logbook data were suitably resolved for this second analysis. Logbook catch and effort data (resolved to a 1 sq km grid) were overlayed on the map of fishing grounds and analysed with respect to fishery subregion, major depth zone, seabed terrain type and fishing ground.

The estimate of the area fished by the trawl sector based on the overlay of grid cells on the 516 fishing ground polygons was corrected by reflecting effort from 135 untrawlable or untrawled grounds to adjacent trawled grounds. This 'reflection' process (Section 4.5.1) resulted in data being restricted to a subset of 381 trawlable grounds, of which only 364 had effort recorded between 1996 and 2001.

Using fishing grounds at units, we estimated a high proportion of grounds (about 71%) experience some trawl activity. These grounds make up about half the total fishery area (47%), of which 35% were regularly trawled, and 12% 'trawled in part' (usually along one to a few trawl shots). Over half the fishery area was estimated to be untrawlable (~45%) or not trawled (~8%).

Using fishing grounds as units, non-trawl fishing was estimated to use only ~ 5% of the total fishery area – but this too is an overestimate because the precise locations of some non-trawl grounds were provided within larger ('buffered') boundaries.

In the second approach, using logbook data resolved to a 1 sq km grid, we estimated that the area trawled in 2001 was 26,469 sq km, or about 19% of the SEF region as defined here (3 n.m. to 1,300 m depth contour) or 37% of the trawlable area.

Subregional patterns in effort distribution need to be interpreted in the context of large differences in subregion size, and the relative size of their continental shelf – which is relatively massive in subregions such as Beachport, West Tasmania and Eden/Smithys. The relative size differences are an important part of the context for interpreting patterns related to the substructure within subregions such as depth zones, seabed terrain types and patterns of use. This is particularly the case for the continental shelf area because it has a profound effect on the estimated proportions of trawlable and untrawlable grounds within subregions.

Trawlable grounds are as defined by operators based on their current state of knowledge and equipment. Previously untrawlable ground is likely to be gradually opened up as operators' knowledge increases, especially if there is no limit on fishing power and trawl design. There is a far more untrawlable ground in subregions to the west of Tasmania (76% untrawlable ground; range 52-86%), compared to subregions east of, and including, South Tasmania (15% untrawlable ground; range 0-48%). Of the 68,410 sq km of untrawlable ground in the SEF region, 58,903 (86%) of it is west of South Tasmania. This is due primarily to very extensive areas of patchy reef terrain ('sediments with many reef patches') on their broad sections of continental shelf.

Southern Tasmania and all eastern seaboard subregions, with the exclusion of Babel to Woolongong are made up of grounds that are 95% or more trawlable. The relatively large areas of untrawlable seabed in Babel and Eden/Smithys are made up by several large rocky banks (reefs) on the shelf (e.g. the "Northeast Babel Reef" and "Gabo Reef") together with extensive rough areas on the upper and mid-slope, much of it associated with tributary canyons that run into the massive Bass Canyon that dominates the geomorphology of eastern Bass Strait. Large areas of untrawlable patch reef terrain ('sediments with many reef patches') occur on the continental shelf off Eden/Bermagui, Ulladulla and Wollongong.

The method for estimating changes in trawl effort distribution over the period 1996 to 2001 underestimates the spatial extent of fishing because only the size of each annual 'footprint' within a fishery subregion/depth combination could be compared rather than their overlap, and movement of effort between grounds within subregion or depth could not be accounted for. This method estimated a total expansion of 4,057 sq km (or 17%) with an increase in all depth zones except for the shallowest (which is inside 50 m depth and mostly not covered by SEF1 logbooks). The degree of change varied substantially between depth zones, and inter-annual variation within depth zones included some years when the trawled area decreased; however, overall net increases were smaller on the mid-shelf (13%) and mid-slope (16%), but larger increases on the deep shelf (23%) and upper slope (27%).

Most subregions (14 of 17) showed increases in net area trawled over this period with only three subregions (South Tasmania, Eden/Bermagui and Ulladulla) showing decreases. The largest area increases were in West Tasmania and Babel (791 and 608 sq km, respectively) with relatively large increases also in the western subregions of Portland, Coral Coast and SW Tasmania (369, 299 and 407 sq km respectively). These five subregions had the largest percentage increases in trawlable area that was trawled (~9-18%), together with the relatively small Maria subregion (13%).

Overall, area trawled increased most in the upper slope depth zone (200-700 m), from 54% of trawlable area in 1996 to 63% in 2001, a 9% increase. Increases were evident in all subregions except Eden/Bermagui (-2%). The largest percentage increases were off the Coral Coast, West Tasmania, SW Tasmania, Maria, and Wollongong (19, 19, 28, 30 and 15%, respectively). The largest increases in area trawled were West Tasmania, SW Tasmania, Eden/Smithys and Wollongong (330, 180, 170 and 130 sq km, respectively). The other depth zone showing a relatively large increase in percentage of trawlable area trawled was the deep shelf (150-200 m), which increased from 28 to 33% (or 5%) between 1996 and 2001. Increases were mostly in the western seaboard: Beachport, Portland, King Island, West Tasmania and SW Tasmania (79, 19, 15, 27 and 16%, respectively), with Wollongong also showing a 15% increase. The increases were steady off Tasmania over the six year period, but recent and rapid between 2000 and 2001 in Portland (43%, or 58 sq km) and Beachport (250% or 136 sq km). This change in Portland was accompanied by a smaller scale, but equally rapid increase on the outer mid-shelf (100-150 m) from 10 to 16% of trawlable area trawled between 1996 and 2001. During this period, trawled area declined in the deep shelf zone in the NSW subregions.

The largest decline overall in percentage trawlable area trawled, in the Ulladulla subregion (minus 18%), stemmed mostly from reduced trawled area on the outer mid-shelf (100-150 m) early in this period. Elsewhere, the outer mid-shelf zone experienced expanded effort in several subregions but particularly Babel, Eden/Smithys and Maria. In Babel, the increase was steady over the period: it fluctuated in the relatively massive Eden/Smithy subregion, and the relatively small Maria subregion. With the exception of Portland (63% or 29 sq km), increases on the shallow mid-shelf (100-150 m) were confined to the eastern seaboard with the largest increase off Sydney (76% or 61 sq km), consistent with the dominance of untrawlable patchy reef over most of the continental shelf of the western seaboard.

Patterns were most variable in the deepest zone, the mid-slope (700-1300 m), with several increases and decreases of trawled seabed > 100 sq km. These are thought to reflect changes of effort moving away from targeting orange roughy concentrations towards less targeted fishing for other mid-slope species such as deepwater dories and deepwater dogsharks. The net positive increase over all subregions of 885 sq km (27%) was due to increases on the western seaboard between SW Tasmania to Portland, where steadily expanded effort covered an additional ~760 sq km in 2001 compared to 1996. Declines were in the traditional orange roughy fishery subregions off Beachport, southern and eastern Tasmania, as well as off Eden/Smithys, but the patterns were different and unstable over the six year period.

There were expansions and contractions of trawl distribution on all three trawled terrain types, and these were highly variable between subregions. Most net increase in trawled area occurred on 'sediment with few reef patches', with relatively large increases in West Tasmania (541 sq km), Babel (405 sq km) and SW Tasmania (298 sq km). Relatively little 'sediment with many reef patches' showed a net expansion, although increases of around 100 sq km occurred in West Tasmania, East Tasmania and Babel. In subregions showing overall trawl effort contraction (South Tasmania, Eden/Bermagui and Ulladulla), there was contraction on all terrain types. Beachport showed a move off sediments with reef to clear sediments, while changes in East Tasmania were from clear sediments to sediments with reef patches.

The proportions of seabed terrain types were estimated overall to be 48% 'sediments with many reef patches' (grounds with ~30-70% reef) and 30% 'sediments with few reef patches' (~5-30% reef), 20% 'clear sediments' (no reef) and 2% 'heavy reef' (>70% reef). Predictably then, the dominance of mixed sediment and reef patches is evident in most fishery subregions, although Sydney and South Tasmania were reported as being mostly clear sediments. In addition to the overall east-west difference noted above, a further east-west difference is in the distribution of large contiguous ('heavy') reefs which were reported mostly in Babel, Eden/Smithys and Eden/Bermagui.

Distinct patterns were also evident in the distribution of seabed terrain types by depth zone. The overall trend is for relatively large proportions of rocky bottom (heavy reef and many reef patches) in shallower depths (inner and mid-shelf); these depth zones also have relatively large plan areas and therefore account for the majority of the rocky bottom in the fishery. Accordingly, relatively higher proportions of sediments with few reef patches as well as clear sediments are found on the deep shelf and continental slope. Large contiguous heavy reefs, such as the 276 sq km Gabo Reef, are found mostly on the mid-shelf, although a large reef area was also reported off King Island on the upper slope (shown in part in Section 5.4.4).

Because net (overall) area changes, for example across subregions, were based on simple summation of changes within individual grounds, the contraction of effort distribution in some grounds had the effect of negating the expansion in others. In the 364 individual grounds that have trawlable areas within them, changes in trawled area in 2001 compared to 1996 varied between large contractions (-70%) and large expansions (+90%). In total, trawling expanded in 202 grounds, contracted in 106 grounds, while 56 grounds showed no net change. A 'zoom' into the West Tasmania subregion, that has the largest overall change, shows expansion in the majority of grounds (34/36) and minor contraction in two. Percentage expansion per ground (change/ ground area x 100) was highly variable, between 0 and 66%, with an average increase of 19%. The maximum area used for trawling within a ground in any year in this period varied interannually (data not shown) but was generally high, averaging 72% and being between 90 and 100% in 15 of the prime grounds.

In the West Tasmania subregion (as an example), percentage expansion was highest at the shelf-break and upper slope, where the seven of the 10 highest values were recorded. Changes in shelf grounds were variable, ranging from zero on the West Tasmania Shelf ground to the highest area overall: the 212 sq km (27%) expansion in the large West Tasmania Shelf (outer N) ground. Of interest among grounds with wide depth ranges were the group of eight canyons that had a consistently high maximum annual trawl use (average of 80% of total area); change in area use was variable, ranging from zero change between 1996 and 2001 to a 39% expansion in the 82 sq km Ling Hole – although some of this may be due to smearing (see Section 5.4.3).

There are many ways to drill further into the data, particularly at the level of individual grounds; this was outside the scope of this project, and detailed analysis at the level of grounds was outside the scope of the project agreed with industry. A few selected examples are given to illustrate the potential of the data set to consider spatial patterns in the fishery.

Plots of total catch (all retained species) against the total catch value (see Section 4.5.2) for each of the 374 trawl grounds show these two attributes are strongly correlated and that it is not necessary to undertake the computationally intensive analysis for calculating catch value – at least at the unit of fishing ground. This may provide a relatively simple way of calculating one aspect of fishing ground "value" (we note there are others) in the context of compensation for grounds lost to MPAs.

Notwithstanding the limitation of using "valuation" based on catch alone, one approach to prioritise areas to be considered for closures is to examine the relationship between area (sq km) and catch value. Relatively large, relatively low value grounds were identified that could provide a starting point for identifying trade-offs between good prospective conservation gains (large area) and low loss to fishers (low catch value).

The numbers of vessels using fishing grounds is an alternative way of examining patterns of effort distribution to using the area of seabed fished. One interesting aspect of the analysis completed was that a total of 47 grounds were fished by less than five vessels and would therefore be lost from data summaries subject to the 5-boat rule.

There is no explicit use of fishing ground or habitat data for calculating CPUE as an index of abundance for SEF species because data with this spatial precision have not previously been available. An alternative 'standardised' CPUE for some species (e.g. pink ling, orange roughy) uses data from a subset of operators, recognising that an improved index may be obtained by considering a smaller number of operators fishing in a similar way from year to year. Implicit in the assumed consistency is that, to a large extent, fishing occurs in the same places.

However, CPUE is vulnerable to overestimating species relative abundances if the relatively productive habitats are increasingly targeted. Such a situation is possible if species are concentrated in particular habitats at particular times, and those habitats are increasingly fished – opened up for the first time, used more often, used by more sectors, or used by more fishers. The 17% increase in area trawled between 1996 and 2001 would have been expected to lead to higher catches or higher catch per unit effort, unless either overall fish abundance declined, or fish abundance on particular grounds declined once they were opened up. Systematic and sequential targeted fish-downs of localised areas within grounds, or of entire grounds, may lead to assessment scientists underestimating the true decline in abundance of fished stocks.

The 2001 trawl CPUE, based on catch (kg of all species combined) and effort (hours), was standardised for each seabed terrain type at the level of subregion using two methods. Both showed a considerably higher catch rate on the most structured bottom type (sediments with many reef patches) than either sediments with few reef patches or clear sediments. This, in combination with the (conservative) estimate of expanded use of structured bottom types in some subregions (Section 5.2.6), indicates that information on habitat use is relevant to tracking CPUE. This finding, taken together with findings of increased fish density on hard bottom (e.g. pink ling, Williams et al., in press), anecdotal reports of increased targeting of 'hard bottom', the ability of the fleet to achieve more precise targeting through the rapid adoption of advanced navigational technology, and the expansion of non-trawl methods into structured bottom types, demonstrates an important topic for future research.

5.3 Scientific data

5.3.1 Photographic surveys

Test deployments of the portable camera system were made from the 22 m long TAFI research vessel FRV Challenger, with several successful deployments made off SE Tasmania to depths of 200 m. Subsequently, the first fishing vessel survey was conducted from the trawler FV Celtic Rose in the Portland subregion. The portable system (winch, gantry and block, and camera platform) was freighted to the wharf at Portland where a local contractor with a long-reach crane was needed to load the gear onto the vessel's deck (Fig. 5.3.1.1a). CSIRO technicians fitted the camera control equipment in the wheelhouse of the vessel. The winch was mounted forward of the net drum (Fig. 5.3.1.1b, c) and the gantry on the central aft deck.

Photographic transects were completed successfully on two grounds: the Portland subregion "Short Shot" and "Horseshoe (inside)" in 200 to 227 m depths. Acoustic data collected from the vessel sounder provided a record of the bottom profile along transects (e.g. Fig. 5.3.1.1e) while about 60 minutes of video imagery and 80 high-resolution images were collected of the seafloor (e.g. Fig. 5.3.1.1 f, g,h). A mechanical problem with spooling the fibre optic tow cable back onto the winch during the camera retrieval (not encountered during the initial trials) prevented any further work on that survey. However, proof-of-concept was established as the rest of the system had worked well and the camera system had been configured around existing fishing equipment.

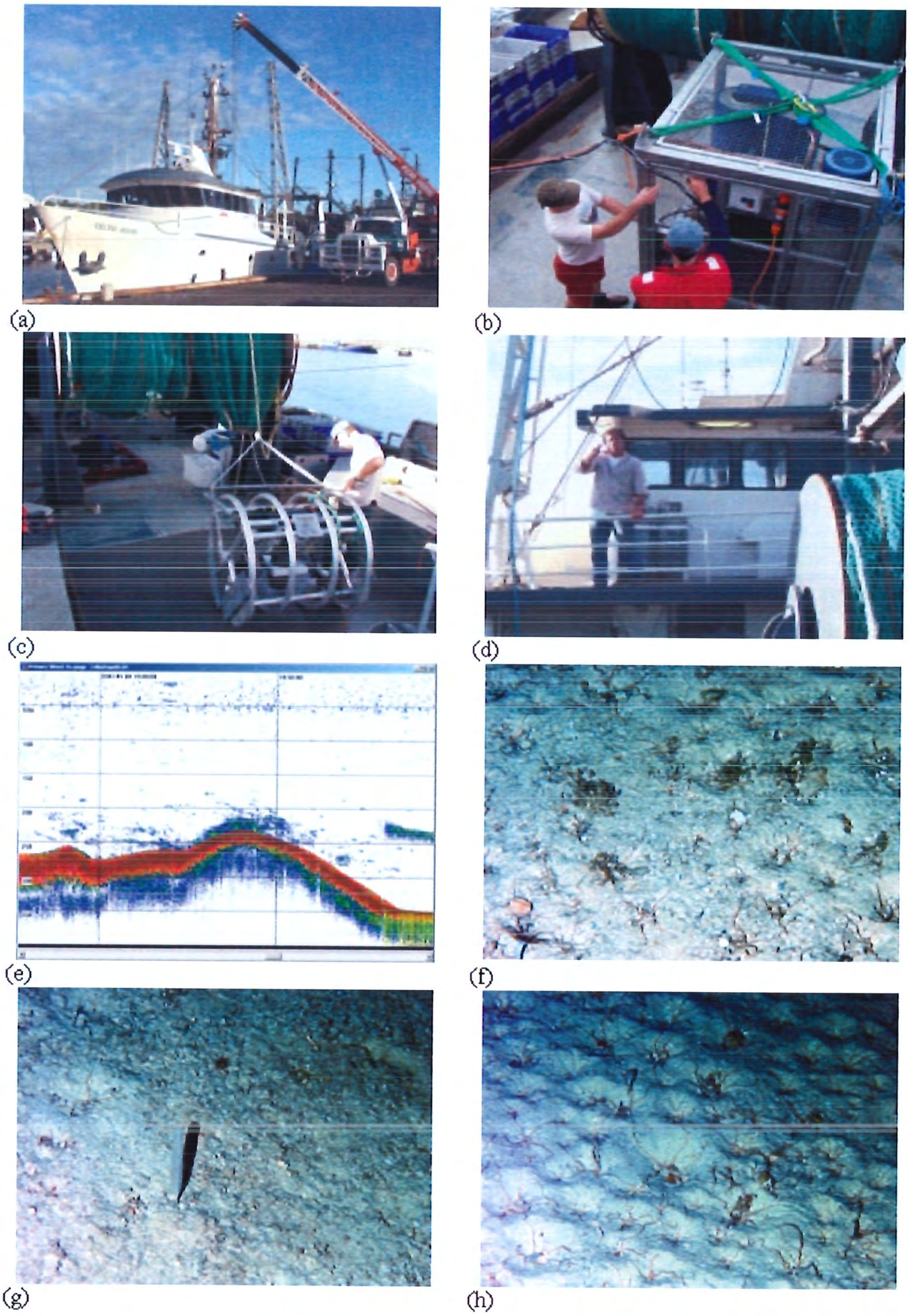


Figure 5.3.1.1 The portable camera system designed to use from industry vessels. The system was successfully used from FV Celtic Rose as illustrated by images showing (a) the Celtic Rose in port during fit out, (b) the winch mounted on the deck, (c) the camera system on deck, (d) the skipper overseeing deck operations, (e) an echo gram of one of the camera tows, (f - h), seafloor images of the Short Shot and Horseshoe (inside) grounds in the Portland subregion in 200-227 m.

Over 50 successful photographic transects have now been completed on SESSF fishing grounds with the camera system from three additional platforms, FV *Dell Richey*, the FRV *Southern Surveyor* and the FRV *Challenger*. These prove its technical success and meet the project's goal to provide an ongoing portable photographic capacity for seabed habitat work in deep water. Many of the images in the photographic plates for Section 5 come from this platform.

The patchy nature of habitats within grounds may require knowledge at a fine spatial scale to effectively target the short sampling transects (typically only 2-3 miles in length) at contrasting habitats and boundaries. Local knowledge provided by an experienced local fisherman on board FRV Challenger during a survey in the Beachport subregion considerably increased the efficiency of sampling, and was useful to discuss and interpret what was seen. Seven transects were completed on the shelf and at the topographically complex shelf edge during which over 6 hours of video and 750 still images were collected in a 30-hour period (exclusive of steaming to the area, equipment installation and decommissioning). Grounds surveyed were the Beachport subregion trawl grounds "Main Drag", "Western Gem", "Short Shot", "Western Gem", and three unnamed areas of untrawled bottom (grounds 164, 171, 186 and 189).

Eight images from the FRV *Challenger* Beachport survey are shown to illustrate the variety of observations across grounds and their relationship to the mapping information provided by fishers (Fig. 5.3.1.2). However, we note that it is not possible to capture the diversity within grounds or to make comments about the differences between trawl grounds and untrawled areas in a snapshot provided by a small number of images.

The first two images show a typical view of the muddy sediments making up the "Main Drag" (Fig. 5.3.1.2a,b) and an example of trawl effect on this ground: the freshly made furrow from a trawl door being deliberately towed by a trawler directly ahead of the survey vessel. All images were consistent with the description provided for the ground: compact mud making up a large flat area of clear sediment. Fauna include small sponges and anemones. The third image (Fig. 5.3.1.2c) is from ground 171 described as a terrain of sediments with many reef patches, but with unknown bottom type, and untrawled. Fauna include small sponges, anemones, hydroids and ascidians. There was a superficial similarity between the trawl and untrawled areas, with fauna observed on the trawled area, including some fauna common to both. These data would be amenable to a quantitative comparison of grounds subject to different degrees of fishing disturbance. Images from grounds 183 and 186, reported as untrawlable heavy reef terrains with unknown bottom types, show a vertical wall representing high heavy reef, and bedrock subcrop and scattered large boulders representing low heavy reef (Fig. 5.3.1.2d,e,f, respectively). Fauna include larger sponges, anemones, and hydroids. The final two images (Fig. 5.3.1.2g,h) show heavy low reef in inner and mid-regions of the continental shelf, each described as extensive plains of sediments with many reef patches, within unknown bottom types and untrawled. The first shows red algae and sponges on low craggy limestone at 35 m depth, and the second, diverse epifauna on low, undercut limestone reef at 70 m depth.

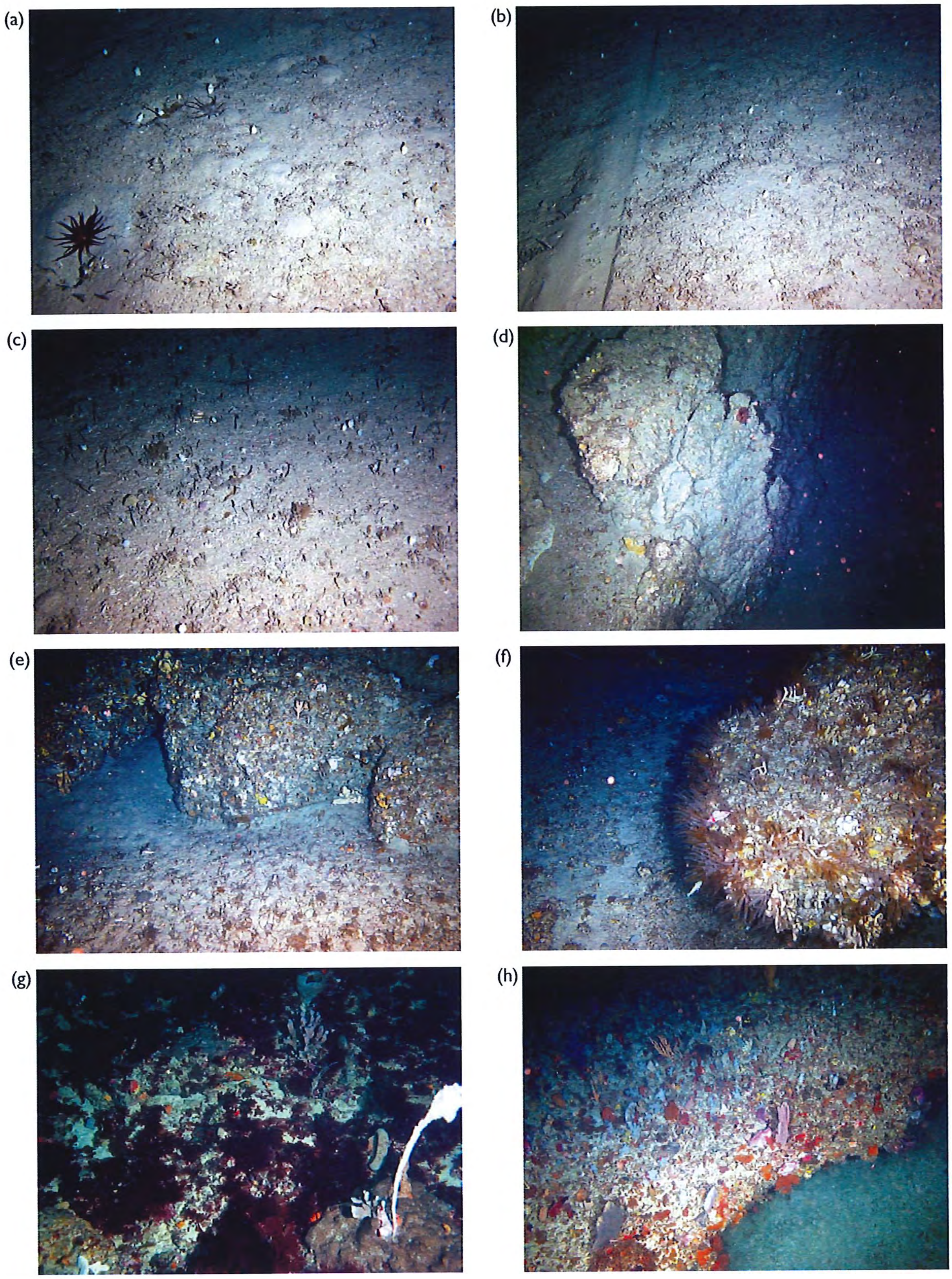


Figure 5.3.1.2 Seabed images from the Beachport subregion; (a, b, c) muddy sediments with small sponges, anemones, hydroids and ascidians making up (a, b) the "Main Drag" terrace with (b) showing a fresh trawl door furrow and (c) untrawled ground 171; (d, e, f) scarps with untrawlable heavy reef terrain with larger sponges, anemones, and hydroids in grounds 183 and 186; a vertical wall of heavy high reef, and bedrock subcrop and scattered large boulders of heavy low reef (d,e,f, respectively); (g,h) heavy low limestone reef with algae and sponges in inner shelf (35 m) depth and diverse epifauna in mid-shelf (70 m) depth that make up plains of sediments with many reef patches.

5.3.2 Illustrating seabed bottom types

Bottom or substratum type ('what the bottom is made of') was recorded as an attribute of each fishing ground in the questionnaire. Information provided was the contributors' best estimate of percentage make up of 10 different bottom types, the descriptions of which were based on a combination of pre-existing scientific samples and the types of seabed fishers described during the design of the questionnaire. The bottom type descriptors proved to be familiar to every contributor and were used consistently during the data collection:

1 - Mud - soft & boggy; 2 - Mud – compact ; 3 – Sand; 4 – Gravel; 5 – Rubble; 6 – Sandstone; 7 – Mud boulders; 8 – Slabby; 9 - Heavy low reef; 10 - Heavy high reef

Seabed samples and photographs from a number of surveys carried out in the SESSF provide a broad range of examples for interpreting the bottom type classes described by fishers. Here we present a selection of images to illustrate each of the classes scored (Plates 1-12) as attributes of each fishing ground. Each class is shown in a variety of SEF fishing grounds. 'Sandstone' was not encountered during the photographic surveys, although its presence was confirmed from rock samples collected by trawl and benthic sleds. The integration of this information with fishers' estimates of where bottom types are distributed is presented in Section 5.4.

'Soft & boggy mud' substrata (Plate 1) comprise a large fraction of the offshore (continental slope) seabed. An irregular fine-scale topography of mounds and burrows is created in places by apparently abundant burrowing animals (bioturbators) including gastropods (snails), crustaceans and fishes. This was most evident in undisturbed areas such as deep sections of the 'Second Howe Ground' in ~560 m (image 93).

'Compact muds' substrata (Plate 2) comprise a large fraction of the offshore (continental slope) seabed. Mud boulders occur in upper and mid-slope depths and can be concentrated in the base of canyons. Scrape marks on boulders from trawl gear together with sheltering orange roughy can be seen at the 'St Helens Ground (deep)' in 950 m (image 432).

'Sand' substrata (Plates 3 and 4) comprise a large fraction of the continental shelf seabed, and are also found in deep current-affected areas of the mid-slope. The effects of current and swell show in surface patterns (ripples and waves respectively), while confused ripples are formed in the current scored base of the Horseshoe Canyon (image 661).

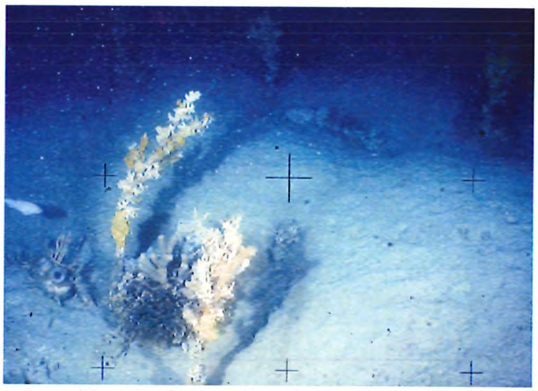
'Gravel' substrata (Plate 5) was often also described as gritty sand and is composed of a mix of components including mollusc shells, bryozoans and coarse sediments. It provides attachment for low-relief communities of small and encrusting animals such as small sponges, ascidians, living bryozoans and hydroids.

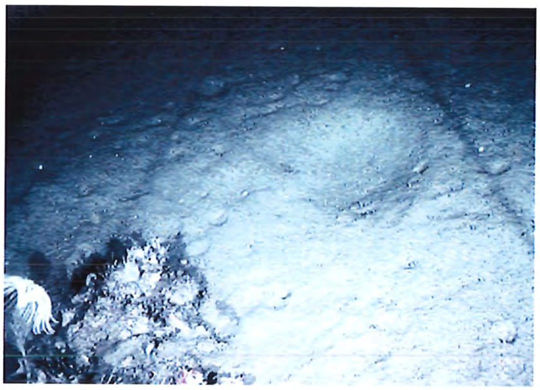
'Rubble' substrata (Plate 6) is composed of small-sized rocks intermediate between gravel and boulders, and often forms patches or flows on scarps and at the base of features such as canyons.

'Slabby' substrata (Plates 7 and 8) is a fishers' term for the flat boulders formed by broken pieces of sedimentary rock. Concentrations form 'slabby' bottom which is one of the most productive types of habitat for fishes in the SESSF, in part because it is structured habitat, supporting attached epifauna and in part because it can often be trawled in one or more directions. Some images show clearly how sedimentary crusts are undercut by current scour enabling slabs to break off and become mobile, isolated or clustered in surrounding sediments.

'Heavy low reef' substrata (Plates 9 and10) describes sub-cropping or low outcropping bedrock or large tracts of patchy immobile rocky 'reef' bottom (as opposed to slabby or other 'hard' bottom types). It frequently supports large and dense attached epifauna. The distinction between low and high reef is indistinct, but relates partly to what may be negotiated by trawlers using robust ground gear. Heavy low reef may be trawlable in particular directions, or using certain gear configurations and with sufficient vessel power. Heavy low reef can be fished by all non-trawl gears (and see Section 5.3.5).

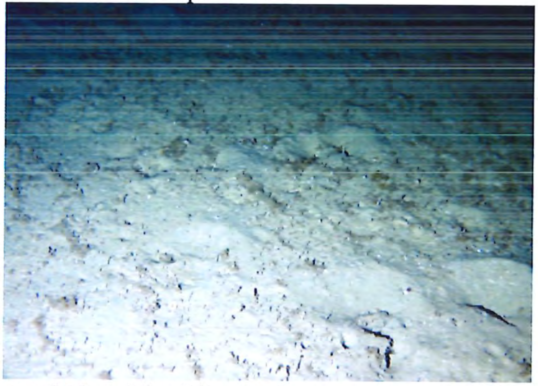
'Heavy high reef' substrata (Plates 11 and 12) describes outcropping bedrock or large tracts of immobile rocky 'reef' bottom (as opposed to slabby or other 'hard' bottom types). It frequently supports large and dense attached epifauna. The distinction between low and high reef is indistinct, but relates partly to what may be negotiated by trawlers using robust ground gear; heavy high reef being considered untrawlable. Heavy high reef can be targeted by drop-line and trap, and in places by all non-trawl gears; it appears that a few areas of high heavy reef, such as parts of the Big Horseshoe canyon (Plate 16, image 999) may not be able to be fished by any gear.

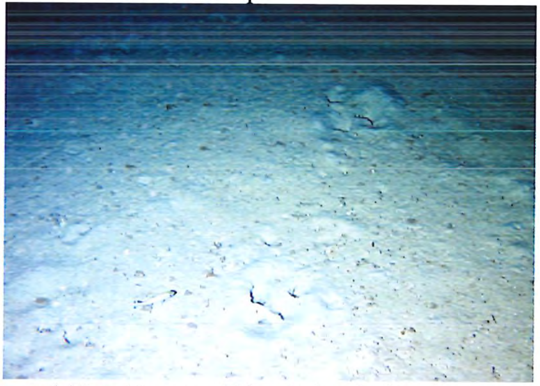

19836 40 m Lakes subregion

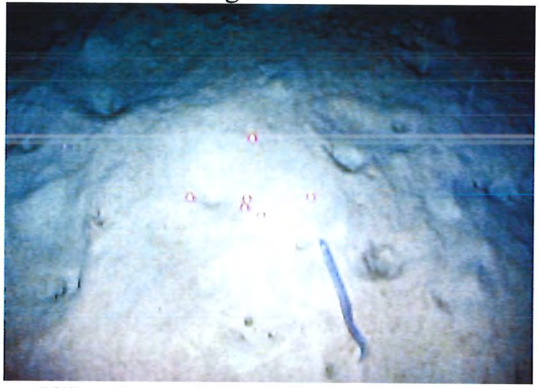

324 180 m Horseshoe Canyon


19838 250 m Cape Ground


238 288 m Eden Deep


286 333 m The Ling Hole


268 445 m Bottom King Island Shot


93 539 m Second Howe Ground

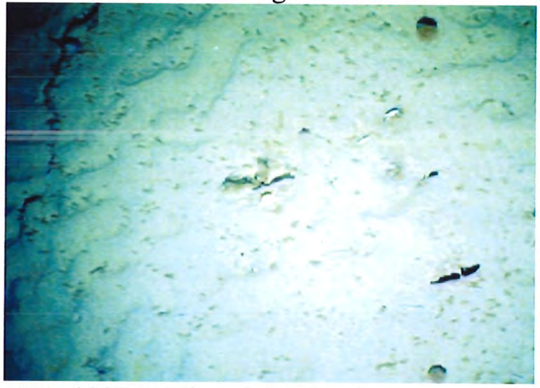
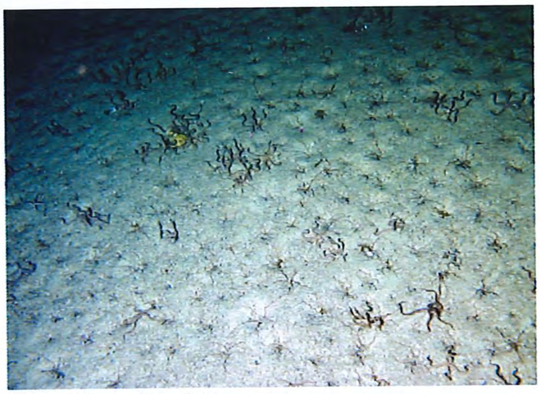
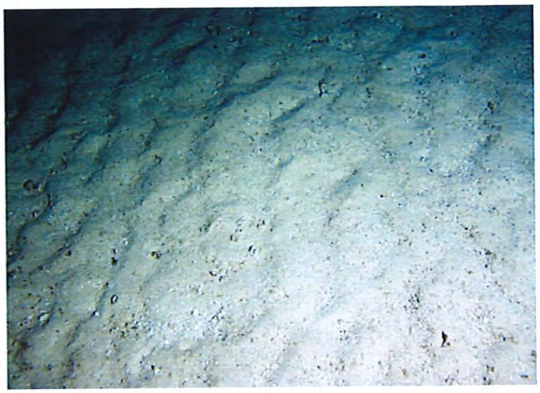

19846 1000 m Hippolyte (deep)

Plate 1 – Eight images showing 'soft & boggy mud' substrata. Note, these comprise a large fraction of the offshore (continental slope) seabed. An irregular fine-scale topography of mounds and burrows is created in places by apparently abundant burrowing animals (bioturbators) including gastropods (snails) and crustaceans. This was most evident in undisturbed areas such as deep sections of the 'Second Howe Ground' in ~560 m (image 93).

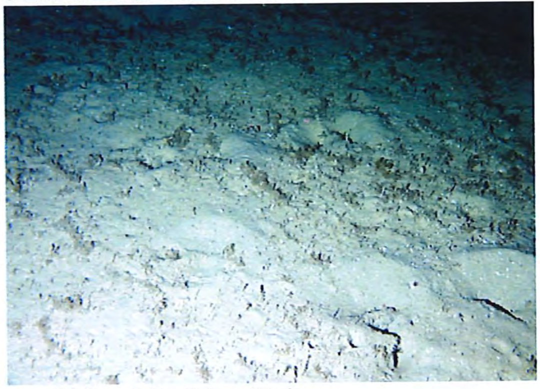


278 230 m Kiwi Corner

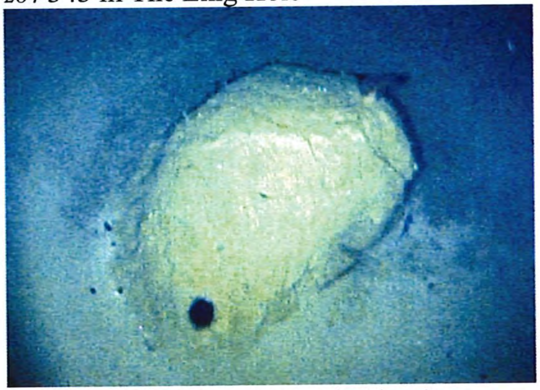


6 263 m Babel Horseshoe

284 343 m The Ling Hole

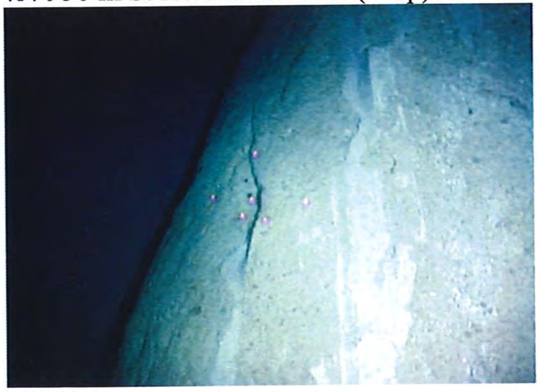


286 333 m The Ling Hole



414 950 m St Helens Grounds (deep)

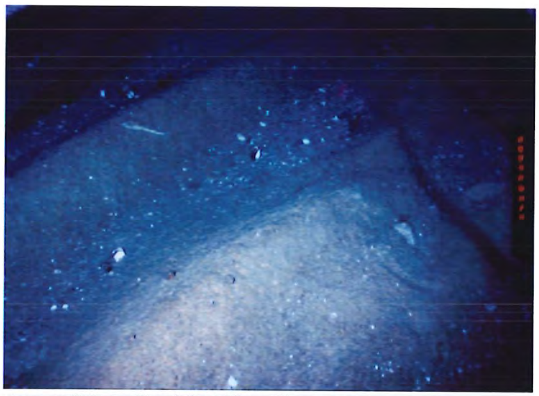
432 950 m St Helens Grounds (deep)



140 995 m Horseshoe Deep

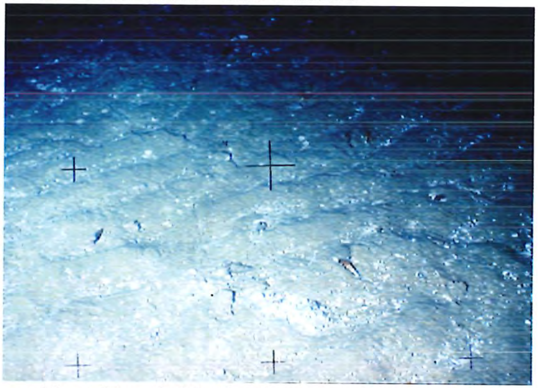
394 700 m St Helens Grounds (outside)

Plate 2 – Four images each showing ‘compact mud’ and ‘mud boulders’ substrata. Note, compact muds comprise a large fraction of the offshore (continental slope) seabed. Mud boulders occur in upper and mid-slope depths and can be concentrated in the base of canyons. Scrape marks on boulders from trawl gear and sheltering orange roughy can be seen at the ‘St Helens Ground (deep)’ in 950 m (image 432).



19837 25 m Inside The Gutters

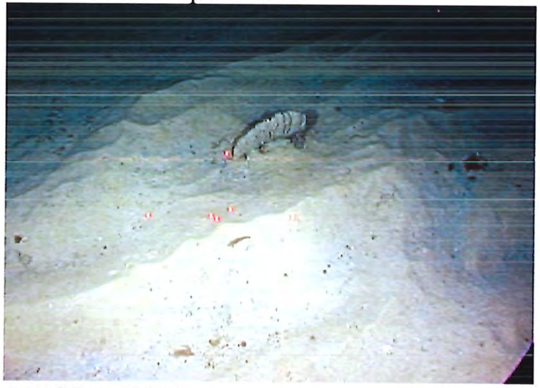
19840 25 m "50's out the front"



44 40 m Twofold Shelf

921 77 m Beachport Shelf

19841 80 m "50's out the front"



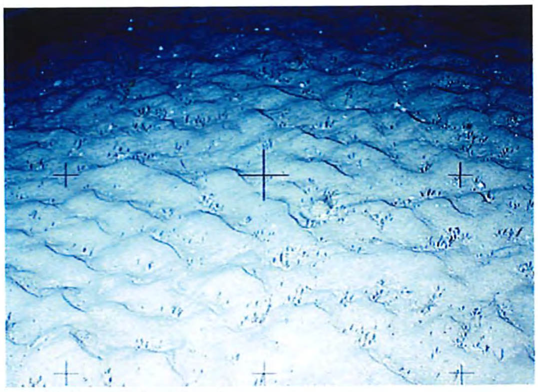
579 95 m GAB

274 116 m King Island Shelf

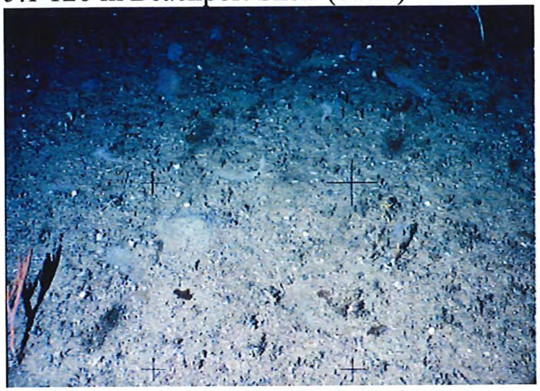
603 119 m Beachport Shelf

Plate 3 - Eight images showing 'sand' substrata. Note, sands comprise a large fraction of the continental shelf seabed and are found in deep current-affected areas of the mid-slope. The effects of current and swell show in surface patterns with ripples and waves respectively. No images were available from the western area of the fishery: image 579 from SE of Kangaroo Is is included to represent sand substrata from mid-continental shelf of the Beachport subregion.

541 120 m Beachport Shelf (outer)

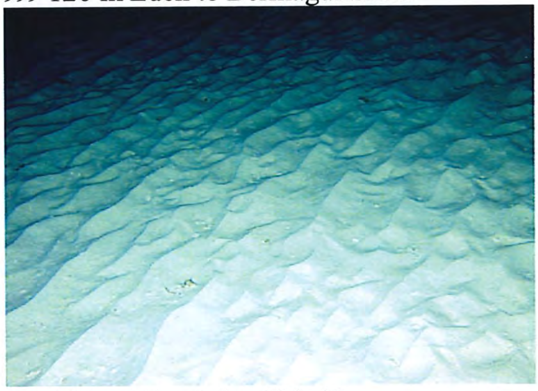


51 120 m Rigs Inshore

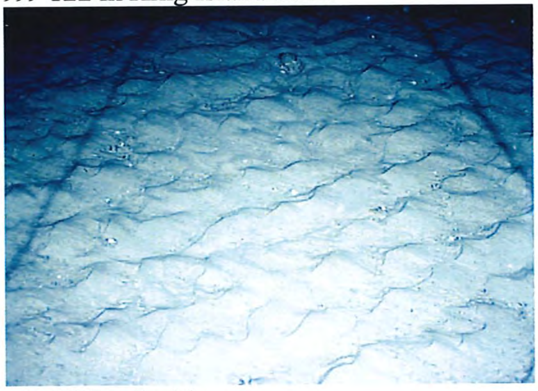


999 120 m Eden to Bermagui Shelf

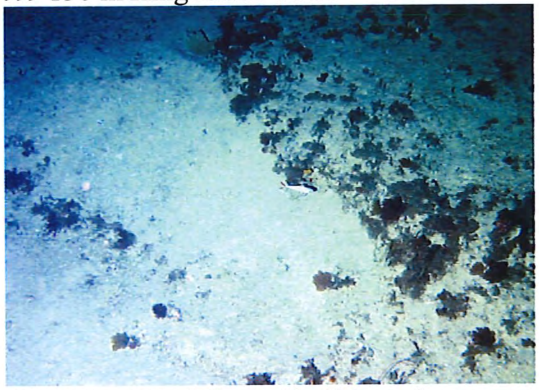
999 122 m King Island Shelf



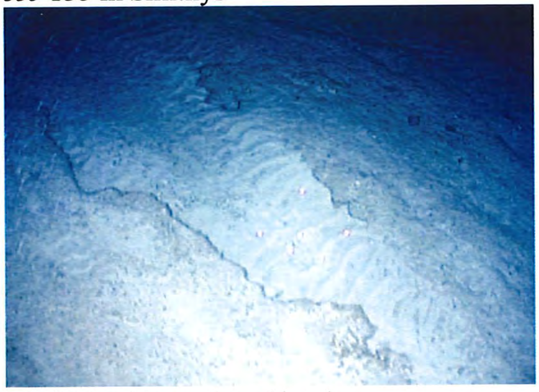
999 130 m King Island Shelf



335 135 m Smithys



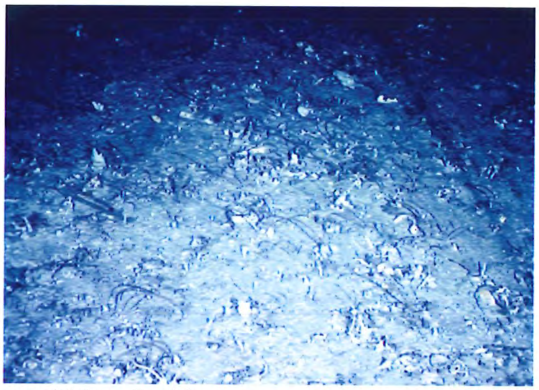
269 154 m Coral Coast Shelf (outer)



661 835 m Horseshoe (deep)

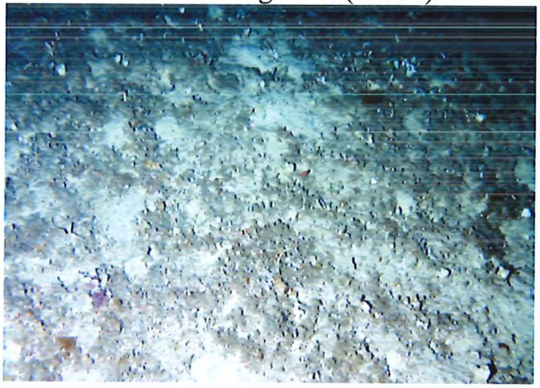
Plate 4 - Eight images showing 'sand' substrata. Note, sands comprise a large fraction of the continental shelf seabed and are found in deep current-affected areas of the mid-slope. The effects of current and swell show in surface patterns (ripples and waves respectively), while confused ripples are formed in the current scored base of the Horseshoe Canyon (image 661).

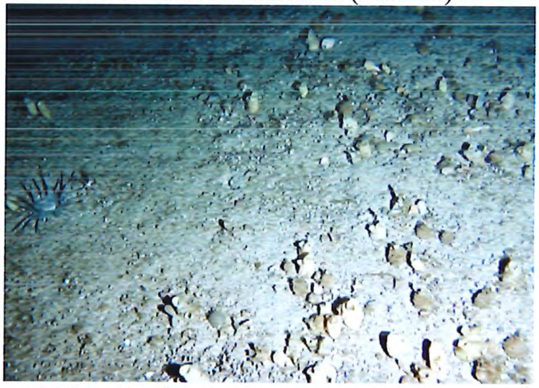

488 57 m Lakes Subregion

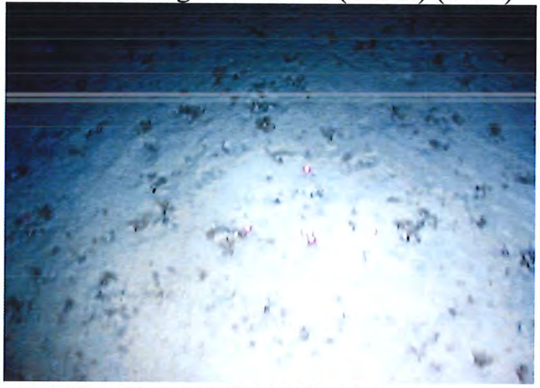

337 135 m Smithys


262 240 m Above Ling Hole (inside)


17 252 m St Helens Grounds (outside)

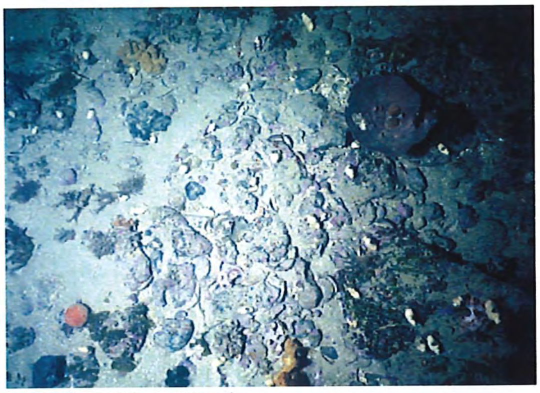

248 265 m King Island Shot (inside) (140k)


22 328 m Banks Strait Ground (101k)

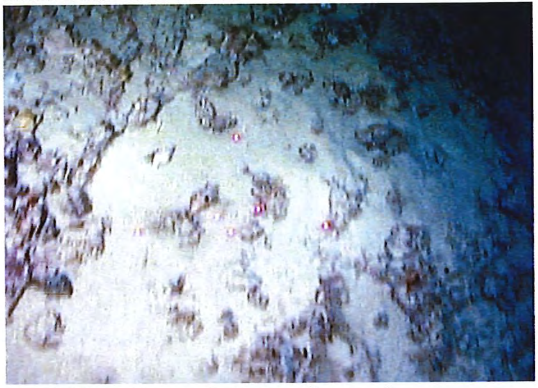

841 529 m Second Howe Ground

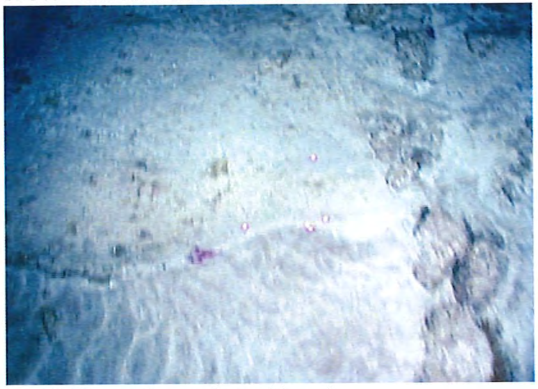

385 700 m St Helens Hill

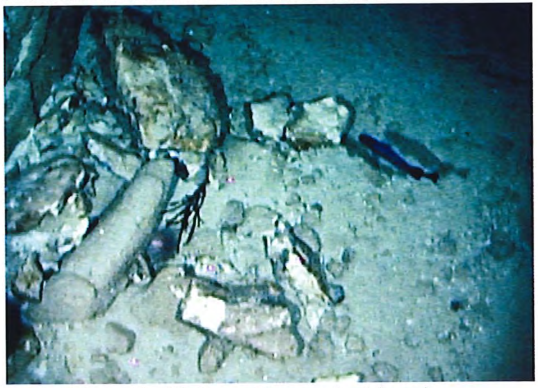
Plate 5 – Eight images showing 'gravel' substrata. Note, 'gravel' (often also described as gritty sand) is composed of a mix of components including mollusc shells, bryozoans and coarse sediments, and provides attachment for low-relief communities of small and encrusting animals such as small sponges, ascidians, living bryozoans and hydroids.

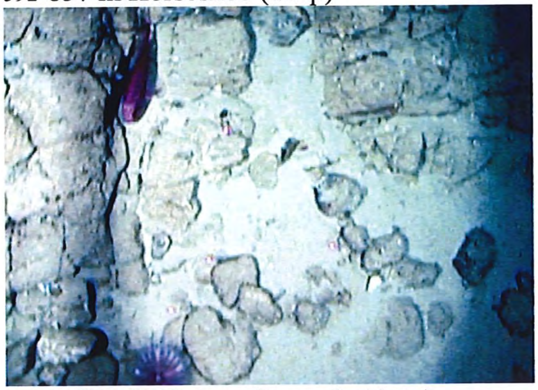

510 31 m Bass Strait

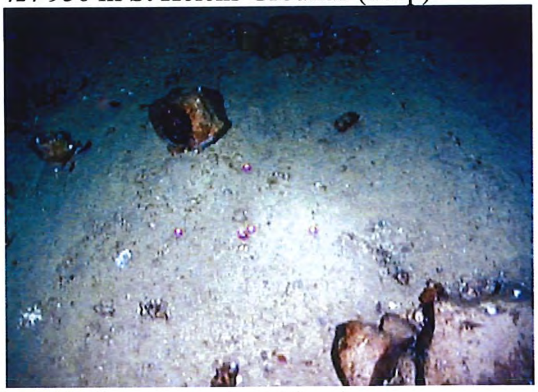

19847 538 m Second Howe Ground


721 539 m Second Howe Ground


592 857 m Horseshoe (deep)


424 950 m St Helens Grounds (deep)


428 950 m St Helens Grounds (deep)


142 1000 m Horseshoe (deep)

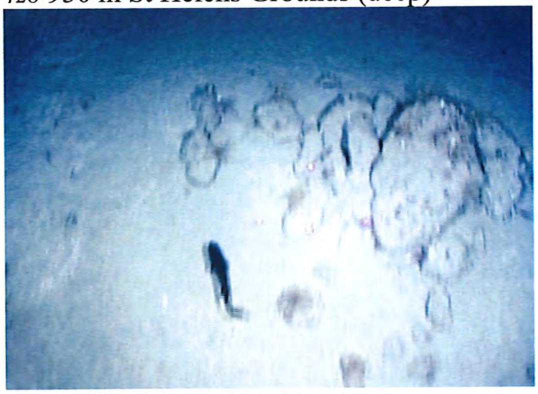
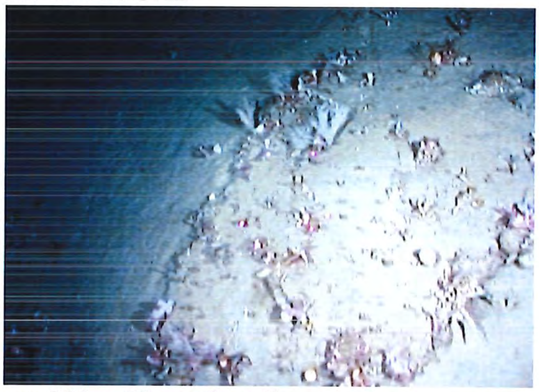

930 1509 m Horseshoe (deep)

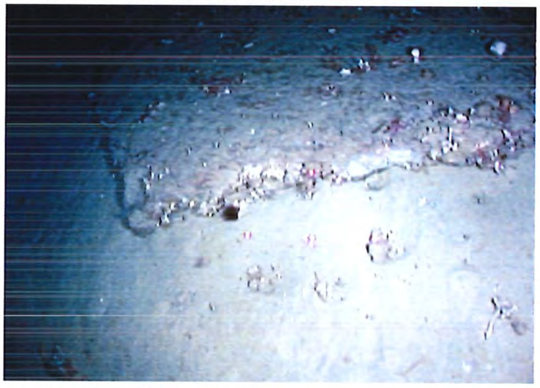
Plate 6 – Eight images showing 'rubble' substrata. Note, composed of small-sized rocks intermediate between gravel and boulders, and often forming patches or flows at the base of features such as canyons.

731 144 m GAB

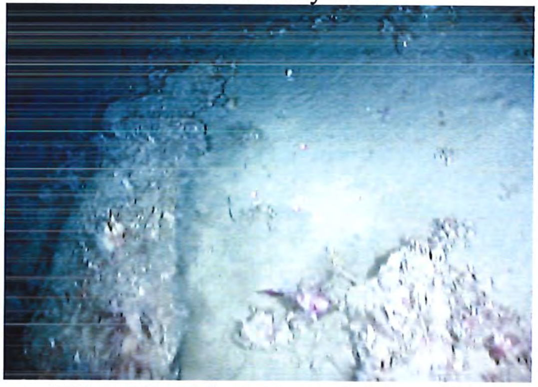
19842 165 m Flower Patch



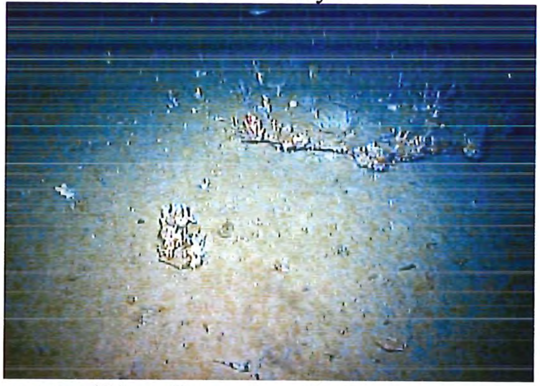
177 388 m Horseshoe Canyon



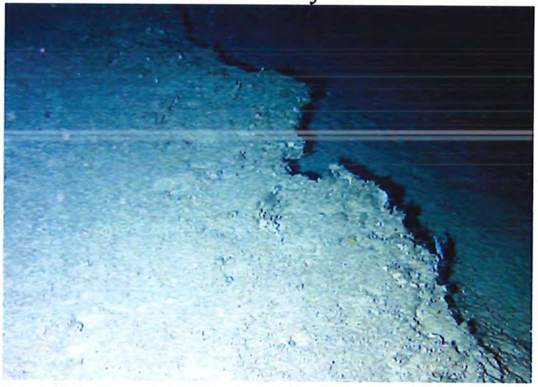
164 390 m Horseshoe Canyon



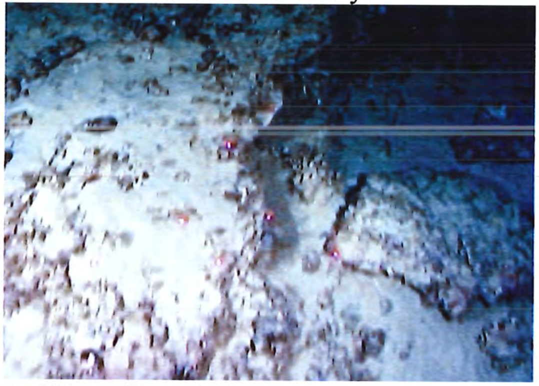
581 390 m Horseshoe Canyon



19859 ~400 m Horseshoe Canyon



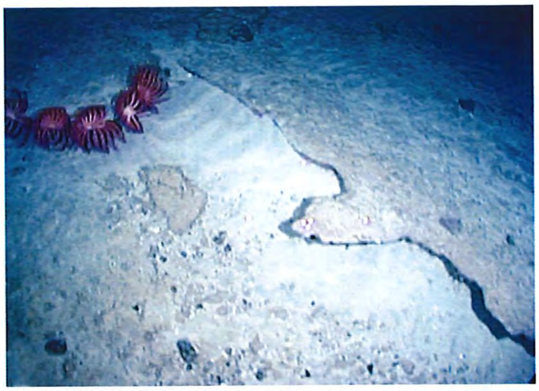
246 482 m King Island Shot (inside) (140k)



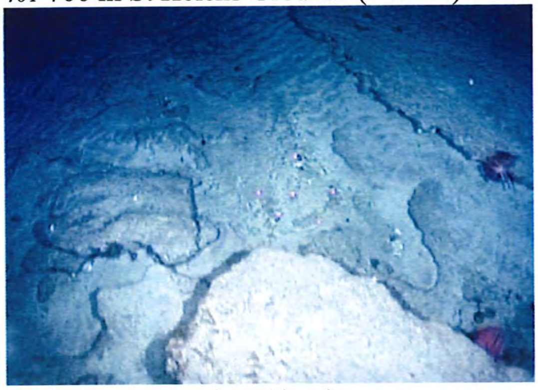
97 539 m Second Howe Ground

Plate 7 – Eight images showing 'slabby' (boulder) substrata. Note, 'slabs' is a fishers' term for the flat boulders formed by broken pieces of sedimentary rock. Concentrations form 'slabby' bottom which is one of the most productive types of habitat for fishes in the SEF, in part because it is structured habitat, supporting attached epifauna. Some images show clearly how sedimentary crusts are undercut by current scour enabling slabs to break off and become mobile, isolated or clustered in surrounding sediments.

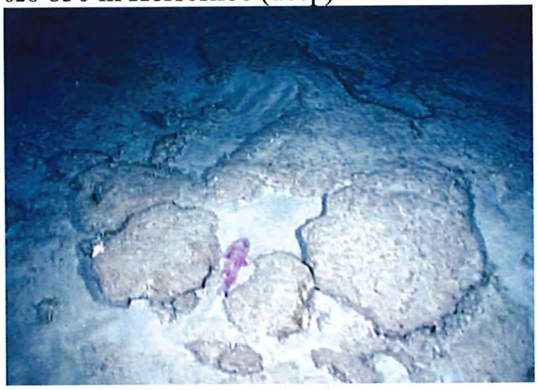
401 700 m St Helens Grounds (outside)



628 830 m Horseshoe (deep)

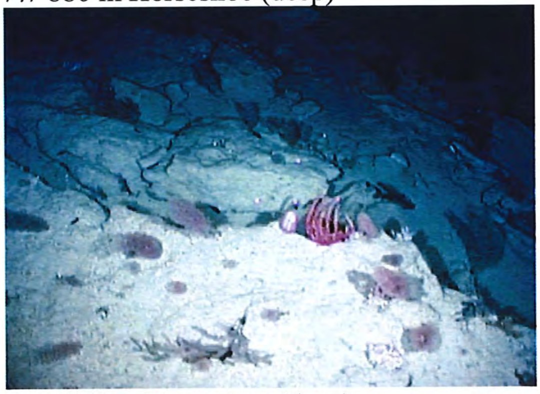


560 839 m Horseshoe (deep)

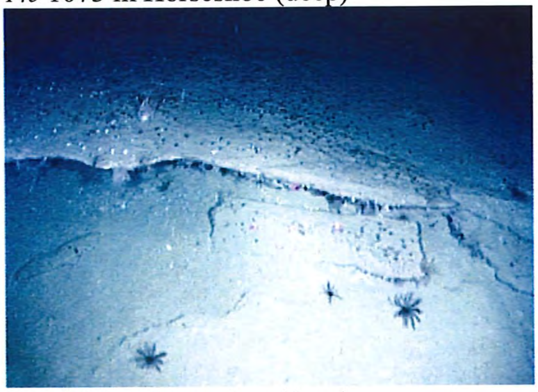


747 880 m Horseshoe (deep)

145 1073 m Horseshoe (deep)



881 1073 m Horseshoe (deep)

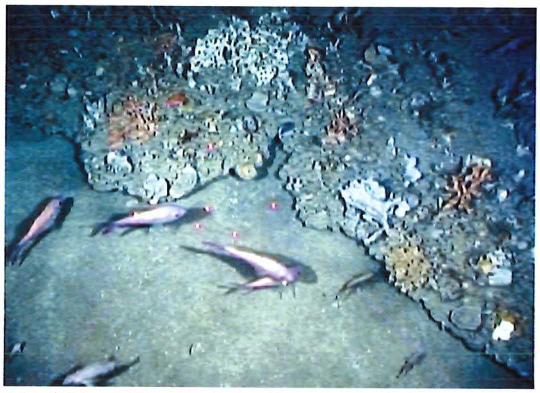


928 1504 m Horseshoe (deep)

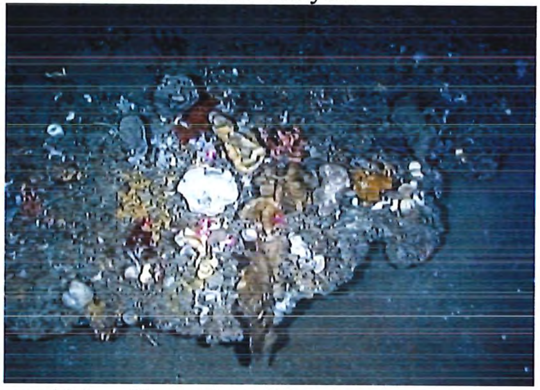
670 1506 m Horseshoe (deep)

Plate 8 - Eight images showing 'slabby' (boulder) substrata. Note, 'slabs' is a fishers' term for the flat boulders formed by broken pieces of sedimentary rock. Concentrations form 'slabby' bottom which is one of the most productive types of habitat for fishes in the SEF, in part because it is structured habitat, supporting attached epifauna. Some images show clearly how sedimentary crusts are undercut by current scour enabling slabs to break off and become mobile, isolated or clustered in surrounding sediments.

198 125 m Horseshoe Canyon

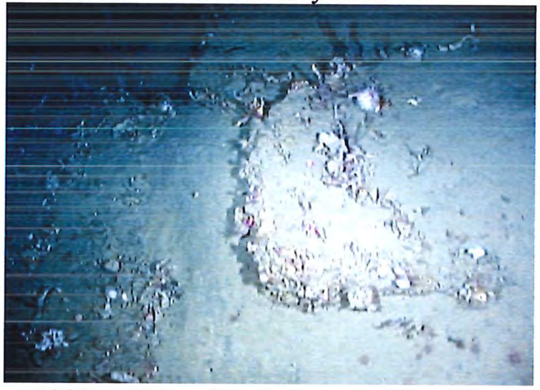


200 125 m Horseshoe Canyon

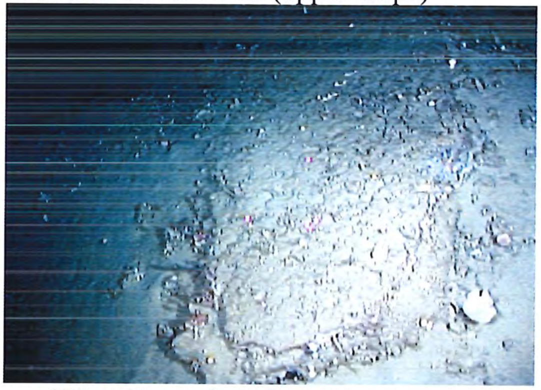


201 125 m Horseshoe Canyon

29 349 m Banks Strait (upper-slope)

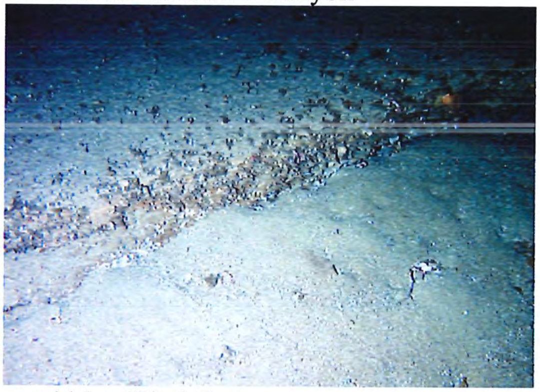


171 389 m Horseshoe Canyon



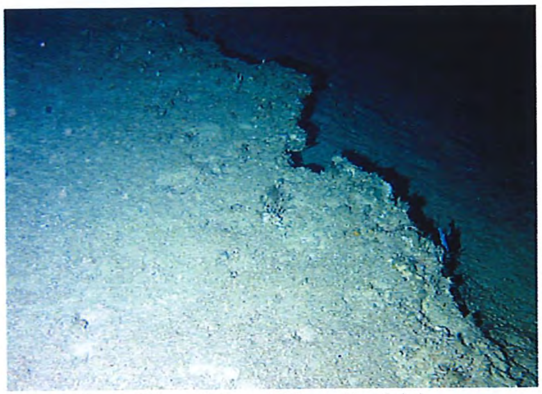
157 390 m Horseshoe Canyon

173 390 m Horseshoe Canyon



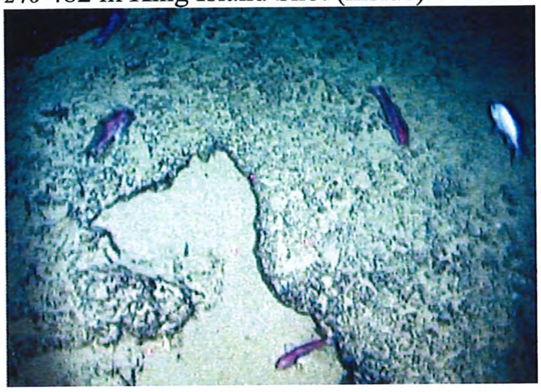
282 446 m Kiwi Corner

Plate 9 – Eight images showing 'heavy low reef' substrata. Note, heavy reef describes sub-cropping or low outcropping bedrock or large tracts of patchy immobile rocky 'reef' bottom (as opposed to slabby or other 'hard' bottom types). It frequently supports large and dense attached epifauna. The distinction between low and high reef is indistinct, but relates partly to what may be negotiated by trawlers using robust ground gear (see Section 5.3.5).

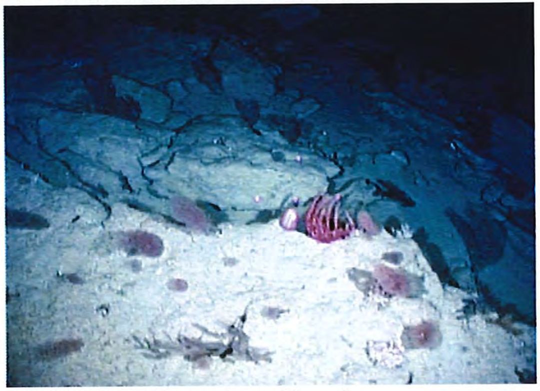


246 482 m King Island Shot (inside)

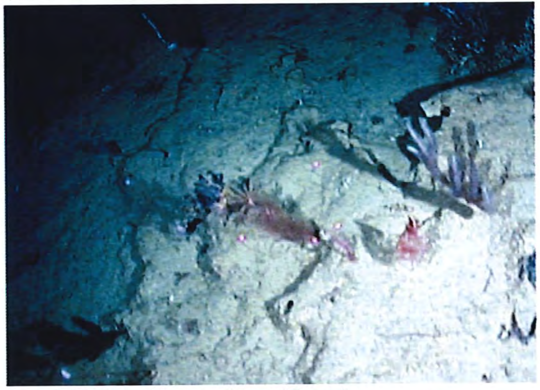
95 540 m Second Howe Ground



439 950 m St Helens Grounds



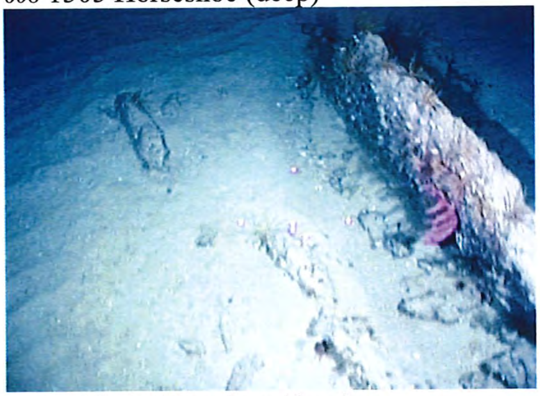
881 1073 m Horseshoe (deep)



150 1087 m Horseshoe (deep)

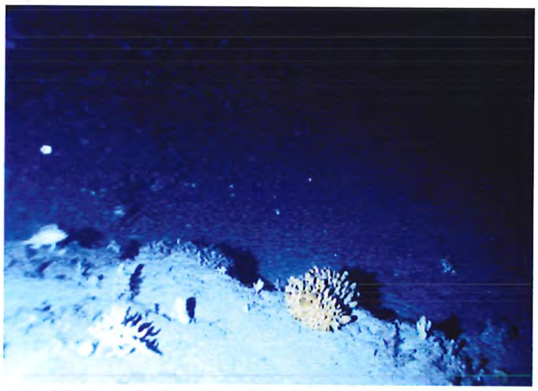
608 1505 Horseshoe (deep)

689 1510 m Horseshoe (deep)

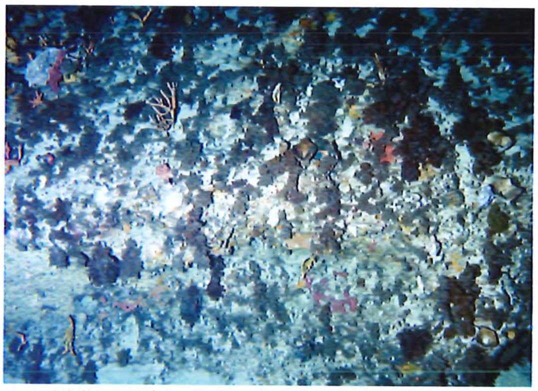


774 1510 m Horseshoe (deep)

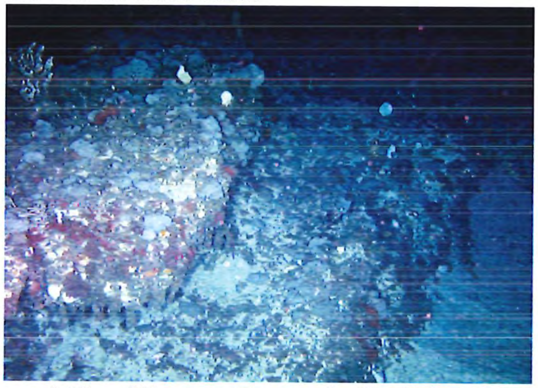
Plate 10 – Eight images showing 'heavy low reef' substrata. Note, heavy reef describes sub-cropping or low outcropping bedrock or large tracts of patchy immobile rocky 'reef' bottom (as opposed to slabby or other 'hard' bottom types). It frequently supports large and dense attached epifauna. The distinction between low and high reef is indistinct, but relates partly to what may be negotiated by trawlers using robust ground gear (see Section 5.3.5).



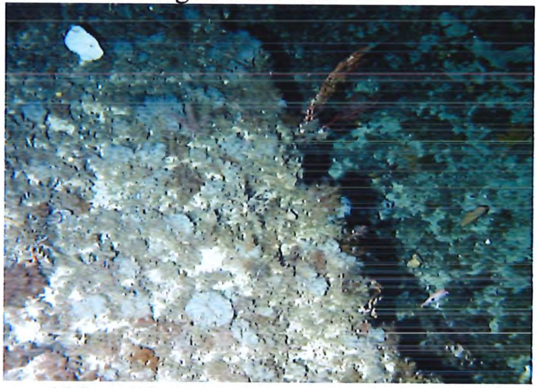
303 115 m Gabo Reef



273 118 m King Island Shelf

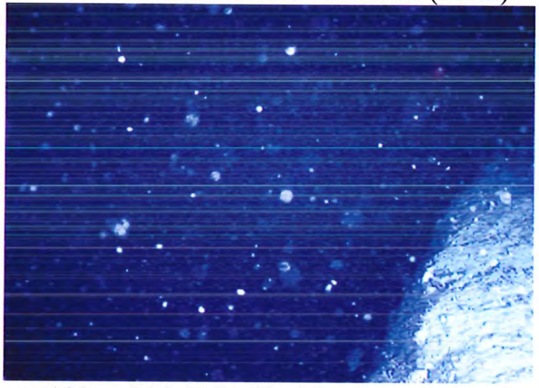


289 118 m Western Tasmania Shelf (north)

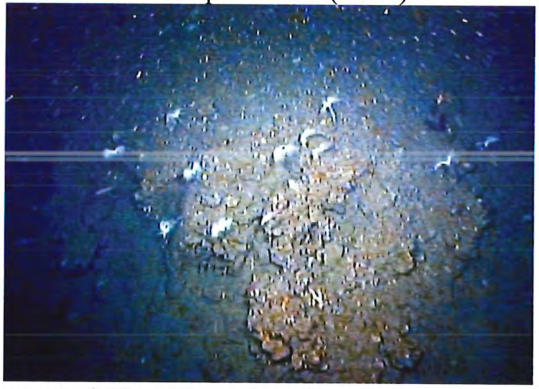


292 120 m Western Tasmania Shelf (north)

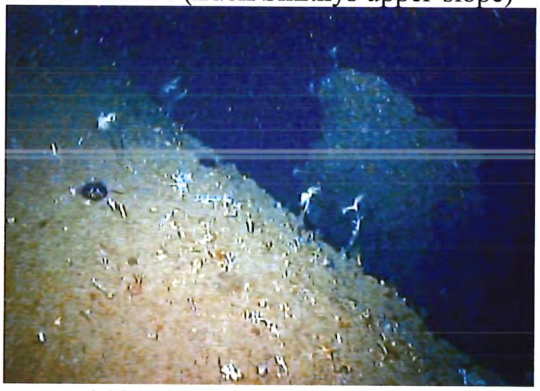
820 127 m Beachport Shelf (outer)



297 190 m 214 (Eden/Smithys upper-slope)



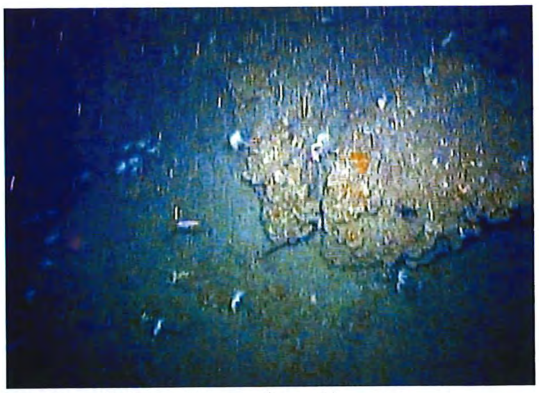
19856 ~250 m Horseshoe Canyon



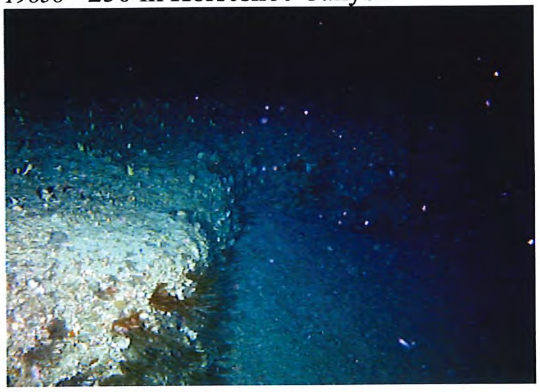
19857 ~280 m Horseshoe Canyon

Plate 11 – Eight images showing 'heavy high reef' substrata. Note, heavy reef describes outcropping bedrock or large tracts of immobile rocky 'reef' bottom (as opposed to slabby or other 'hard' bottom types). It frequently supports large and dense attached epifauna. The distinction between low and high reef is indistinct, but relates partly to what may be negotiated by trawlers using robust ground gear (see Section 5.3.5).

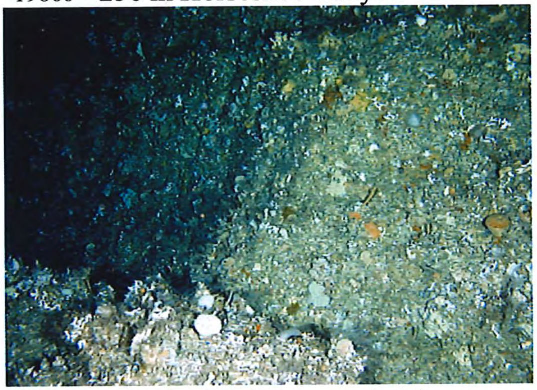
19858 ~250 m Horseshoe Canyon



**19860* ~250 m Horseshoe Canyon



8 307 m Babel Horseshoe

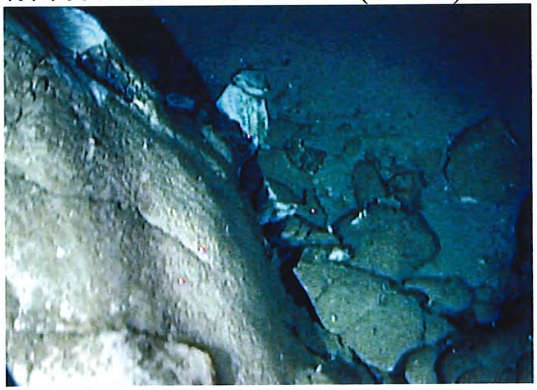


31 328 m Banks Strait (upper-slope)

30 411 Banks Strait (upper-slope)

404 700 m St Helens Grounds (outside)

418 950 m St Helens Grounds (deep)



429 950 m St Helens Grounds (deep)

Plate 12 – Eight images showing 'heavy high reef' substrata. Note, heavy reef describes outcropping bedrock or large tracts of immobile rocky 'reef' bottom (as opposed to slabby or other 'hard' bottom types). It frequently supports large and dense attached epifauna. The distinction between low and high reef is indistinct, but relates partly to what may be negotiated by trawlers using robust ground gear (see Section 5.3.5).

5.3.3 Visualising the form of the seabed (geomorphology)

Geomorphology ('what the bottom looks like') was also recorded as an attribute of each fishing ground in the questionnaire, but recorded only as presence or absence of ten features or characteristics:

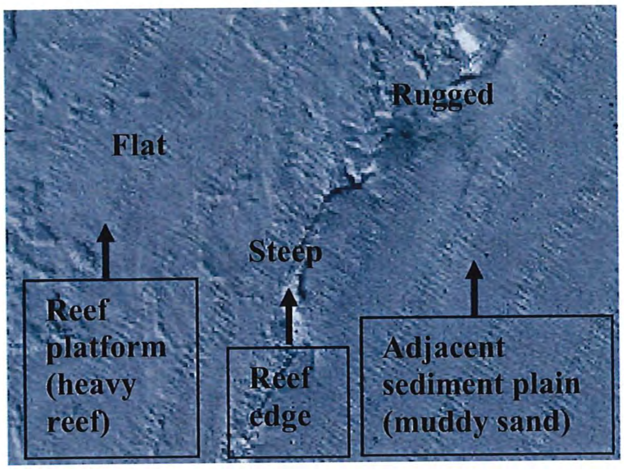
1 – Flat; 2 – Sloping; 3 – Steep; 4 – Undulating; 5 – Rugged; 6 – Bank; 7 – Valley; 8 - Canyon; 9 – Hill; 10 - Seamount

Again, during the life of the project we were able to accumulate additional data – most importantly in the form of swath bathymetry – from a variety of areas including several key grounds, to more fully understand the seascape and how it is used by fishers. Here we present three multibeam swath images to help visualise each of the classes scored (Plate 13).

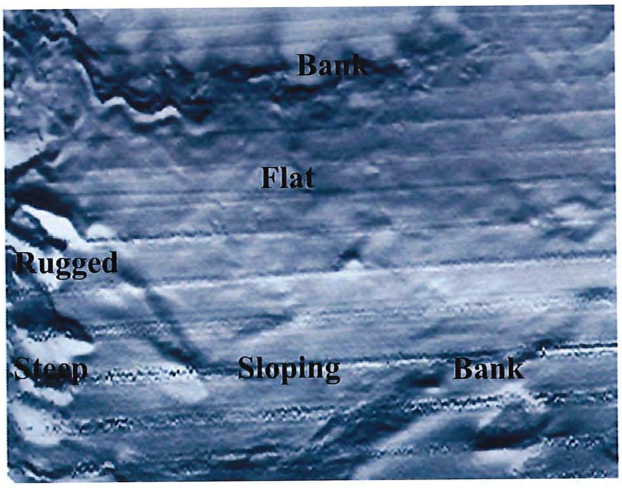
The first (Plate 13a) shows a section of the distinct outer margin of 'Gabo Reef', a high relief, tabular limestone bank ('high heavy reef') off southern NSW in about 130m depth. Fishers recorded this ground as being flat, steep and rugged. These forms can be seen on the multibeam images, respectively, as the reef platform which has depressions and small rises, but is generally flat on top; the outer edge of the reef with near vertical 6 m drops; and the cracked and creviced reef margin.

The second (Plate 13b) shows the western portion of the 'Second Howe Ground', a large terrace sloping from about 300 to 700 m depth seaward of the shelf break scarp and east of the Big Horseshoe Canyon. Fishers recorded this ground as variously flat and sloping, with banks. The ground can be seen to be a mosaic of muddy calcareous sand plains that are mostly flat but which slope away at their southern margin; banks are formed by patches of sedimentary rock rubble, and at the base the shelf break scarp. Rugged and steep areas can be seen in the canyon at the western margin.

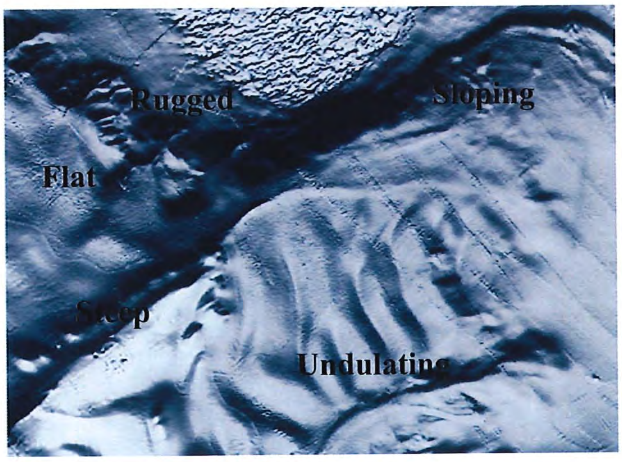
The third (Plate 13c) shows the 'Ling Hole' ground, the shelf edge and upper slope portion of a complex canyon feature off NW Tasmania. Fishers recorded this ground as canyon. It is bounded by the shelf break escarpment, which is steep to the NW, contains a distinct central rugged channel, an extensive area of undulating sediments in the SE, and is flat in its outer (SW) region.



(a) 'Gabo Reef' recorded as flat, steep and rugged; image showing a section of the outer reef edge in ~130 m depth.



(b) 'Second Howe Ground' recorded as flat, sloping and bank; image showing western end of ground and part of the steep rugged adjacent Big Horseshoe Canyon
(in ~ 200-800 m depths).



(c) The 'Ling Hole' recorded simply as a canyon because of its complex structure. Area shown is ~ 150-800 m depths.

Plate 13 - Three multibeam (swath) acoustic images illustrating geomorphology ('what the bottom looks like') recorded by fishers as an attribute of each fishing ground.

5.3.4 Physical modification of the seabed by fishing gears

Our photographic data have not been analysed in detail for the purpose of identifying fishing impacts; this was not an aim of this project, and the majority of photographic observations come from ground-truth sampling for multibeam seabed mapping and spawning stock surveys. However, images do provide insights into how fishing gear directly modifies the seabed and therefore to understanding what constitutes sustainable habitat use. Modification mainly took the form of drag marks, although removal of epifauna, dislodged boulders, discarded catch and lost gear were also seen (Plates 14 and 15).

Many of these images come from recognised trawl grounds where we expected to see drag marks made by the ground gear and trawl doors of bottom trawls; this impact was seen most commonly, and was most obvious on sediment bottom types. Trawl gear are recognisable by their regular pattern and extent: long, regularly-spaced, parallel and relatively shallow furrows made by the rubber rollers of ground gear (images 884, 533, 254, 112) or wider, relatively deep and irregular marks made by trawl doors (images 160, 103 and 19853 – Banks Strait). Drag marks were also evident on harder bottoms such as mud boulders (image 432) and hard rock (image 379).

In some other cases, drag marks appear different and their source is less clear. Image 19833 (St Helens Grounds) is from an area fished with strings of large traps for giant crabs as well as by trawl, and both are plausible causes of the observed marks.

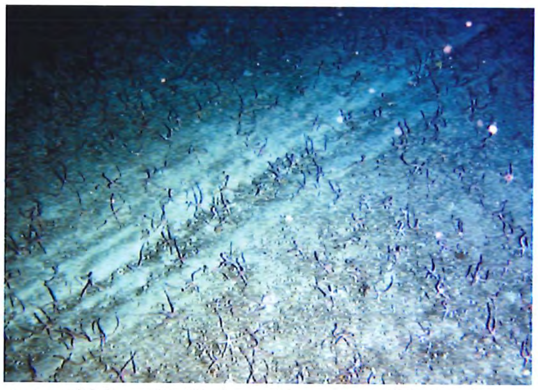
Signs of modification by removal of epifauna (e.g. image 19853 – Banks Strait) are less easy to recognise. On a working fishery landscape it may be difficult to assess the presence or severity of impact on fauna without a 'before and after' study, but this has not been attempted. In fact, in the SEF fishery's 100 year history of fishing there has been little dedicated survey work to examine fishing impacts; the exception in offshore waters is the work of Koslow et al. (2001, who looked at the restricted and unique habitats of seamounts. A study that includes an examination of the vulnerability of shelf edge grounds used for giant crab trap and trawl fishing is underway at this time (2004), and images from that work are included here (images from St Helens Grounds, King Island and Banks Strait). However, we recognise that controlled 'before and after' impacts studies on 'virgin' ground are needed to quantify impacts.

Despite the untargeted nature of the photographic survey to date, there are observations of obvious but widely different impacts on fauna from some locations. A degrading impact is shown when low encrusting communities associated with coarse carbonate muddy sands at the shelf edge are crushed and removed (image 19833, St Helens Grounds). There appears to be much less effect on upper slope muddy sediments supporting few structural epifauna (image 254); here burrowing animals are active in disturbed sediments – although the time between trawl activity and animal activity is not known.

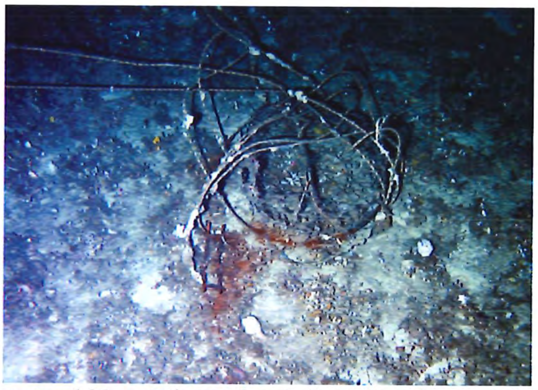
An important type of impact is on 'slabby' habitat which is vulnerable to degradation by trawling because slabs are moveable and may be overturned or redistributed. 'Slabby' bottom (Plates 7 and 8) is a productive habitat type for species including ling, blue eye trevalla, deep ocean perch and ribaldo because its cracks, crevices, edges and attached epifauna provides structured microhabitats. Unattached slabs lying in sediment were seen to have been overturned and dislodged by a trawler fishing directly ahead of the camera (Plate 14, images 168 and 182 respectively), and it is known that they may also be removed and redistributed. This will result in a degradation of habitat because microhabitats are lost, and may have a direct impact on fishery productivity if the impact is high in the areas where concentrations of slabs form key habitats to aggregate fish.

Indirect modification through discarded or lost catch was seen only rarely (e.g. image 186 shows ribbonfish lost when a commercial trawl hooked up on slabby bottom). Lost gear was encountered infrequently, but included lobster traps (image 19852, King Island Shot), and trawl wires (image 378, and see Plate 16, image 281).

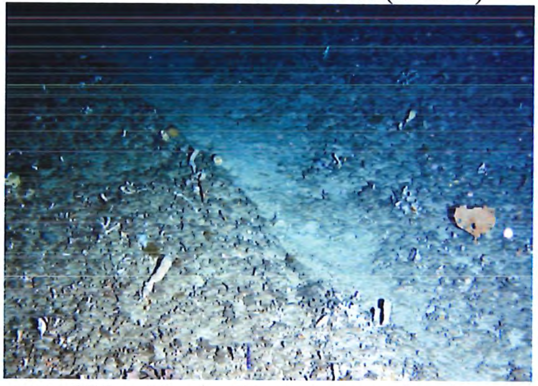
Modification of habitat by fishing activities have been examined through the Ecological Risk Assessment project (Wayte et al., 2006). In that process, impacts on seabed habitats are assessed by first considering the susceptibility (resistance) and productivity (resilience) of habitat types to gear types, and second by the likelihood of them being 'encountered' or used by each fishery sector. An overview of that process for the SESSF is discussed in Section 5.4.10.



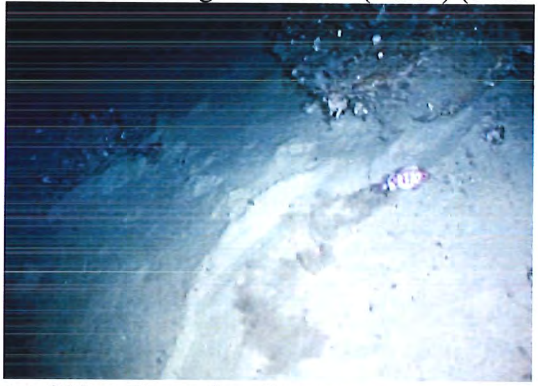
19833 132 m St Helens Grounds (522km)



19852 183 m King Island Shot (inside) (140km)

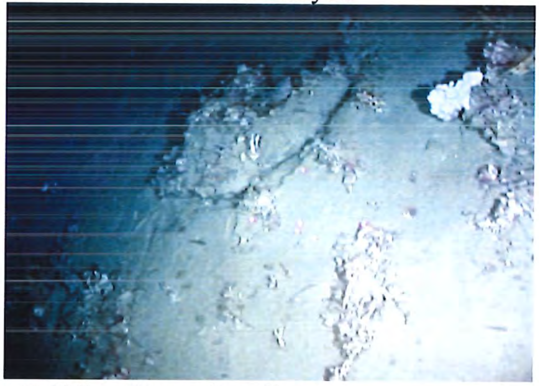


19835 330 m Banks Strait (upper-slope)



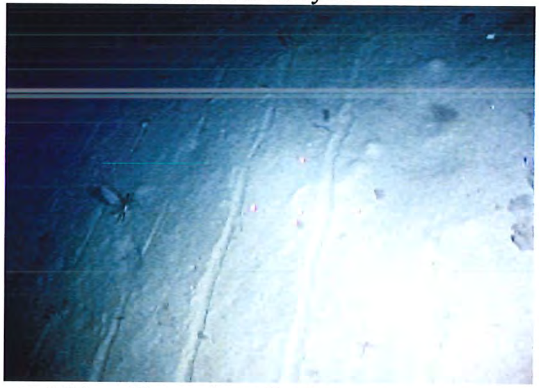
160 390 m Horseshoe Canyon

168 390 m Horseshoe Canyon



182 390 m Horseshoe Canyon

884 390 m Horseshoe Canyon



533 391 m Horseshoe Canyon

Plate 14 - Eight images showing physical impact of fishing gears. Degradation of low encrusting communities on shelf (image 19833) and slope (19835) by dragging of unidentified gears. Rock 'slab' boulders overturned (168) and dislodged (182) by trawl gear. Furrows in muddy sediment from trawl door (160) and trawl footrope discs (884, 533). Lost or discarded trap (19852).

186 393 m Horseshoe Canyon

103 397 m Second Howe Ground

254 537 m King Island Shot (inside) (140km)

112 553 m Second Howe Ground

378 700 m St Helens Hill

379 700 St Helens Hill

432 950 m St Helens Grounds (deep)

139 995 m Horseshoe Deep

Plate 15 - Eight images showing physical impact of fishing gears . Negatively buoyant discards (ribbonfish) settling on seabed in fishing ground (image 186). Furrows in muddy sediment from trawl door (103, 112) and trawl footrope discs (254), and drag marks from trawls on rocky bottom (379), mud boulders (432) and compact mud bottom (139). Lost or discarded wire (378).

5.3.5 Unfishable bottom

Seabed types reported as unfishable were mostly related to trawling, and examples of untrawlable bottom are shown (Plate 16 and Fig. 5.3.1.2d,e,f,g,h). Untrawlable means either that it is not possible to tow the gear along the seabed, or that there is an unacceptable risk of damage to the gear when doing so. Bottom trawl nets and the wires that attach the net to the trawl doors, the 'sweeps' and 'bridles', are towed on or in close proximity to the seabed. This means they are at risk of becoming caught on, or under, any rock outcrop with relief above the surrounding substratum. Seabed types that prevent trawling due to the gear 'pinning up' may therefore be either high relief reef, low relief reef with undercuts or raised outcrops, or flows of rocky debris including large boulders. Continental shelf 'reefs' often have one or more of these characteristics (e.g. all images shown as less than 200 m depth in Plates 11 and 16, and Fig. 5.3.1.2g,h).

Rock hardness also influences what is trawlable, since gear may be winched off softer rock types without damage to the gear but remain attached to, or be severely damaged by, harder types. Shallow cemented (indurated) limestones (e.g. Plate 11, image 820) and volcanic igneous rocks (e.g. Plate 10, image 950) are relatively hard. Relatively soft types include friable sedimentary claystones (e.g. Plate 7, images 246; Plate 8, image 628) and mud boulders (e.g. Plate 2, images 414, 432), as well as other rock types such as granite that have weathered at mid-slope depths and become soft.

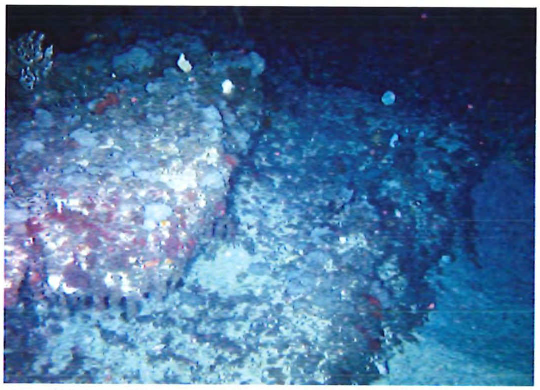
Bottom slope is another factor affecting what can be trawled, with steep and complex bottom topography not providing a sufficiently flat or large enough area to set the gear on. Commercial fish trawl nets used in the SESSF are typically towed between a pair of trawl doors with 200 m or more of wire (sweep plus bridles) between each door and the net giving a door spread of 80 m or more when fished.

Untrawlable bottom may therefore be attributed to small, isolated, hard outcrops or habitats at terrain scale. For example, small hard bedrock outcrops in otherwise clear sediment plains or terraces may halt the progress of a trawl (stoppers) and damage gear, or trap the trawl wires leading to loss of gear (e.g. Plate 8, image 281). Shelf edge terrain, especially scarps, may be high relief rocky banks many tens of metres higher than surrounding substrata with steep cliff-like or steep (to 40° slope) margins (e.g. Plate 16, images 31 and 402).

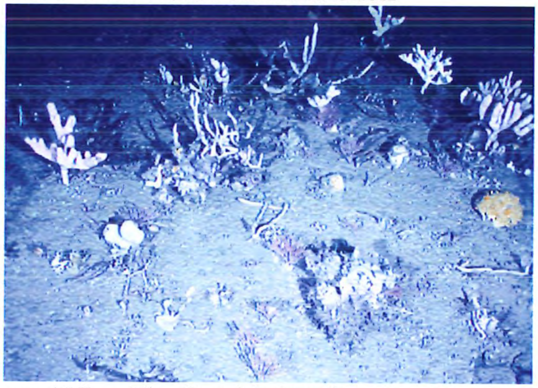
However, bedrock that just extends above surrounding sediments (subcrop) with a smooth profile at its perimeter may be accessible to trawls. It may also be possible to trawl heavy reef outcrop in a certain direction, either because the "dip", or tilt angle, in elevated sedimentary rock runs strongly in one direction, or where the gear can pass over a relatively flat surface and then be 'flown' over the rock edge and out and down into open water off the bottom. It is therefore difficult to define untrawlable bottom, and it is neither distinguished by, nor provides a consistent definition for, low and high heavy reef.

Untrawlable bottom is also strongly related to gear type: in particular vessel power and features of ground gear including bobbins and/or large rubber discs. Coupling GPS with advanced mapping packages that permit 3-D interpolation of echosounder data provide the means to target small areas of trawlable bottom between untrawlable areas that the gear must be flown over. In contrast, most bottom types are accessible to all non-trawl gears, including many types of heavy reef. High heavy reef can be fished by, and is targeted by, drop line and traps, and possibly all non-trawl gears. Locations where non-trawl gears could not be used on high heavy reef would be linked more strongly to the risk of water currents moving and tangling gear around rocky outcrops or under ledges, than to the inability of fishers to set gear over such features.

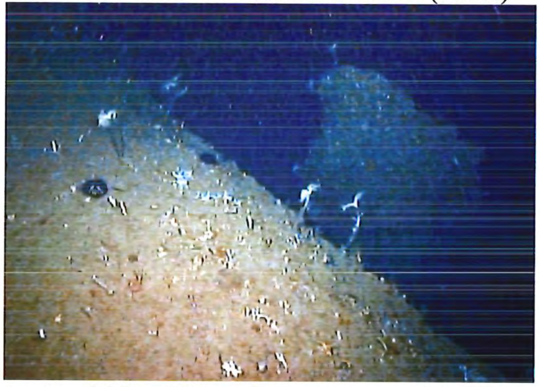
19843 40 m Inside Twofold Shelf



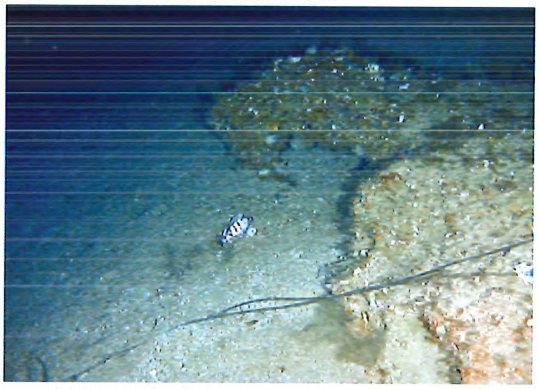
289 118 m Western Tasmania Shelf (north)



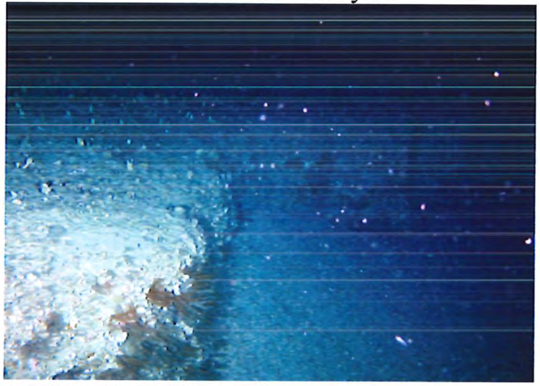
312 120 m The Outside Reef



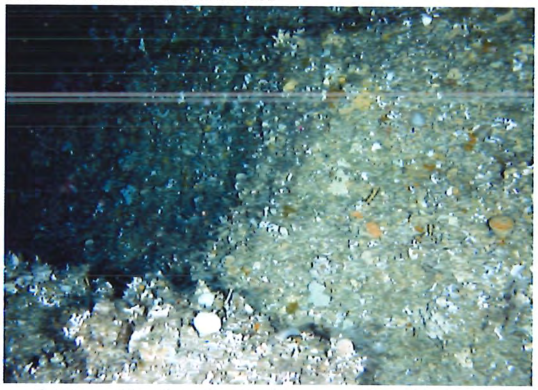
19857 ~280 m Horseshoe Canyon



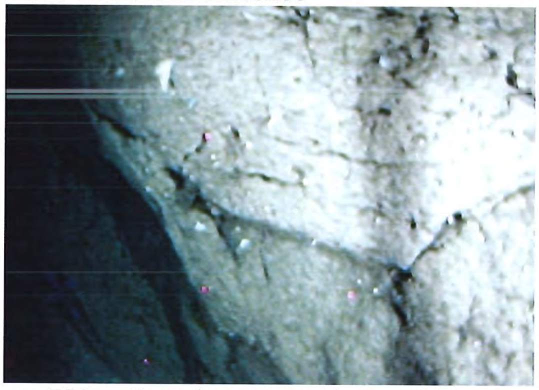
281 441 m Kiwi Corner



8 307 m Babel Horseshoe



31 328 m Banks Strait (upper-slope)



402 700 m St Helens Grounds (outside)

Plate 16 - Eight images showing untrawlable bottom types

5.3.6 Seabed fauna

A variety of seabed invertebrate animals are part of the habitats used by many bottom or near- bottom fishes in the SESSF. Several major groups of the invertebrate fauna, including sponges, seawhips, and stalked crinoids, are attached to the seabed and have erect forms that provide structure in which fish shelter or feed. In certain places where conditions are suitable, these groups may form dense covers rising to half a metre or so off the surrounding seabed. Such places include current swept reef platforms and canyon walls where currents bring plentiful food to filter-feeders and suspension feeders. In exceptional locations of high food supply such as seamounts, long-lived black corals (potentially reaching hundreds of years old, pers. comm. Ron Thresher) may reach several metres in height.

In a fishery habitat context, seabed invertebrates can be classified into three general groups: mobile animals that live primarily on the seabed (mobile epifauna); animals that are attached to the seabed, living on or above it (attached epifauna); and animals that are mobile and live in the seabed (infauna). Underwater photography is a particularly effective means of viewing the make up and distribution of the group that provides structural habitat for fishes – the attached epifauna. A range of examples is provided here to illustrate the variety of habitat forming epifauna seen on the SEF seabed (Plates 17-19). A range of example of fish-habitat associations is also provided (Plates 20-21).

This information adds to our understanding of what fishery habitats are, why they support particular fish species, and the key attributes of habitat that are needed to sustain fishery productivity. The information is incomplete because many small epifaunal animals and the infauna cannot be differentiated on video. These 'unseen' animals are known only from physical samples taken with sleds or grabs and may be used to 'ground-truth' photographic observations. However, even with physical samples, identifying many of the larger animals observed on video is complicated because their taxonomy is poorly known, or their shape and size may vary with ambient conditions, such as current strength. Sponges for example, which appear to be the dominant epifaunal group in the SEF in terms of biomass, have a poorly known taxonomy and can be recorded only in terms of their body form, e.g. as bushy, lumpy, branched etc. Sponge body form is known to vary with environmental conditions; so these categories may not be definitive.

Epifauna distribution correlates with substratum (bottom type), depth and geomorphology. Water currents are another key environmental driver, but these have to be inferred from other habitat features when using video observations. The strongest pattern in faunal distribution is with bottom type. Many groups rely on hard and stable attachment sites, typically where consolidated substrata extend above sediments, or where sediments are semi-consolidated or contain substantial fractions of larger fragments such as mollusc shell. These attachment sites are large rocky banks (reefs), subcropping and outcropping bedrock, boulders and rubble, and consolidated coarse (often shelly) sediments. The most stable and most elevated appear often, but not always, to support the most dense and largest animals. For example, the densest cover of sponges and largest individual sponges were seen on the heavy limestone reefs of the inner and outer shelf at locations including Pt. Hicks and Gabo Reef (Plate 17 images 19843, 311 and Plate 18, image 338). Other habitat forming epifauna such as seapens and seawhips, as well as some smaller sponges, appear to be able to attach to small isolated fragments of hard material in sediments such as small pebbles or mollusc shells (Plate 17 images 209, 211 and Plate 18, image 238). Many smaller groups such as branching, erect and some lumpy sponges, solitary ascidians, soft bryozoans, hydroids, and tube-dwelling polychaetes are able to attach on sediments such as coarse carbonate sands where they appear to form a stable 'turf' (Plate 18 images 25, 26, 15, 22). However, where these animals form dense communities, it is often not possible to tell whether a veneer of sediment obscures underlying rock. This was commonly the case for sandy bottom types on the shelf supporting sponges (Plate 17 image 921) and muddy bottom types on the mid-slope supporting gold corals (Plate 19 images 922, 881, 740).

The general distribution of different epifaunal groups with depth can be seen in Plates 17-19 that are ordered in increasing depth. This is discussed in more detail in Section 5.4.7 in the context of the overall distribution of habitat types.

Plates 17-19 Photographic illustration of epifaunal communities found at a variety of SEF fishing grounds

Plate 17

001 – Low, mixed, encrusting invertebrates (and clumps of large brown algae) on cobble/boulder rubble with low relief reef and sand pockets

002 – Low lumpy sponges and encrusting invertebrates (and sparse large brown & red algae) on sand and cobble rubble

476 – Isolated massive sponges and fenestrate bryozoan clumps, encrusting sponges and other encrusting invertebrates on sand and cobble rubble

19843 – Dense cover of sessile invertebrates, dominated by large bushy and massive sponges on high relief, reef with cracks and crevices

470 – Clumps of large sea tulips (stalked solitary ascidians – *Pyura spinifera*), isolated bushy and erect lumpy sponges on coarse sand with gravel/pebble rubble and patches of low reef subcrop

332 – Dense cover of bushy, erect lumpy and laminar sponges, and some smaller octocorals on sand with low subcropping reef

921 – Isolated bushy, erect and massive sponges and occasional fenestrate bryozoans with subsurface attachment, perhaps to isolated boulder or rubble, among highly irregular coarse sands

660 – Isolated bushy, erect and occasionally massive sponges with subsurface attachment, perhaps to isolated boulder or rubble, on sand

234 – Isolated sparsely-bushy sponges and seawhips overgrown with small encrusting invertebrates on muddy sand

236 – Seawhips (live and heavily encrusted dead skeletons) and bushy sponges, with subsurface attachment, on muddy sand

219 – Isolated bushy and occasional lumpy sponges attached to subsurface and subcropping rock with muddy sediment veneer

220 – Isolated bushy and occasional lumpy sponges attached to subsurface and subcropping rock with muddy sediment veneer

209 – Sparse bushy and occasional lumpy sponges attached to subsurface and subcropping rock with muddy sediment veneer

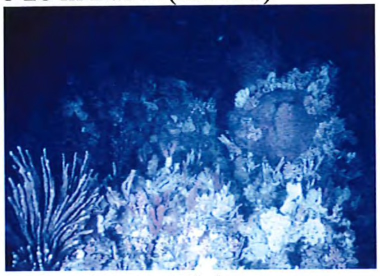
211 – Sparse bushy sponges attached to subsurface rock with muddy sediment veneer, streaming in current.

311 – Large bushy, erect, lumpy and laminar sponges, occasional seawhips and some smaller octocorals attached to heavy tabular reef platform beneath sediment veneer

1 28 m Babel (inshore)

2 28 m Babel (inshore)

476 40 m Lakes subregion

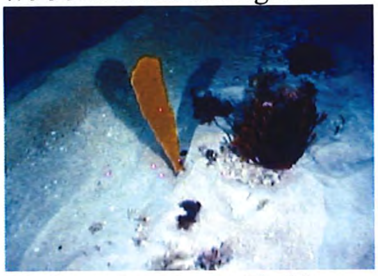


19843 40 m Pt Hicks

470 58 m Lakes subregion

332 70 m Twofold Shelf

921 77 m Beachport Shelf



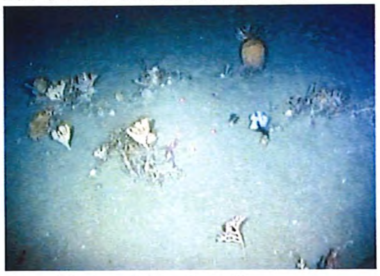
660 79 m Beachport Shelf

234 90 m Second Howe Ground

236 96 m Cumberland Reef

219 110 m Flat Patch

220 111 m Flat Patch



209 112 m Flat Patch

211 114 m Flat Patch

311 115 m Gabo Reef

Plate 17 - Epifauna (animals living on the sediment)

Plate 18

275 – Numerous clumps of soft bryozoans and hydroids, and occasional bushy and lumpy sponges, on irregular sand patch in amongst heavy reef

338 – Large bushy sponges, with mixed smaller sponges and other sessile invertebrates, attached to heavy tabular reef platform beneath sediment veneer

199 – Patches of low sponges on silt covered sedimentary rock outcrop, with small erect and bushy sponges on edges outcrop

005 – Sparse bushy and lumpy sponges with other small encrusting invertebrates on sand with scattered pebble and cobble rubble

623 – Dense clusters of the stalked crinoid (*Metacrinus cyaneus*) on sedimentary rock boulders (slabs) subcropping from surrounding soft mud

025 – Branching, erect and some lumpy sponges, solitary ascidians and a turf of soft bryozoans, hydroids and polychaete tubes on coarse carbonate sands

026 – Branching, erect and some lumpy sponges, solitary ascidians and a turf of soft bryozoans, hydroids and polychaete tubes on coarse carbonate sands with subsurface rock

015 – Small lumpy and encrusting sponges, solitary ascidians and a turf of soft bryozoans, hydroids and polychaete tubes with some larger mobile invertebrates including seastars on silty mud and gravel

238 – Isolated seapens, some small lumpy sponges and solitary ascidians, and polychaete tubes on silty coarse sand, with soft bryozoans and hydroids attached to the large sediment fragments

266 – Small lumpy sponges, solitary ascidians, polychaete tubes and some larger mobile invertebrates including seastars on silty coarse sand, with soft bryozoans and hydroids attached to the large sediment fragments

022 – Isolated sea anemones, solitary ascidians and a few small lumpy sponges on consolidated silty carbonate sand with larger fragments, with soft bryozoans and hydroids attached to the large fragments

19831 – Numerous brittlestars on silty, highly bioturbated sand; most individuals with their disc at the bottom of a small depression in sediment

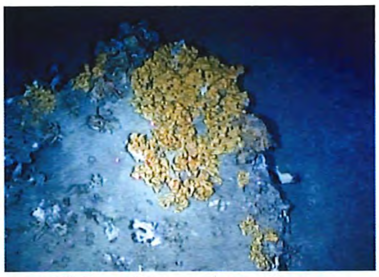
194 – Moderately dense cover of bushy, erect and lumpy sponges, various octocorals and other encrusting invertebrates on silt covered sedimentary rock outcrop

635 – Moderately dense cover of bushy, erect and lumpy sponges, various octocorals and other encrusting invertebrates on silt covered sedimentary rock outcrop

849 – Bushy, erect and lumpy sponges, various octocorals and other encrusting invertebrates on silt covered sedimentary rock subcrop

275 119 m King Island Shelf

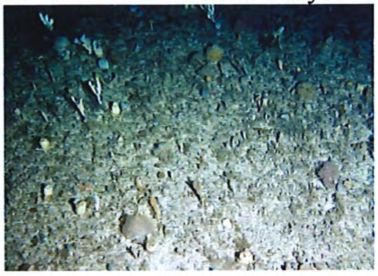
338 120 m Gabo Reef



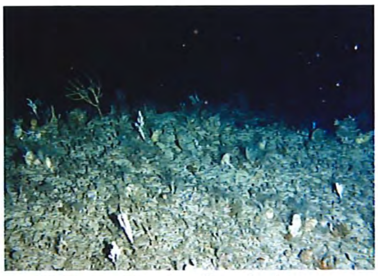
199 125 m Horseshoe Canyon

5 155 m Babel Horseshoe

623 229 m Big Horseshoe West



25 245 m Banks Strait (upper-slope)

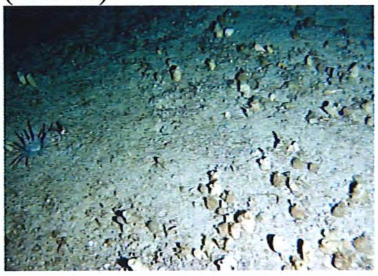


26 251 m Banks Strait (upper-slope)

15 287 m St Helens Grounds (outside)

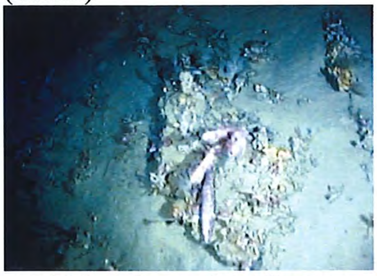
238 288 m Eden Deep

266 326 m 1 Below Ling Hole (inside)

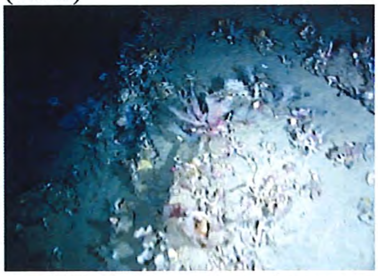


22 328 m Banks Strait Ground (101k)

19831 ~215 m Short Shot



194 390 m Horseshoe Canyon



635 390 m Horseshoe Canyon

849 390 m Horseshoe Canyon

Plate 18 - Epifauna (animals living on the sediment)

Plate 19

102 – Numerous sea urchins (most likely pancake urchins) on heavily bioturbated muddy sand

381 – Large sea anemones, brisingoid seastars, solitary corals and small octocorals on flat rocky boulder with ledges

385 – Solitary sea anemone on coarse coral/shell debris ('gravel')

393 – Stalked crinoids, solitary corals and dead coral debris at base of rock outcrop

394 – Cluster of stalked crinoids on mud boulder

405 – Large frond of black coral on silty rock outcrop with cobble/ boulder debris

628 – Brisingoid seastars on low sedimentary rock crust undercut by current scour with coarse sand and pebble/cobble debris

438 – Black coral fronds on igneous rock outcrop

441 – Stalked crinoids, live colonial coral and octocorals, some mobile invertebrates including gastropods and hermit crabs on igneous rock outcrops.

456 – Stalked crinoids, live solitary corals and octocorals on small, bulbous igneous rock outcrops

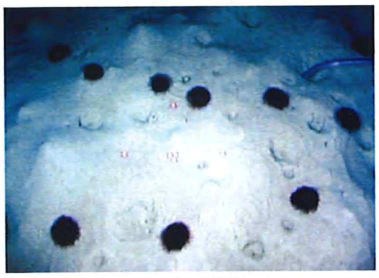
922 – Gold corals, sea anemones and live colonial coral attached to low reef with sediment veneer

881 – Brisingoid seastars, sea urchins (*Dermechinus horridus*), gold corals, sea anemones and stalked crinoids attached to low reef

564 – Large spiny stone crab (Lithodidae) with small stalked crinoids, sea anemones and octocorals on silty, dead coral debris

740 – Gold corals, seawhip and other octocorals, and sea anemones attached to low reef with sediment veneer

828 – Large and small stalked crinoids, and octocorals on small isolated mud boulders surrounded by soft mud


102 579 m Second Howe Ground


381 700 m St Helens Hill


385 700 m St Helens Hill


393 700 m St Helens Grounds (outside)


394 700 m St Helens Grounds (outside)

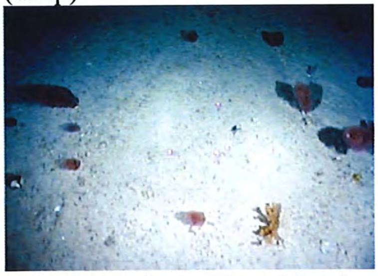

405 700 m St Helens Grounds (outside)

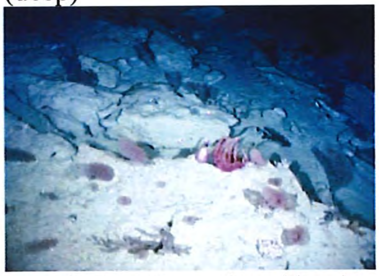

628 830 m Horseshoe (deep)


438 950 m St Helens Grounds (deep)


441 950 m St Helens Grounds (deep)


456 950 m St Helens Grounds (deep)


922 1070 m Horseshoe (deep)


881 1073 m Horseshoe (deep)


564 1077 m Horseshoe (deep)


740 1087 m Horseshoe (deep)


828 1512 m Horseshoe (deep)

Plate 19 - Epifauna (animals living on the sediment)

Plates 20 - 21 Photographic illustration of fish and crustaceans observed at a variety of SEF fishing grounds

Plate 20

19844 – Juvenile redfish school around a rocky outcrop covered with large sponges

658 – Gemfish close to heavily rippled fine sediments

304 – Butterfly perch and redfish near subcropping rock and attached epifauna

603 – Latchet on heavily rippled fine sediments

291 – Jack mackerel school near outcropping reef with attached soft bryozoans, sponges and whips

198 – Adult redfish using low undercut outcropping reef for refuge

200 – Adult redfish using low undercut outcropping reef (densely covered with attached epifauna) for refuge

19849 – Jackass morwong on fine sediments with subcropping rock

19832 – Crayfish on flat sediments with a sparsely distributed sponges and whips

929 – Gemfish near bottom with stalked crinoids on slab

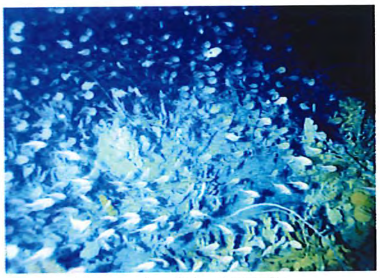
249 – Giant crab nestled amongst mixed bryzoan and sponge thicket

283 – Two giant crabs on bryozoan thicket

19851 - Blue grenadier over flat fine sediments

725 – A green-eyed dogfish over flat fine sediments

267 – A draughtboard shark swimming above bryozoan thicket

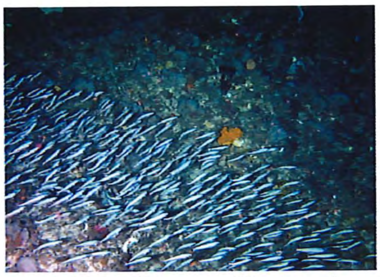


19844 74 m inside NZ Star Banks

658 94 m GAB

304 115 m Gabo Reef

603 119 m Beachport Shelf



291 121 m Western Tasmania Shelf (north)

198 125 m Horseshoe Canyon

200 125 m Horseshoe Canyon

19849 126 m Beachport Shelf (outer)

19832 134 m Babel Horseshoe

929 199 m Big Horseshoe West

249 291 m King Island Shot (inside)(140km)

283 310 m Kiwi Corner

19851 ~300 m King Island Shot (inside) (140km)

725 321 m Horseshoe Canyon

267 338 m 1 Below Ling Hole (inside)

Plate 20 - Fishes

Plate 21

19848 – Mirror dory near subcropping reef with attached small sponges

19850 – Ling amongst sponges and rock structure on outcropping reef

156 – Blue eye travalla near subcropping rock with attached epifauna

911 – Ccean perch near outcropping reef with attached soft bryozoans and sponges

172 – Blue eye trevalla near subcropping rock with attached epifauna

195 – Ling amongst sponges and rock structure on outcropping reef

19834 – Imperador on steeply sloping ground.

19853 – Silver dory on fine sediments

797 – Ghost shark on bioturbated fine sediments

583 – Ling on bioturbated fine sediments

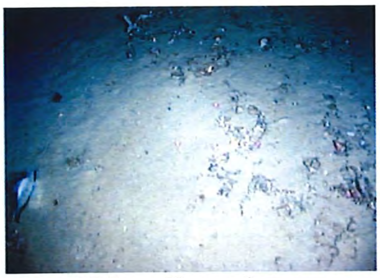
251 – Deepwater flathead on bioturbated fine sediments

114 – Ling on bioturbated fine sediments

65 – Ribaldo on bioturbated fine sediments and rock edge

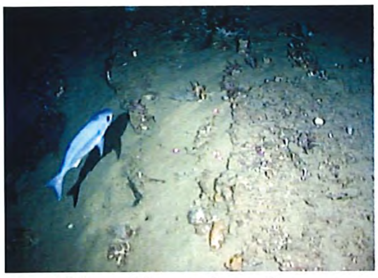
999 – Orange roughy over outcropping reef

391 – Deep water shark over boulder and rock bottom



19848 375 m Horseshoe Canyon

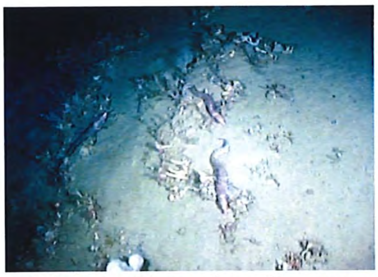
19850 ~380 m Horseshoe Canyon



156 388 m Horseshoe Canyon

911 389 m Horseshoe Canyon

172 390 m Horseshoe Canyon



195 390 m Horseshoe Canyon

19834 399 m St Helens Grounds North (267km)

19853 ~400 m King Island Shot (inside) (140km)

797 431 m Horseshoe Canyon

583 443 m Horseshoe Canyon

251 447 m King Island Shot (inside) (140km)

114 457 m Second Howe Ground

65 546 m Second Howe Ground

19845 700 m St Helens Grounds (outside)

391 700 m St Helens Grounds (outside)

Plate 21 - Fishes

5.3.7 Scientific data: summary

Photographs, multibeam acoustic maps and physical samples of the seabed from many different areas and fishing grounds were accumulated during the life of the project. These have enabled the habitat attributes described by fishers and recorded in the questionnaire (what the bottom 'is made of' and 'looks like') to be illustrated and visualized. Images also provide evidence of fishing gear directly modifying the seabed in the form of drag marks, removal of epifauna, dislodged boulders, discarded catch and lost gear.

Many of these modifications are easily recognisable, and were unsurprising because prime fishing grounds were being observed. Signs of modification by removal of epifauna and substratum are less easy to recognise, partly because the photographic data have not been analysed in detail for this purpose, but partly because removal of habitat is difficult to assess without a 'before and after' study – and many areas have been fished for a considerable period of time. However, impacts from trawling were observed on slabby bottom, and this is significant because degradation of slabby bottom habitat represents a potential loss to fishery productivity because microhabitats used by species such as pink ling are lost when slabs and their attached epifauna are moved or removed.

Images from 'unfishable' areas, mostly reported by trawl fishers as untrawlable, showed these are high relief reef, low rocky features that are undercut or with raised outcrops, and flows of rocky debris including large boulders. There is no clear distinction between trawlable and untrawlable seabed, since trawling may be prevented by small, isolated, features in an otherwise trawlable terrain, while comparatively small terraces on an otherwise untrawlable escarpment can be targeted. For example, small hard bedrock outcrops in otherwise clear sediment plains or terraces may halt the progress of a trawl (stoppers) and damage gear, or trap the trawl wires leading to loss of gear (e.g. Plate 8, image 281). Shelf edge terrain, especially scarps, may be steep and contain high relief rocky banks many tens of metres higher than surrounding substrata with steep cliff-like or steep (to 40° slope) margins (e.g. Plate 16, images 31 and 402) that are not sufficiently flat or large enough to set the gear on. Rock hardness also influences what is trawlable, since gear may be winched off softer rock types without damage to the gear but remain attached to, or be severely damaged by, harder types. Trawl 'access' is also strongly related to gear type: in particular vessel power, features of ground gear including the sizes of bobbins and/or rubber discs, and accurate positioning and mapping navigational technologies. For example, heavy low sedimentary reef may be trawlable in particular directions, or using certain gear configurations including larger and more robust ground gear and with sufficient vessel power, but may also be inaccessible to some trawl types or smaller vessels.

In contrast, most terrains/ bottom types, including many heavy reefs, are accessible to all non-trawl gears. In many, if not most situations, high heavy reef can be fished by, and is targeted by, drop line and traps, and possibly all non-trawl gears. Locations where non-trawl gears could not be used on high heavy reef would be linked more strongly to the risk of water currents moving and tangling gear around rocky outcrops or under ledges, than to the inability of fishers to set gear over such features.

Several major groups of the invertebrate fauna, including the sponges, seawhips, and stalked crinoids, are attached to the seabed and have erect forms that provide structure forming part of productive habitat in which fishes shelter or feed. Current swept reef platforms and canyon walls where currents bring plentiful food to filter and suspension feeders support dense covers of sponges, stalked crinoids and seawhips rising to half a metre or so off the surrounding seabed. The general distributional patterns of the epifauna correlate strongly with substratum (bottom type) and many epifaunal groups rely on hard and stable attachment sites, typically large rocky banks (reefs), subcropping and outcropping bedrock, boulders and rubble, and consolidated coarse (often shelly) sediments. The most stable and most elevated hard bottom types appear to support the most dense and largest animals: the densest covers of sponges and largest individual sponges were seen on the heavy limestone reefs of the inner and outer shelf at locations including Pt. Hicks and Gabo Reef. Other habitat-forming epifauna such as seapens and seawhips, as well as some smaller sponges, appear to be able to attach to small isolated fragments of hard material in sediments such as small pebbles or mollusc shells. Many smaller groups such as branching, erect and some lumpy sponges, solitary ascidians, soft bryozoans, hydroids, and tube-dwelling polychaetes are able to attach on sediments such as coarse carbonate sands where they appear to form a stable 'turf'.

5.4 Integrated mapping data

5.4.1 Background to integrating industry and scientific habitat mapping data

The types of seabed maps made by fishers and scientists each contain unique features that are related broadly to scale and resolution. Fishers' maps mostly identify bottom types only at a rather coarse resolution, but relate these to features at a scale of 10s kilometres or larger with finer scale information in places; importantly though they have knowledge for large areas of 100s to 1000s of kilometres. Scientists' maps have tended to identify seabed types at relatively high resolution but at relatively small scales of kilometres or less; however, scientists typically lack the resources to map large areas at this high resolution (although the recent advent of multibeam 'swath' mapping is increasing that capacity – see examples below). Integrated habitat mapping data combines the unique features of both scales of mapping, and this can be illustrated with an historical perspective in the SEF.

Prior to the 1990s there had been no scientific mapping of offshore habitat in the SEF despite over 100 years of fishing. The first area mapped was part of the continental shelf between Wilsons Promontory and the Victorian/ NSW border during a study of the regional ecosystem in the mid 1990s (Bax and Williams, 1999). At the commencement of that project, navigation around the study region was based on third-party, coarse-scale bathymetry data and navigation charts: primarily point-source depth soundings, the approximate positions of key depth contours including the continental shelf edge at ~200 m, and the positions of some near-surface rocky banks identified as shipping hazards. This information was used in combination with limited existing survey data, and some rapid exploration by single-beam echo-sounding during surveys, to fix a set of transects and sampling sites, stratified by depth and latitude, for trawl surveys. These sites provided broad-scale information across the study area, but only for sediment substrata.

It was dialogue with knowledgeable local fishers that enabled targeted sampling of consolidated substrata, mostly rocky reefs, to be progressively built into those field surveys. What evolved at the end of that study was the first integrated science-industry habitat map – the 'fisher map' – a mix of fisher-delineated geomorphic features at scales of 10s to 100s of kilometres (such as sediment plains and rocky banks) that were ground-truthed with physical samples and photographs from surveys that identified biological inhabitants and their association with bottom types at finer scales.

In many ways the present study is a geographical extension of the previous study, but with a systematic approach incorporating security for industry data and an intention to use the data more quantitatively. Maps of fishing grounds (as defined in Section 4.3.3) provide boundaries, areas and names for a mosaic of patches across the fishery, mostly at scales of 10s to 100s of kilometres. Each ground is provided with fishers' coarsely resolved habitat information, and importantly with fishers' ecological interpretations (Williams and Bax, 2003a). These features permit a fishery-wide understanding of habitat type and distribution by providing a template on which to overlay more finely resolved data from logbooks and scientific survey. In addition, they are the best way of understanding the real 'footprint' of trawl fishing effort by enabling 'reflection' of interpolated trawl effort data off unfished areas

In many respects, scientific data on habitats are a way of ground-truthing industry data at finer scales; historically this has been only of small features at scales of a kilometre or less, but this is now increasingly possible at scales of 10s of kilometres using multibeam acoustics (see following examples). This provides habitat information that, at some level, can be extrapolated over industry's mosaic of fishing grounds.

5.4.2 Integrated data example 1: the "Second Howe Ground"

Scientific mapping by CSIRO took place at this specific location primarily because it had been mapped previously with a low frequency multibeam (swath) instrument by Geoscience Australia (GA) for geological reasons. The goals were to trial and compare a mid-range frequency multibeam instrument, and to ground-truth the acoustically-defined terrain types with video and physical sampling. There was no prior knowledge of how the slope area was used for fishing, only that it was adjacent to the Big Horseshoe Canyon, a renowned fishery area, where some scientific sampling had been conducted on the shelf (Bax and Williams, 1999). As such, this example clearly shows how integrating industry and science data can be used to understand the spatial characteristics of fishery habitat, including its value to fish stocks and fishers.

Fishers' information showed that the mapped area (Fig. 5.4.2.1) is the western section of the "Second Howe Ground" where it meets the Big Horseshoe Canyon in the Eden/ Smithys subregion. Shown here is ~150 sq km of the ground; the remainder extends eastwards as a long narrow terrace. Fishers describe the "Second Howe Ground" as a large upper slope ground of 565 sq km occurring in approximately 275 to 550 m depths, with physically distinct western and eastern boundaries (canyons) and distinctly depth defined inner and outer boundaries. It is characterised by hard ledges among soft muddy sediments, with soft muds 'out wide'; the bottom type was scored as type 3 (sediments with few reef patches), the geomorphology as a mix of flat and sloping with banks (and see Plate 13b), and the substratum as soft mud (30%), sand (30%), gravel (20%), slabby (15%) and heavy low reef (5%).

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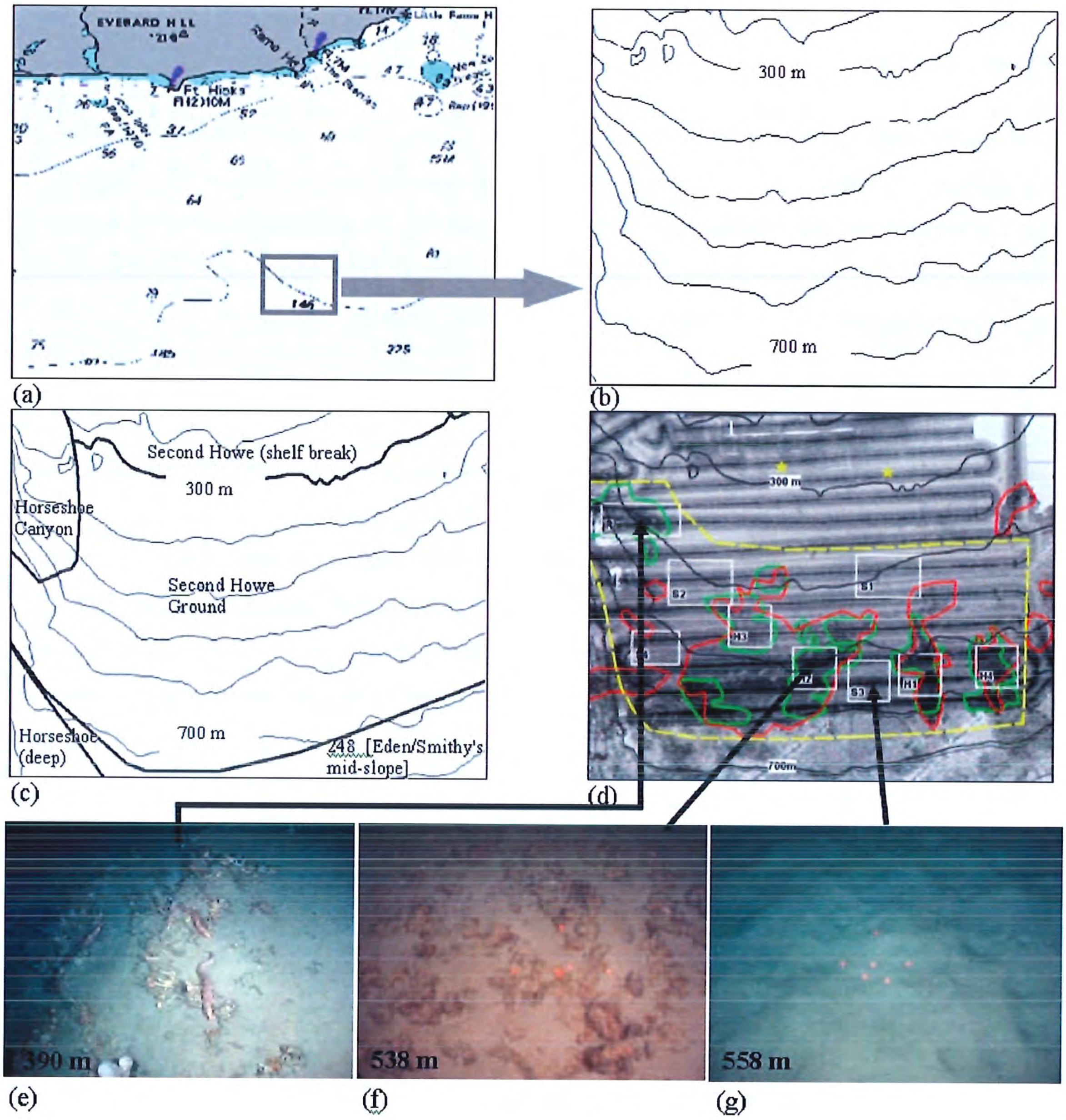

Figure 5.4.2.1 A series of maps and images of the western section of the "Second Howe Ground" at its margin with the "Big Horseshoe" canyon fishing grounds in the Eden/ Smithys fishery subregion showing (a) general location and bathymetry from navigational chart, (b) scientific bathymetry data, (c) ground boundaries and names from fishers' information, (d) multibeam 'swath' map showing acoustic backscatter along 'tram-line' transects; darker shading in patches with red or green boundaries is harder terrain; scientific 'ground-truth' sampling areas are shown as boxes with three example images showing habitat types; (e) pink ling on 'slabby' claystone hard ground, (f) rubble bank, (g) muddy sediments with pits and mounds created by burrowing animals

Only the location, general form and depth range of these grounds was generally known prior to the mapping by GA and CSIRO (Fig. 5.4.2.1a). The mapping by GA provided detailed bathymetry data (Fig. 5.4.2.1b), with fishers' information providing boundaries that differentiated the fishing grounds of the canyon, the adjacent sediment terraces of the upper and mid-slope and the rocky continental shelf on its landward margin (Fig. 5.4.2.1c). A multibeam 'swath' acoustic map made in 2000 (amalgamated data from the GA and CSIRO surveys) shows the location of 'ground-truth' sampling areas and a sample of three images showing habitat types (Fig. 5.4.2.1d).

Video and physical sampling to ground-truth the swath map was targeted at areas that appeared to represent contrasting terrain types ('acoustic facies' based on pulse length, slope, texture and backscatter profile; Kloser et al, 2002a,b). Samples corresponded well with acoustic terrains (Fig. 5.4.2.1e) and showed that sediments are homogeneous calcareous muddy sands that form large unrippled patches at the shallower terrace sites, and irregular (bioturbated) patches at the deeper sites. Rubble and debris of extensively burrowed claystones formed mosaics of numerous, smaller hard patches and ledges interspersed with sediments mainly around the southern perimeter of the terrace. Relatively small patches of sedimentary claystone rock were exposed on steep slopes at the boundary with the canyon.

It can be seen that there is a high degree of agreement between fishers' and scientific descriptions (boundary and bottom type were both given a confidence score of 'high' in the project database, noting that only part of the information had been verified and two contributors were interviewed together so there was no independent corroboration). This shows that fishers' data can be reliable and sufficient to characterise seabed habitat at this scale and resolution. The high level of agreement between the two data sources is important because it suggests that fishers' data can be used to characterise the entire fishery region whereas only small areas can be swath mapped.

While, fishers' data can be used to map and characterize seabed habitats, it is only after industry and science data sets are integrated that it is possible to understand the finer scale distribution and nature of seabed habitats. Fishers' data provides the broadscale context from which we can interpret fine-scale scientific information to provide an overall picture of how the SESSF works as a system supporting fish production and other important values. The value of combining these data sources is discussed below, particularly in relation to pink ling which is further explored in Section 5.4.9.

5.4.3 Integrated data example 2: the "Ling Hole" ground

The "Ling Hole" fishing ground in the Western Tasmania fishery subregion (Fig. 5.4.3.1) is a submarine canyon feature used for trawl, dropline, autolongline, fish trap (and giant crab trap) fishing. The annual trawl 'footprint' increased from 44 to 76 sq km between 1996 and 2001, although effort on the steep shelf edge escarpment may include some midwater trawls, and be 'smeared' from recording of vessel position at the beginning or end of a tow. Trawl effort has not been reflected from the smaller scale 'sub-structure' within grounds; although details of substructure were recorded, bottom type is mapped at the level of entire grounds.

Until earlier this year (2004) general knowledge of this canyon and adjacent areas was known only from depth data (bathymetry) which showed its location, general form and depth range (Fig. 5.4.3.1a). Fishers' information provided boundaries that differentiated the fishing grounds of the canyon, the adjacent sediment terraces of the upper and mid-slope and the rocky continental shelf on its landward margin (Fig. 5.4.3.1b). A multibeam 'swath' acoustic map made in April 2004 shows the strong correspondence of fishing grounds with the bottom types and features (Fig. 5.4.3.1c), while an overlay of logbook data shows 2001 trawl ling catch mapped in 1 km sq grid cells with darker shades representing higher catches (note that low catches in the shallowest areas may be 'smeared' from recording of vessel position at the beginning or end of a tow) (Fig. 5.4.3.1d). The final part of the figure (Fig. 5.4.3.1 e) shows the location of 'ground-truth' video sampling transects and a sample of six images showing habitat types. These correspond well to the bottom terrains indicated in the swath maps, and to the substratum types detailed in non-trawl questionnaire data.

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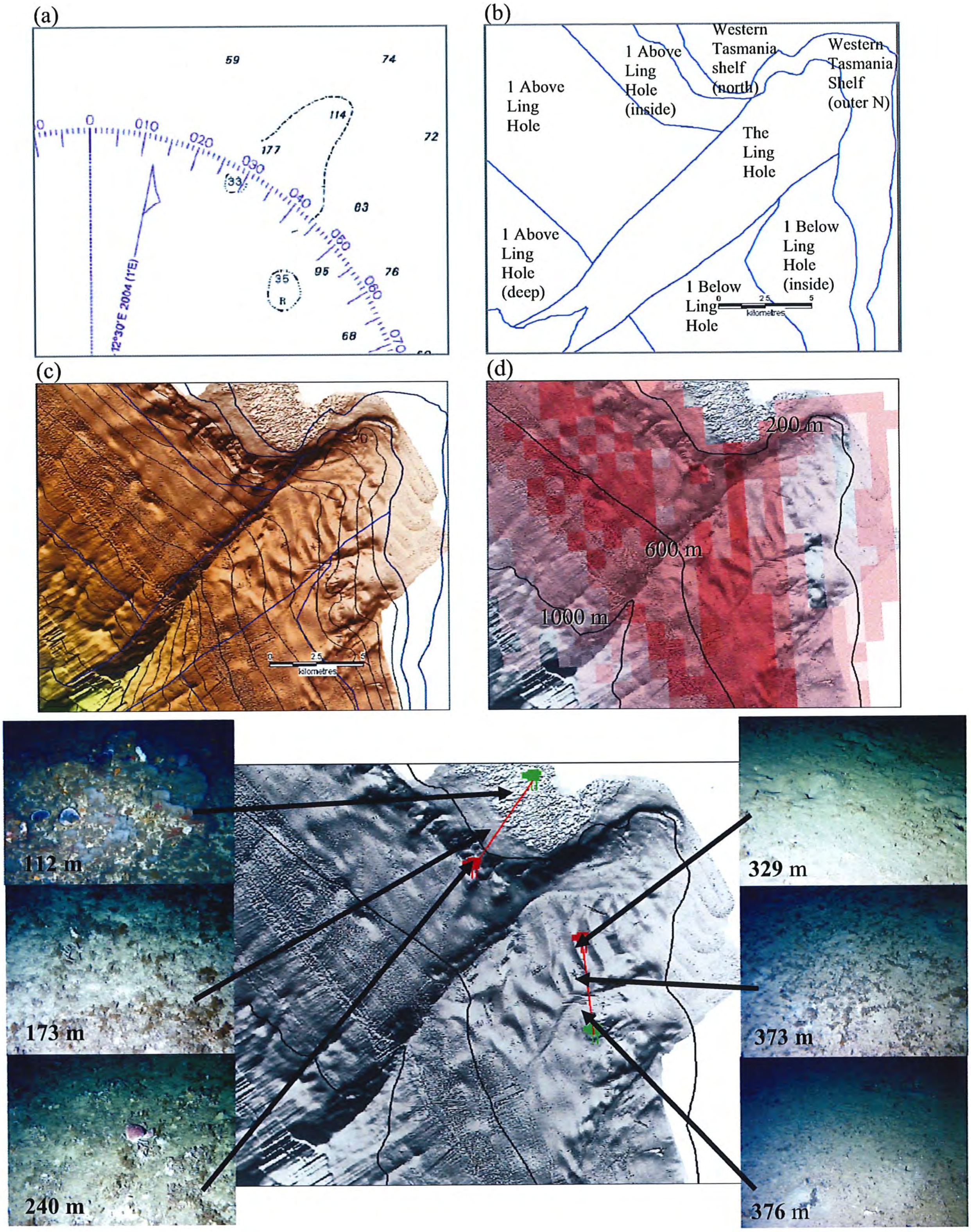

Fig. 5.4.3.1 A series of maps and images of the "Ling Hole" fishing ground in the Western Tasmania fishery subregion showing, (a) general location, (b) ground boundaries and names from fishers' information, (c) a multibeam 'swath' acoustic map showing detailed bathymetry, bottom features and texture, and the strong correspondence of fishing grounds with bottom types and geomorphic features, (d) an overlay of 2001 trawl ling catch from logbook data mapped in 1 km sq grid cells with darker shades representing higher catches (showing effort smear onto shelf), (e) the location of 'ground-truth' video sampling transects and a sample of six images showing habitat types.

No single map in isolation permits the links between habitats and sustainable fishing to be understood. It is their combination – or integration – that enables stakeholders (including fishers, managers, scientists and conservationists) to visualize what the seabed looks like at multiple scales, how it is used, the kinds of issues that will be involved in area-based management (such as relevant locations, suitable sizes and boundary placements), and the possibilities and limitations of area-based management in controlling fishing effort over a complex seascape.

5.4.4 Integrated data example 3: the 'Zeehan' draft candidate MPA

The relationship of integrated map data to the process of defining and managing offshore marine protected areas is illustrated for the 'Zeehan' draft candidate MPA located in the King Island fishery subregion. It is composed of three separate areas off NW Tasmania and King Island, of which the largest area runs from the continental shelf (in approximately 100 m depth) to abyssal depths (greater than 3000 m) (Fig. 5.4.4.1a,b). Illustrated here is the section running across the offshore fishing grounds of the shelf edge and slope (Fig. 5.4.4.1c,d,e).

Specifications for designing the SE MPAs include a requirement that each MPA bounds two complete submarine canyons. Pre-existing scientific bathymetry data provided the basis for estimating canyon positions and indicated that the MPA boundary included one and parts of three others (Fig. 5.4.4.1c). A multibeam bathymetry map (made in April 2004) of the real structure of canyons over the slope region (untextured regions at the deep and shallow margins have no multibeam coverage) (Fig. 5.4.4.1e), shows that four canyons, one large and three small, are bounded by the MPA. Two of the three "canyons" identified from the pre-existing (deepwater and coarse resolution) bathymetry data have negligible presence on the slope. Pre-existing bathymetry data predicted the larger canyons well, but missed or mis-identified smaller canyons that have more impact at slope depths.

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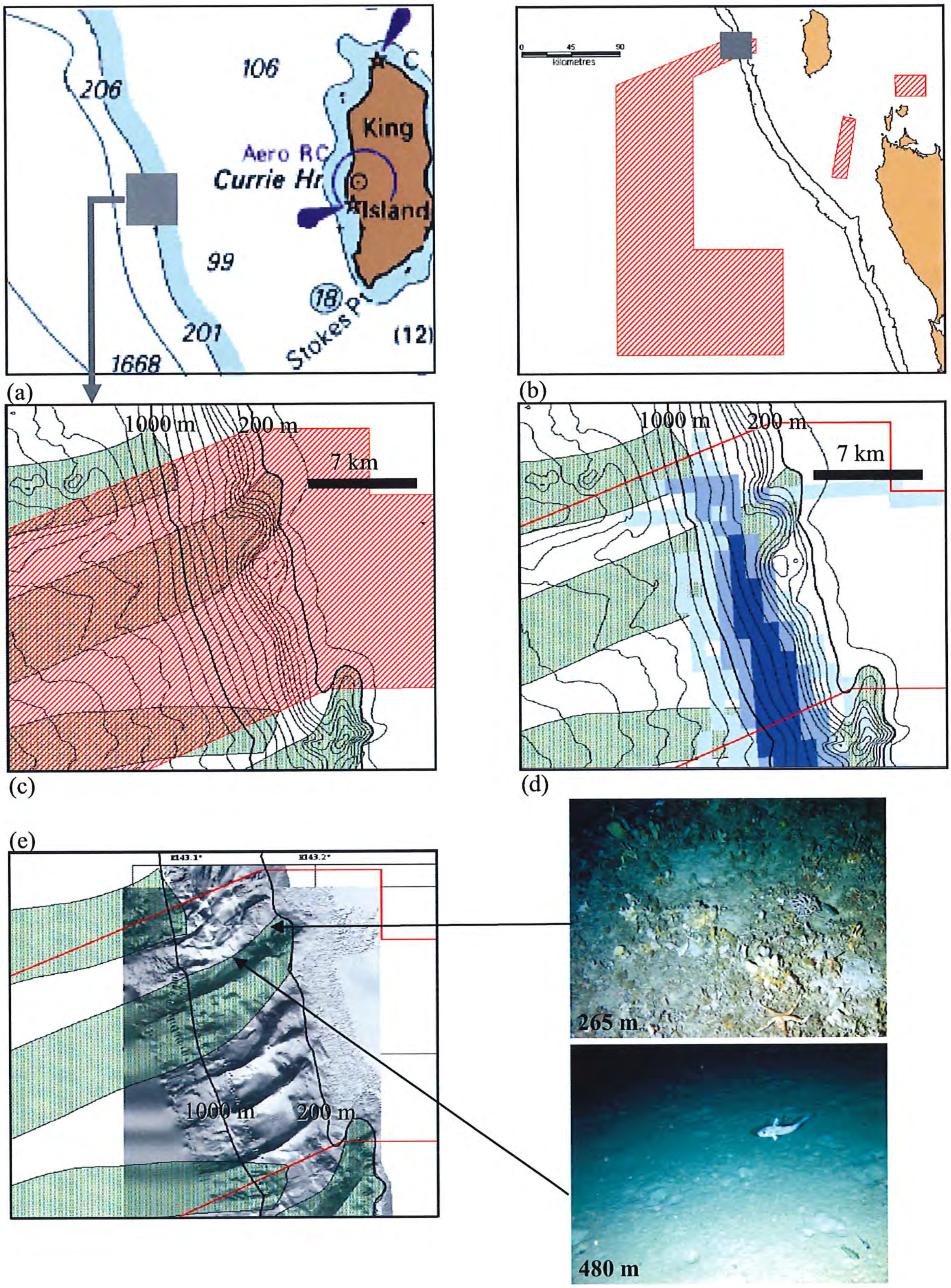

Fig. 5.4.4.1 A series of maps and images of the Zeehan draft candidate MPA in the King Island fishery subregion showing (a) general location and bathymetry from navigational chart, (b) regional location of the three MPA boxes and location of example areas in grey, (c) example area showing scientific bathymetry data, indicative canyon features and boundary of the large offshore MPA box, (d) data from c) with 2001 trawl effort distribution overlaid (> 5 boats, no data reflection); (e) data from c) with multibeam acoustic bathymetry map underlaid showing the actual positions of canyons with two example images showing characteristic habitat types: epifaunal 'turf' of bryozoans, sponges and ascidians, and soft mud sediments

Design specifications for MPAs also require pristine habitat to be a priority over disturbed habitat. An overlay of 2001 trawl effort distribution (> 5 boats, no data reflection) shows the deep upper slope and mid-slope depth zones of the MPA are mostly a trawl area, whereas the untrawled area immediately north lies outside the boundary.

Data supplied by this project through SETFIA and ASIC did identify the shallow upper slope as a region of untrawled heavy reef, and this helped site the MPA over some undisturbed seabed. Photographic validation confirmed the presence of rocky outcrops at the shelf edge and undisturbed habitat types including an epifaunal 'turf' of bryozoans, sponges and ascidians, and soft mud sediments (Fig. 5.4.4.1e). Further information that could be provided by integrated maps and would have bearing on the potential success of this MPA include:

- whether the southern MPA boundary cuts across a trawl ground that continues from further south and, if so, what are the implications for loss of productive fishing grounds and enforcing the boundary?
- whether trawling is restricted to the sediment terraces (clearly visible between canyons) or extends into the canyons?
- what non-trawl effort maps onto this area (the coarse scale of non-trawl logbook data in 2001 does not permit this here)?
- whether the area conserved covers the distribution of any important fishery species, especially resident species or spawning stocks, and therefore whether there is a fishery benefit?

The role of fishers' maps and scientific interpretations in improving selection of spatial management options for the SESSF is discussed further in Section 5.4.8.

5.4.5 Spatial management in the SESSF

A key component of the 'ecosystem based' approach to managing the SESSF is based on the hypothesis that regulating human activities in particular areas is an effective way to provide fishery and biodiversity benefits through protecting key habitats and species. This requires that ecosystems, or areas of habitats that can act as surrogates for ecosystems, are defined as spatial units so that 'managed areas' can be defined in space (and perhaps time) (e.g. Williams and Bax, 2001). These units were termed 'bioregions' in the process to introduce offshore MPAs in the southeast region. Successful management of identified units (meeting conservation needs while not unnecessarily sacrificing economic needs) depends on understanding the roles of particular ecosystems or habitats for biodiversity and fishery productivity (production and availability of fishes) at a variety of spatial and temporal scales. For example, an effective seasonal closure for a spawning stock relies on knowing exactly where and when the stock spawns so that a closure can be effective without unnecessarily impacting on other fishing activities.

The general method of 'bioregionalization' depends on referring to a framework of different scales in which to view bioregions as they are sequentially subdivided into different units representing (usually) smaller identifiable ecosystems or habitat areas. This is exemplified by the process that underpins the development of the southeastern MPA network. Here the framework is termed a hierarchal classification of "habitats" and is effectively used as a proxy for the hierarchy of ecological units and processes that are to be conserved within MPAs.

Broad-scale bioregionalisation of the SE region used available scientific data separately for the SE continental shelf (<200 m depth) (IMCRA 1998) and deeper regions (NOO 2002b). Available information included bathymetry and physical oceanography gathered for the entire region, and archived (museum) data such as taxonomic and geological inventories assembled over decades. Restricted fine-scale data on habitat types and their associated species for an opportunistic and sparse set of locations further informed the process. What was lacking was 'intermediate scale' information that details the distributions of habitats and species at scales of tens to hundreds of kilometres – the range of scales most relevant to use and management of a regional fishery. *This is the scale of information provided by this project.* Previously, intermediate-scale habitat distributions have been mapped for only one SE area – the shelf between Wilsons Promontory and Gabo at the VIC/ NSW border (Bax and Williams 2001; Williams and Bax 2001) – and this relied heavily on information provided by commercial fishers. Scientific data based on single-beam or multi-beam acoustics in conjunction with cameras and physical samplers (Kloser et al. 2002b) are providing increasingly detailed and accurate 'pictures' of seabed habitats and biodiversity at an intermediate scale as illustrated earlier in Section 5.4. However, substantial resources are required before scientific mapping at these intermediate scales can be completed for large areas.

Intermediate scale features in the Wilsons Promontory to Gabo region included the distribution of sediments, biological communities, and size classes of abundant fishes, which were influenced primarily by latitude, hydrology and depth at scale of hundreds of km. At a scale of 1-10 km or less, substratum type, geomorphology and locally modified hydrology influenced habitat use by fish and invertebrate morphotypes (Williams and Bax 2001).

The understanding that habitats (by themselves or as a proxy for ecosystem processes) are ordered in a hierarchy has important implications for management. The hierarchical structure indicates that habitats at any one spatial scale do not exist in isolation, but will be affected by (are nested within) processes at higher levels in the hierarchy and depend on processes at lower levels. Effective management will need to reflect this hierarchical structure. For example, spatial management (MPAs or fishery closures) requires management objectives, performance measures, indicators, reference points and decision rules that take at least one higher spatial scale into account – this will provide context and higher level constraints (eg. overall effort, gear types, TACs) . In addition, at least one lower spatial scale is required to improve monitoring power in a heterogenous seascape.

Managing the spatial hierarchy present in a regional-scale seabed 'seascape', whether for fishery and conservation goals, requires interpreted maps of habitats at scales relevant to management questions. Of high importance to fishery management is what we have termed 'intermediate scale' data – at 10s to 100s of kilometres – because at this scale we can answer the key questions of what is fishery habitat, how much is there, and where is it? To put these scales into perspective, we next look at the spatial scales of southeastern bioregions, how they match management and industry goals, and see where maps of fishing grounds fit in.

5.4.6 Fishing grounds and spatial management

A habitat classification scheme being applied to Regional Marine Planning in Australia recognises habitat units as a series of 'levels'. The highest levels represent habitats at large 'regional' scales, intermediate levels represent habitats at the scale of 'features' or 'terrains', and lower levels represent habitats characterized by bottom type and dominant bottom fauna, and microhabitats characterized by the cracks and crevices used by individual fish. The levels are illustrated for pink ling (Section 5.4.8).

The key to understanding where fishing industry information fits in is to realise that the bioregions defined as planning units for the southeast region are only at higher levels: Level 3 for offshore waters (greater than 200 m) (NOO 2002b), and at Level 2 for shelf waters (less than 200 m) (IMCRA). Finer level habitat distributions, at 'intermediate' or megahabitat-scale, are not used because they are not publicly known for the vast majority of the continental shelf and slope seabed around southeastern Australia. Fishing industry maps represent several of these missing finer-scale levels, and in fact tend to be a mix of Levels 3–6.

Fishing grounds are mostly 'Features' at scales of tens to hundreds of kilometres which correspond to the Biogeomorphic Units of the framework (Level 3). These include plains (made up of clear sediments or sediments with reef patches), large rocky banks (reefs), terraces, canyons and hills (including small seamounts). 'Terrains' describing the general mix of sediments and rocky reefs are Primary Biotopes at Level 4, and 'Bottom types' describing the make up of substratum types are Secondary Biotopes at Level 5. In rare examples, features such as the 'Flower Patch Reef' (where the stalked crinoid Metacrinus cyaneus – Plate 7, image 999) characterises the benthic epifauna) can also correspond to Biological Facies at Level 6.

Interpreted maps of fishing grounds, and their substructure of terrains and bottom types, fit in to regional (fishery) scale habitat mapping and spatial planning by providing information at intermediate scales. The particular value of this information, when collected systematically such as in this project, is that it provides continuous mapping for a region. This enables an overview of fishery habitat for the fishery, -- what they are, where are they, and how much is there of each type – and is illustrated in section 5.4.8 for pink ling.

5.4.7 SESSF habitats: what are they, where are they and how much of each?

Integrated science and industry data enables the types, distributions and quantities of seabed habitats to be estimated at intermediate Levels over the scale of the fishery. The 'what, where and how much' has been detailed for habitat units at the scales of Depth Zones, Features,Terrains and Bottom Types in previous sections for the whole fishery and by fishery subregion (Sections 5.1.9; 5.1.10; 5.1.14). Features and bottom types are illustrated with a set of photographic and multibeam images in Plates 1-13.

However, defining the goals of habitat related management (for fishery health or biodiversity conservation), and assessing the effectiveness of management intervention, also requires an understanding of habitats at the finer scales. Information is needed on the biological component of habitat to estimate biodiversity and to understand how larger attached epifauna such as sponges contribute to providing habitat structure, and on the 'micro' structure (e.g. cracks and crevices) that provide microhabitats in which individual fishes live. In the language of the habitat classification scheme, these are habitats at Level 6 (Biological Facies) and Level 7 (Microhabitats).

Industry-science mapping data provides a unique starting point for estimating the distributions and amounts of fine scale habitats where bottom types provide reliable proxies for the occurrence of biota. In turn, this provides additional insight into what constitutes valuable or rare fishery habitats. A complete analysis of the biological data and the use of proxies is outside the scope of this project; however, the underlying patterns evident in our results are significant to spatial management of fishing effort and valuable fishery habitat.

Habitat forming epifauna have distributions that generally correlate with bottom type and depth, modified by geomorphology (at feature and microhabitat scales) and water currents (Section 5.3.6). Therefore, within their key depth ranges, epifaunal groups that rely on hard and stable attachment sites can be expected to be found on large rocky banks (reefs), subcropping and outcropping bedrock, boulders and rubble, and consolidated coarse (often shelly) sediments. High densities and relatively large individuals may be found on the most stable attachment sites, and because most are filter or suspension feeders, at locations bathed by currents bringing suspended food. Locations of persistent or accelerated currents will include habitats at scales of Depth Zones, notably the shelf, Features, notably canyons and hills, and Microhabitats, notably boulders and the edges of rocky banks. For example, the largest individual sponges were seen on the heavy outer shelf limestone of Gabo Reef (Plate 17, 18, images 115, 338) and the densest stands of stalked crinoids on rock subcrop and claystone slabs at the shelf edge in the Big Horseshoe Canyon (Plate 7, image 999 and Plate 18, image 623).

Many commercial fishes and their prey aggregate at locations where structured physical and epifaunal microhabitats and dynamic water currents (bearing food or to disperse eggs) occur together. In the offshore SESSF, these habitats are the deep shelf and slope Depth Zones where the vast food resources of the deep scattering layers intersect the continental margin; Features such as canyons, scarps and hills and the areas immediately adjacent to them that have complex topography and elevated currents; and rocky Terrains/Bottom types that provide an abundance of structured microhabitats for refuge and feeding. We suggest these factors are the key to understanding what constitute productive fishery habitats, and in conjunction with knowledge of the 'what, where and how much' habitat at the scales presented here, form a sound basis for spatial management planning in the fishery.

Here we provide an overview of the scales of habitats and the factors necessary to analyse the distribution of fishery habitats in the SESSF – both in the context of fishery management and biodiversity conservation goals. Clearly there is considerable potential to drill down into the project data, to evaluate fishing habitats in the context of their dollar value, to incorporate additional data on water currents, and to examine individual grounds. These more detailed analyses are tasks for future projects – the Alternative Management Strategies project in the case of spatial management of fishing effort. However, in the following section we provide a case study with immediate relevance to spatial management planning in the fishery to illustrate the concept of multi-scale habitats, the operational issues, and the role of fishing industry data.

5.4.8 Spatial management of pink ling

Review of the status of SESSF stocks in late-2002, strategic assessment of the SESSF, and changes to effort distribution (especially auto-longlining), has led AFMA to plan for wide-ranging spatial management to supplement the existing management arrangements based on TACs. Arguably the most immediate need for successful spatial planning is an evaluation of management options for the upper slope fishery ecosystem (in 200-700 m depth) because this zone is presently experiencing a rapid expansion of non-trawl effort, mostly from auto-longlining, and a continued expansion of trawl grounds.

Taken together, trawl and non-trawl activities can use all seabed types so there are no longer refuge habitats for most targeted species including pink ling. We have shown in previous sections that trawl fishing effort in the depths where ling are targeted has increased. Non-trawl effort will also have increased, probably more rapidly, although data are lacking. The increasing spatial extent of fishing has three consequences for the fishery: increased effective effort of the fishing fleet will be underestimated; exploitation of new areas may mask the serial depletion of hard bottom habitats where adult ling aggregate; and, increased targeting of harder bottom may degrade the preferred habitats for pink ling and other important (target, byproduct and TEP) species.

Integrated data address these concerns, and this is illustrated by referring to the habitat levels being used for Regional Marine Planning and MPA design (see Section 5.4.5), and describing the relevant habitat features at each level, showing the sources of information and the benefits flowing from using integrated science-industry data. Most reference is to the margin of the "Second Howe Ground" and "Big Horseshoe Canyon" (or "Everard Canyon") illustrated in Fig. 5.4.3.2.

The context to view pink ling habitats in the entire regional fishery is at the provincial scale (level 1: 100s-1000s km). In the deep temperate Australian marine environment, habitat distributions are correlated mostly with depth at these scales (e.g. Williams and Bax 2001) and so the primary substructure is a series of Depth Zones within each province (level 2). Among these is the upper slope (between about 200 and 700 m depths) that is a distinct habitat within the continental slope biome. Its communities include a suite of large demersal (benthic and benthopelagic) fishes, including the pink ling at its peak population abundance. Because the upper slope forms a long sinuous ribbon of seabed off SE Australia – approximately 3,000 km in length but averaging less than 8 km in width – the core habitat of adult pink ling makes up a relatively small area of the SEF area.

Ling habitat at the next level in the classification scheme is illustrated by two important multi-sector pink ling fishing grounds: the "Ling Hole" and the "Second Howe Ground" shown in Figs. 5.4.3.1 and 2. This is habitat at the level of Features ('Geomorphic units'), which in the SEF include plains, terraces, escarpments, canyons and hills at scales of 10s km and larger. Habitats at this scale may correspond to locally distinct ecosystems, e.g. canyons that are defined by topography, locally defined circulation, and which may support enhanced productivity and biological aggregations (e.g. the Big Horseshoe canyon, Bax and Williams, 2001).

Industry and integrated information at this scale can be visualized at the "Ling Hole" (Fig. 5.4.3.1) in parts (b) and (c) respectively. It would take approximately two days to scientifically map this area (without ground-truth sampling), so only a small number of habitats at this scale could be mapped. One effective application of integrated science-industry mapping is for industry delineated priority areas to provide the focal points for scientific mapping. This combination of fishing ground boundaries with targeted scientific mapping provides pragmatic and ecologically meaningful boundaries for managed areas. Managed areas with well-defined boundaries based on recognised grounds or clusters of grounds are more likely to be successful for ecological and enforcement goals than are simplistic or arbitrary 'boxes' that may miss key habitats and cut across working grounds.

Habitats at level 4 are 'Terrains' (1 km-10s km) and can be defined in multibeam maps. Three main types form the western section of the "Second Howe Ground" where it meets the Big Horseshoe Canyon: (1) large areas of homogeneous, rather flat, (~1° slope), soft bottom which makes up the majority of the area (approximately 101 of 150 sq km); (2) smaller interspersed heterogeneous, rather flat (~1° slope), hard areas (several patches making up ~43 of 150 sq km): and (3) the western margin of the terrace which is heterogeneous, steeply sloping (to 15° slope) hard bottom (~6 sq km of 150 sq km).

Terrain is the coarsest level at which to judge the 'value' of habitat types to a fishery by understanding the ways in which different terrains are used by species and by different fishing gears. In the "Second Howe Ground" example area, a total of 85 individual adult pink ling were observed by video during a survey in 2000. Because the great majority were strongly associated with the 'Rough' terrain at the canyon margin it can be inferred that this habitat type has a high importance to pink ling. Understanding how terrains are used can be considerably aided by industry information from different fishing sectors because it is at this scale that experienced fishers know and use parts of the seabed, and their knowledge at this level is the basis for successfully targeting fishing effort at features that aggregate certain species (such as pink ling) in commercial concentrations (Bax and Williams 2001).

Ground-truth sampling of Terrains provides the information to resolve habitat at the next level in the framework -- Bottom Types (level 5; 10s m-1 km). Ground-truthing includes, first, observing the predominant elements of physical substrata and geomorphology and their fine-scale distribution using video, and second identifying the composition of substrata from physical collections.

A mosaic of six Bottom Types identified at the Second Howe Ground (Table 5.4.8.1) corresponded well with Terrains determined before ground-truth sampling was undertaken. Homogeneous flat soft terrain is calcareous muddy sand that forms large unrippled patches at the shallower terrace sites, and irregular (bioturbated) patches at the deeper sites. Mixed flat terrain is rubble and debris of extensively burrowed claystones, mostly composed of gravel/ pebble sized clasts, but some of cobble/ boulder size, that form mosaics of numerous, smaller patches interspersed with sediments mainly around the southern perimeter of the terrace. Hard steep terrain is exposed sedimentary claystone rock that formed relatively small patches of subcrop and outcrop in distinct elongate horizontal ridges interspersed with patches of sediment and rubble/ debris at the boundary with the canyon.

Video data shows that most pink ling are associated with Bottom Types of sedimentary claystones (Table 5.4.8.1); this was confirmed by additional data collected in 2004 when large numbers of ling were observed in the same habitats at adjacent sites.)

Table 5.4.8.1. The association of pink ling with habitats in the western section of the "Second Howe Ground" at its boundary with the "Big Horseshoe Canyon" based on video imagery (data pooled for all sites); N=number of pink ling individuals observed; N%= percentage of individuals. Note: habitat is described at the scale of Bottom Type which is Terrain with ground-truth information on substratum type added.

Substratum	Geomorphology	N	%
Mud	Unrippled	8	9.4
	Highly irregular	2	2.4
Gravel/ pebble	Debris flow/ rubble banks	2	2.4
Cobble/ boulder	Debris flow/ rubble banks	1	1.2
Sedimentary rock (claystones)	Subcrop	58	68.2
	Outcrop (<1 m); with holes/ cracks	14	16.5
Total		85	100.0

Bottom Types represent the minimum resolution level necessary for resolving habitat boundaries and patch structure for monitoring, and therefore mapping, during surveys. High spatial variability ignored at larger scales will obscure changes in habitat resulting from its use, and any restoration resulting from management intervention. For example, clearly delineating claystone-based habitats in a boundary region such as between the western section of the "Second Howe Ground" and the "Big Horseshoe Canyon" is necessary to effectively evaluate the targeted effort of each gear type on pink ling with respect to degradation of habitat (by trawling) and serial depletion (by non-trawl gears).

While Bottom Type is the appropriate scale for monitoring habitat changes, spatial management of habitat would target higher levels (level 4 – Terrains, or level 3 – Features or fishing grounds), where enforcement is practical but fishers would not be unnecessarily excluded from adjacent grounds or important parts of larger fishing grounds.

Ground-truth sampling provides further information that is used to more clearly delineate the interaction between fish and habitat at the level of Biological Facies (Level 6; 1-10s m). Fifteen predominant facies were observed in the "Second Howe Ground" area, of which small encrusting and erect epifauna were the most commonly observed in association with claystone debris/ rubble. Beds of small sponges were also attached to this substratum where it was present on the canyon margin, and to debris/ rubble composed of larger (cobble/ boulder) sized clasts. The facies representing the greatest density of epifauna, the largest-sized individuals, and possibly the greatest biodiversity, were beds of small and large sponges associated with subcropping and outcropping claystone rock at the canyon margin. These were the facies most important to pink ling.

Microhabitats at scales of a metre or less represent the lowest level (Level 7) in the habitat classification scheme. Those observed by video at the boundary of the "Second Howe Ground" and "Big Horseshoe Canyon" are crevices, cracks, edges and ledges associated with rocky outcrops and subcrops, irregular features such as pits and mounds associated with bioturbated sediments, and erect epifauna – mostly sponges – also associated with rocky outcrops and subcrops. The abundance of crevices, cracks edges and ledges results from the combination of high seabed slope (to 15°) that exposes claystone elsewhere buried in sediment on flatter bottom, and the pronounced up-slope dip, or tilt, in the rock that results in the down-slope rock faces being slightly elevated. Video showed these are the structured microhabitats with which high densities of pink ling were associated.

Spatial management in the marine environment is ultimately directed at the biological inhabitants of habitats (level 7), either to conserve biological diversity and local ecosystems, or protect particular species such as pink ling. While it would be impractical to manage or monitor at this fine level, there is a need for at least some surveys at this level because this is the scale at which pink ling distributions vary and at which fishing impacts can be recognised and quantified.

An example is the physical impact on rocky claystone (or 'slabby') bottom when loose pieces are turned and moved when bottom trawls 'hook-up' (Plate 14, images 168 and 182 respectively). This is evidence of vulnerability, where fishing impacts the habitat of the fish being targeted, and is, at least in part, irreversible. But assessing the risk of impact also relies on mapping at Terrain and Bottom Type scales to understand the likelihood of fishing interaction occurring in the first place (Bax and Williams 2001). The key attribute for understanding impact on rocky claystone habitats is that these rock types are sedimentary and therefore friable, forming loose claystone boulders ('slabs'), many of which are only partially embedded in sediments. A reduction in this habitat type has been a necessary historical part of forming trawl grounds to develop the potential of the fishery, but now the key question for the long-term health of the fishery (see Section 5.4.7) is, how much needs to be left in natural condition to sustain the productivity of the species such as pink ling that use it?

Habitat impacts resulting from targeting of hard substrate by trawlers is only one of the outcomes of increased targeting for ling. Intensive targeting of aggregated pink ling populations on rocky habitat by static fishing methods such as longlining and trapping together with the more gradual expansion of trawl effort runs the risk of serially depleting populations of this species. One consequence is that all habitat types on the upper slope used by pink ling are being commercially fished, and many of them with increasing effort. There is no longer any insurance of unfished habitat to guard against excessive effort, incorrect stock assessments, or inadequate management implementation. The combination of targeted trawl and demersal longlining off Southern Africa resulted in severe depletion of kingklip (the closely related *Genypterus capensis*) (Punt and Japp 1994). While it is not known whether the different methods were targeting different habitats, Punt and Japp (1994) reported that reduced trawl catches were attributed by trawl operators to the systematic removal of the aggregated kingklip spawner stock by longline fishing.

The close association of ling with spatially discrete habitat and the intensive targeting of these habitats by fishers indicates that ling populations would be amenable to area-based management.

5.4.9 Spatial management: MPA development

Protection of biodiversity in the Australian marine environment will be implemented partly through a comprehensive, adequate and representative national system of MPAs – a systematic 'CAR' approach. In simple terms this means reserving areas that reflect the biodiversity of particular marine ecosystems (representative), of sufficient size and spatial distribution to ensure their ecological viability (adequate), for the full range of ecosystems (comprehensive). MPA development in the SER has two interactive phases: identifying broad candidate areas based on regionalisations of biological and physical data to differentiate major ecosystems (see Section 5.4.5, and selection of reserve sites from, or within, candidate areas based on human and scientific considerations.

The many guidelines and actions needed to implement the NRSMPA (ANZECC TFMPA 1999) rely on a variety of spatial data to define ecosystems. However, for the offshore seascape, data that are both detailed and wide-ranging are rarely available. Unlike spatial management on the land – which has benefited from numerous datasets available from visual observation of the landscape – similar information is not available for the seascape because it cannot be observed directly (except at the shallowest depths).

Implementation decisions for MPAs will have to be made using the best information available, which in many instances will be limited in time and space, and sometimes based on proxies (ANZECC TFMPA 1999). Fishing industry mapping data, and ideally integrated data as illustrated above, are likely to be the best information in at least two respects. First, it is wide ranging, and, second it provides finer resolution. MPA planning is using habitat information only from Levels 1 to 3 in the classification scheme (Section 5.1.14) whereas industry information mostly relates to habitats at Levels 3 to 5 ('Features', 'Terrains' and 'Bottom Types').

The outcomes for the two draft candidate SE MPA areas identified before this report was written (Murray and Zeehan) show that using data of the type and scale presented by this project would have improved the conservation outcomes for benthic communities with respect to locations and boundary placements. Boundary positions over the slope were finely-tuned around estimated canyon positions that turned out to be a useful, but not accurate, proxy for reality. Boundaries of both MPAs cut across natural habitat 'Features' (canyons and small sediment terraces) that are used for fishing, and are therefore counter-intuitive to fishers working them. Boundaries that dissect recognised fishing grounds are likely to be more difficult to enforce as a result. In the case of Zeehan, the boundary fails to incorporate the upper and mid-slope at the northern margin that is unique in the sense that it is an extensive debris field associated with a large slump scar on the slope escarpment and is not used for trawling.

At present, the finest scale habitat information generally available for the areas bounded by MPAs is at Level 3 – 'Features' that are used as proxies for biodiversity and ecosystems. Fishers' information provides both an estimated inventory of terrain and bottom types, but as importantly, precise locations where scientific ground-truthing can reveal details of biodiversity and ecosystem structure. Only with information at these multiple scales can the ecological value be assessed, and monitoring conducted to evaluate the efficacy of the closures.

5.4.10 Understanding habitat vulnerability

Modification of habitat by fishing activities is being examined by two processes: an Ecological Risk Assessment of the Effects of Fishing project by CSIRO and AFMA, and a Fishery Risk Assessment for southeastern Commonwealth MPAs by the DEH. In both, the risk of impacting seabed habitats is assessed by considering habitat vulnerability based on assessing its susceptibility (resistance) and productivity (resilience) to modification, and by considering the likelihood of habitats being 'encountered' or used by each fishery sector.

The overview of vulnerability provided in the draft of this report has been removed because the outcomes of the two formal processes are now published, see Wayte et al. (2006) and DEH (2005) respectively.

5.4.11 Epilogue (2003 to 2004)

In the two years (2003-2004) since our project data were collected, six observations on the fishery are relevant to our discussion of fishery habitats.

First, visual examination of the trawl effort distribution (all vessels, no reflection from untrawlable bottom) shows effort has continued to expand in every fishery subregion. The depth range of these expansions has not been analysed, but they clearly include all depth zones in various subregions. Most new effort appears to be in the following subregions: Beachport, Coral Coast, SW Tasmania, South Tasmania, and Eden/Smithys.

Second, there has been a rapid increase in auto-longlining. This method targets species including ling, blue eye and ghost cod in a relatively narrow depth range on the upper slope, and has the ability to fish on hard bottom inaccessible to trawls which therefore had provided a refuge habitat for these species. On the upper slope, it is now probable that virtually all habitats are fishable, and that hard bottom habitats are being increasingly fished.

Third, there has been widespread adoption of computing technology to display echosounder data as sophisticated 3-D maps that can be interfaced with the vessels navigation technology. Prospectively, this can considerably enhance the ability of skippers to navigate through habitat features such as canyons and escarpments, and to negotiate habitat terrain such as mixed sediments and reef. Trawls can now be flown between small trawlable areas isolated by unfishable terrain, which would previously have been too risky or uneconomic to fish.

Fourth, larger vessels have entered the fleet. We suggest that this development represents a prospective increase in the range of habitats fished (because larger trawlers can potentially tow harder vulnerable bottom), furthering serial habitat modification, and serial fish depletion (because larger auto-longliners have a greater capacity to fish down resident populations that aggregate on hard, structured bottom).

Fifth, increased fuel costs are likely to affect fishing patterns in a variety of ways – including reducing the frequency of visits to grounds far from port, and reducing the risk of additional costs from gear damage and steaming associated with prospecting new grounds.

Lastly, some voluntary seasonal spatial closures were implemented in 2005 in the SEF region of the SESSF to protect spawning stocks of ling. These include the Ling Hole (see Fig. 5.4.3.1).

5.4.12 Integrated mapping data: summary

The types of seabed maps made by fishers and scientists each contain unique features that are related broadly to scale and resolution. Fishers' maps identify bottom types with limited resolution, but relate these to features at a scale of 10s kilometres or larger with finer scale information in places. Fishers' knowledge is important in providing the means to map large areas of 100s to 1000s of kilometres. Scientists' maps have tended to identify seabed types at relatively high resolution but at relatively small scales of kilometres or less; and, scientists typically lack the resources to map larger areas (although the recent advent of multibeam 'swath' mapping is increasing that capacity. Integrated habitat mapping data combines the unique features of both scales of mapping, and this is illustrated here with examples from the 'Second Howe Ground', the 'Ling Hole', and the largest draft candidate 'Zeehan MPA' (Figs. 5.4.2.1 to 5.4.4.1).

Maps of fishing grounds (as defined in Section 4.3.3) provide boundaries, areas and names for a mosaic of patches across the fishery, mostly at scales of 10s to 100s of kilometres. Each ground is provided with fishers' coarsely resolved habitat information, and importantly with fishers' ecological interpretations (Williams and Bax, 2003 a,b). These features permit a fishery-wide understanding of habitat type and distribution by providing a template on which to overlay more finely resolved data from logbooks and scientific survey. In addition, they are the best way of understanding the real 'footprint' of trawl fishing effort by enabling 'reflection' of interpolated trawl effort data off unfished areas. In many respects, scientific habitat data are a way of ground-truthing industry data at finer scales; historically this has been only of small features at scales of a kilometre or less, but this is now possible at scales of 10s of kilometres using multibeam acoustics (see examples in Sections 5.4.2-4). This provides habitat information that, at particular levels, can be extrapolated over industry's mosaic of fishing grounds providing wider coverage and better resolution than either dataset alone.

No single map in isolation permits the links between habitats and sustainable fishing to be understood. It is their combination – or integration – that enables stakeholders (including fishers, managers, scientists and conservationists) to visualize what the seabed looks like at multiple scales, how it is used, the kinds of issues that will be involved in area-based management (such as relevant locations, suitable sizes and boundary placements), and the possibilities and limitations of area-based management in controlling fishing effort over a complex seascape. They demonstrate particularly how relevant integrated data are to achieving an optimal result from the CAR MPA process.

A key component of the 'ecosystem-based' approach to managing the SESSF is based on the hypothesis that regulating human activities in particular areas is an effective way to provide fishery and biodiversity benefits by protecting key habitats and species. This requires that ecosystems, or areas of habitats that can act as surrogates for ecosystems, are defined as spatial units so that 'managed areas' can be defined in space (and perhaps time) (e.g. Williams and Bax, 2001). These units were termed 'bioregions', in the process to introduce offshore MPAs in the southeast region.

The information available to identify bioregions, particularly in offshore areas, typically includes large scale data, e.g. bathymetry and physical oceanography gathered for an entire region, and archived (museum) data such as taxonomic and geological inventories assembled over decades. There is also some restricted fine-scale data on habitat types and their associated species for an opportunistic and sparse set of locations. But what is often lacking, and was in the SESSF, is 'intermediate scale' information that details the distributions of habitats and species at scales of tens to hundreds of kilometres – the range of scales most relevant to use and management of a regional fishery because it is at this scale we can ask the key questions of, 'what is fishery habitat, how much is there, and where is it'?

A classification framework for understanding habitat is being applied to Regional Marine Planning in Australia, and recognises habitat units as a series of 7 levels. The highest levels represent habitats at large regional scales, intermediate levels represent habitats at the scale of features or terrains, and lower levels represent habitats characterized by bottom type and dominant bottom fauna, and microhabitats characterized by the cracks and crevices used by individual fish.

The key to understanding where fishing industry information fits in is to realise that the bioregions used as the basis for planning in the southeast region were based on only higher levels: Levels1-3 for offshore waters (greater than 200 m) (NOO 2002b), and

Levels1-2 for shelf waters (less than 200 m) (IMCRA). Intermediate scale information was not used because they were not publicly known for the vast majority of the continental shelf and slope seabed around southeastern Australia. Fishing industry maps represent several of these missing finer-scale levels, and in fact tend to be a mix of Levels 3–6.

Fishing grounds are mostly Features at scales of tens to hundreds of kilometres which correspond to the Biogeomorphic Units of the framework (Level 3). These include plains (made up of clear sediments or sediments with reef patches), large rocky banks (reefs), terraces, canyons and hills (including small seamounts). Terrains describing the general mix of sediments and rocky reefs are Primary Biotopes at Level 4, and Bottom types describing the make up of substratum types are Secondary Biotopes at Level 5. In rare examples, features such as the 'Flower Patch Reef' (where the stalked crinoid Metacrinus cyaneus characterises the benthic epifauna occurs; Plate 7, image 999) can also correspond to Biological Facies at Level 6.

Integrated science and industry data enable the types, distributions and quantities of seabed habitats to be estimated at intermediate levels over the scale of the fishery. Habitat has been described and mapped at the scales of Depth Zones, Features,Terrains and Bottom Types in previous sections for the whole fishery and by fishery subregion (Sections 5.1.9; 5.1.10; 5.1.14). Features and bottom types are illustrated with a set of photographic and multibeam images in Plates 1-13.

However, defining the goals of habitat related management (for fishery health or biodiversity conservation), and assessing the effectiveness of management intervention, also requires an understanding of habitats at the finer scales. Information is needed on the biological component of habitat to estimate biodiversity and to understand how larger attached epifauna such as sponges contribute to habitat structure, and on the physical component (e.g. cracks and crevices) that provide microhabitats in which individual fishes live. In the language of the habitat classification scheme, these are habitats at Level 6 (Biological Facies) and Level 7 (Microhabitats).

Industry-science mapping data provide a unique starting point for estimating the distribution and amounts of fine scale habitats where bottom types provide reliable proxies for the occurrence of biota. In turn, this provides additional insight into what constitutes valuable or rare fishery habitats. A complete analysis of the biological data and the use of proxies is outside the scope of this project; however, the underlying patterns evident in our results are significant to spatial management of fishing effort and valuable fishery habitat.

Habitat forming epifauna have distributions that generally correlate with bottom type and depth, modified by geomorphology (at feature and microhabitat scales) and water currents (Section 5.3.6). Therefore, within their key depth ranges, epifaunal groups that rely on hard and stable attachment sites can be expected to be found on large rocky banks (reefs), subcropping and outcropping bedrock, boulders and rubble, and consolidated coarse (often shelly) sediments. High densities and relatively large individuals may be found on the most stable attachment sites, and because most are filter or suspension feeders, at locations bathed by currents bringing suspended food. Locations of persistent or accelerated currents will include habitats at scales of Depth Zones, notably the shelf, Features, notably canyons and hills, and Microhabitats, notably boulders and the edges of rocky banks. For example, the largest individual sponges were seen on the heavy outer shelf limestone of Gabo Reef (Plate 17, 18, images 115, 338) and the densest stands of stalked crinoids on rock subcrop and claystone slabs at the shelf edge in the Big Horseshoe Canyon (Plate 7, image 19842 and Plate 18, image 623).

Many commercial fishes and their prey aggregate at locations where structured physical and epifaunal microhabitats and stronger water currents (to supply food or disperse eggs) occur together. In the offshore SESSF, these habitats are the deep shelf and slope Depth Zones where the vast food resources of the deep scattering layers intersect the continental margin. Features such as canyons, scarps and hills and the areas immediately adjacent to them that have complex topography and elevated currents further accelerate currents and concentrate food. Rocky Terrains/Bottom types provide an abundance of structured microhabitats for refuge and feeding. We suggest these factors are the key to understanding what constitute some of the most productive fishery habitats in the SESSF, and in conjunction with knowledge of the distribution and amount of habitat at the scales presented here, form a sound basis for planning spatial management in the fishery.

Clearly there is considerable potential to drill down into the project data, to evaluate fishing habitats in the context of their dollar value, to incorporate additional data on water currents, and to examine individual grounds. These more detailed analyses are tasks for future projects, but two case studies are provided to illustrate the concept of multi-scale habitats, the operational issues, and the role of fishing industry data. The first relates to spatial management planning in the fishery – spatial management of pink ling (Section 5.4.8) – and the second to MPA development (Section 5.4.9).

Modification of habitat by fishing activities is a key issue to both sustainable fishery development and biodiversity conservation. This is being formally examined in the SESSF through the Ecological Risk Assessment project (Wayte et al., 2004). In that process, the risk of impacting seabed habitats is assessed by first considering habitat vulnerability based on assessing its susceptibility (resistance) and productivity (resilience) to modification, and secondly by considering the likelihood of habitats being used by each fishery sector. Using these criteria, inner shelf sediments with no large attached fauna, or small or encrusting epifauna are least vulnerable, while sediments and boulders supporting large epifauna are most vulnerable. Rocky reef with large epifauna has high resistance but low resilience and is therefore of intermediate vulnerability.

Evaluating risk involves considering the likelihood of habitats of different vulnerability being or used by each fishery sector, as well as the extent of modification and the area of each habitat type in the fishery. This analysis is not presented here, but some aspects have been discussed elsewhere in this report (accessibility in Section 5.3.5 and 'how much' in Section 5.4.7). There is a low likelihood of encounter between bottom trawls and high relief reef, low relief reef with undercuts or raised outcrops, or flows of rocky debris including large boulder, hard rock types such as cemented (indurated) limestones and volcanic igneous rocks, or steep and complex bottom topography. Most habitats are accessible to non-trawl gears, particularly drop line and traps, including many types of heavy reef. However, areas of high water currents may be avoided to reduce the risk of tangling gear around rocky outcrops or under ledges.

Visual examination of the trawl effort distribution (all vessels, no reflection from untrawlable bottom) in the last two years (2003-2004) since our data collection was completed, shows effort has continued to expand in every fishery subregion and all depth zones in some subregions. Most new effort appears to be in the Beachport, Coral Coast, SW Tasmania, South Tasmania, and Eden/Smithys subregions.The capacity to expand into new areas is partly due to the widespread adoption of new 3-D mapping technology (interfaced with the vessels' navigation systems) that enhances the ability of trawlers to navigate through habitat features and terrains – canyons, escarpments; mixed sediments and reef – and partly due to larger vessels that have entered the fleet, both larger trawlers that can tow harder, more vulnerable bottom, and larger auto-longliners that have a greater capacity to fish down resident populations aggregated on hard, structured bottom. Auto-longlining targets species including ling, blue eye and ghost cod in a relatively narrow depth range on the upper slope, and has the ability to fish on hard bottom that previously provided a refuge from trawling for these species. All, or almost all, upper slope habitats can now be fished and hard bottom habitats are being increasingly targeted. We suggest that this development represents an increase in the serial modification of habitat, and has the potential to serially deplete hard-bottom habitat-associated fish populations.

6 DISCUSSION

6.1 The value of habitat to the fishery

The value of habitat to fish is well accepted by fishers and fisheries scientists. Fisheries scientists describe habitat as a place, or set of places, in which fish can find the physical and chemical features needed for life (Orth and White 1993) or "simply the place where an organism lives" (Hudson et al 1992).

For fishers – habitat is where they catch fish. Traditionally the non-trawl sector in the SESSF has targeted relatively small specific areas of structured 'hard bottom' habitats on which they set their gear, and which are associated with higher catch rates; recent increases in autolongline effort has expanded the range of habitats used. The trawl sector targets relatively large flat areas of relatively unstructured 'soft bottom' where they can tow their gear for a period of time (often several hours); areas close to unfishable habitat are targeted because experience has shown trawl fishers that these distinct features aggregate desirable fish species. Thus, trawl CPUE on "sediment with many reef patches" is typically higher than on "sediment with few reef patches" and an order of magnitude higher than on "clear sediment" (Fig. 5.2.10.1).

Structured habitats that aggregate fish are also generally more vulnerable to physical disturbances that result from trawl doors, sweeps, trawl bottom gear, traps and anchors being dragged across them (Sections 5.3.4). These physical disturbances change the physical attributes of the habitat that attracted the desirable fish in the first instance. While this disturbed habitat might be more suitable to some fish species, the most likely change is to a habitat less suited to the targeted fishes. If habitat is disturbed to the point where it becomes less productive, further unmodified habitat is needed to maintain catch rates, resulting in the serial modification of habitat. An additional 4,057 km2 was trawled between 1996 and 2001, an increase of 17%, together with an unknown change in the area used by non-trawl. The 2003 logbook data (not shown) indicate that new habitat continues to be used by both sectors. The rate of increase is not known, but expansion of trawl activity in all subregions (mostly Beachport, Coral Coast, SW Tasmania, South Tasmania, and Eden/Smithys), and the rapid increase in auto-longlining, indicates that it may even have increased. The availability of 3-D maps for navigation based on echosounder data means effort may also be more precisely targeted in structured habitat.

This expanded use of habitats, which will have led to serial habitat modification of at least the vulnerable components, has not resulted in greater catches or catch rates overall, indicating that the modified habitat does not support the same abundance of fish as when it was first opened up. Thus between 1993 (when orange roughy catches were reduced to sustainable levels) and 2002, total SEF catch (quota and non-quota species) has remained essentially flat, while trawl effort increased by over 50 percent (Caton 2003). So in the 10 years since 1993, the trawl fleet has worked 50% longer, and fishes possibly 40% more habitat (if the rate of expansion over the 10 years is similar to that between 1996 and 2001) to produce the same catch. As there is now increasing competition between and within the trawl and non-trawl sectors for the same species in the same habitats (e.g. ling), there seems little prospect of reversing this trend without specific management intervention.

Increasing the area trawled reduces undisturbed habitat, including vulnerable structured habitat types used by fish species, including those of commercial value. This has two adverse effects. First, it removes a localised area of relatively high abundance, forcing fishers to fish harder or to open up new areas in an attempt to maintain catch rates. Second, at some point in time it will reduce the capacity of the SESSF ecosystem to maintain the production of fish species that were associated with the removed or altered habitat.

It is this second undesirable and long-term effect that we are most concerned with here. Unfortunately we know little about it and we cannot distinguish loss of stock production due to simple overfishing from loss due to habitat modification. We will probably only be able to distinguish these two causes of stock decline, as fishing pressure is reduced. If the stocks recover in a period of years we can assume that excess effort was the primary cause; if the recovery takes decades, or longer, then we can assume that habitat modification was responsible for at least part of the decline in stock production.

6.2 The extent of habitat modification in the SEF

Interpretation of fishing ground information developed from fishers' data showed that untrawlable ground makes up 45% of the area of the fishery. Of 516 fishing grounds in the SEF (3 n.m. to 1300 m depth), 381 (74%) were trawlable and of these 364 (96%) had effort recorded between 1996 and 2001. Within the 516 grounds, at least 153 areas were used by non-trawl operators, and in many cases these were the untrawlable grounds or rocky bottom in trawlable grounds. The 364 trawled grounds make up about half the total fishery area (47%). Regularly trawled grounds comprised 35% of the total fishery area, while 12% were trawled in part (usually along one or a few trawl shots), leaving 8% of the trawlable area of the fishery (based on fishing grounds) that has not been trawled.

However, fished grounds are not fished in their entirety and a more accurate picture is obtained by looking at logbook data corrected by reflecting trawl effort out of untrawlable ground. Thus, from logbook data, 48% of the SEF region between the 3nm State boundary and 1300m depth is untrawlable, and 19% of the SEF region (37% of the trawlable area) was trawled in 2001.

The relative degree of disturbance or modification of habitat by the gears used in the offshore fishery – trawls, traps, gillnets droplines and autolonglines – is not known, but scientific evidence and fishing industry opinion in other parts of the world (e.g. Dorsey and Pederson, 1998) indicates trawling is the relatively high impact method. For this reason, and the fact that finely resolved non-trawl data were not available in 2001, we focus here on modification by trawling.

On first inspection, modification of up to 19% of the habitat in the SEF region by trawling, would be unlikely to dramatically affect productivity of stocks dependent on habitat, unless the relationship between habitat modification and stock production is very non-linear. Unfortunately the analysis is not this simple, because all habitat is not equal and different habitats support different fish species, and sometimes different life history stages (or events) of individual species. Trawling will target a particular subset of habitats – clear sediments, sediments with few reef patches and a proportion of the sediment with many reef patches habitats – while avoiding most of the sediment with many reef patches and heavy reef habitat, much of it classified here as untrawlable.

Untrawlable area is concentrated to the west of South Tasmania -- 86% of the total untrawlable area of 68,410 sq km. This is due primarily to very extensive areas of patchy reef ('sediments with many reef patches') on their broad sections of continental shelf. Thus 76% (range 52-86%) of subregions to the west of South Tasmania is untrawlable, while to the east only 15% (range 0-48%) of the subregions is untrawlable; excluding the subregions from Babel to Wollongong leaves subregions that are 95% or more trawlable.

Over the 5-year period between 1996 and 2001, the area trawled in the SEF increased by 4,047 sq km (17%), with increases especially noticeable in the deep shelf (150-200 m) (23%) and upper slope (200-700m)(27%). The largest increases (9-18%) from a subregional perspective were in the west – West Tasmania, Portland, Coral Coast, and SW Tasmania – and Babel. Recent maps of trawl effort show that since 2001, the main increases in trawl effort are in Beachport, Coral Coast, SW Tasmania, South Tasmania and Eden Smithys. There were some declines in area trawled between 1996 and 2001 (17 or the 85 subregion/depth combinations; range -0.3 to -9.7%) with the majority in subregions from South Tasmania to the east.

Effort expanded most in sediment with few reef patches (2,604 sq km), then clear sediment (1,564 sq km) and last sediment with many reef patches (590 sq km). There was no trawl effort recorded on heavy reef.

Effort is concentrated in particular depth zones of particular subregions. More than two-thirds of the shelf break (150-200m) was trawled in 2001 in the following subregions: Eden/Smithys; Eden Bermagui; and Uladulla. More than two-thirds of the upper slope (200-700m) was trawled in 2001 in the following subregions: Portland, West Tasmania, Maria, Eden, Ulladulla and Wollongong (Table 5.2.6.2).

As we stated above, no-one knows the relationship between stock production and undisturbed habitat, but under most scenarios, reductions in undisturbed habitat of more than two-thirds in particular depth zones and subregions, suggests that maintaining the capacity of those areas would depend on the capacity of adjacent subregions to compensate for lost production. If effort starts to shift from subregions where habitat modification is highest to other subregions, where a higher proportion of unmodified habitat remains, then this provides the mechanism for serial habitat modification and the potential for a long-term decline in fisheries production.

6.3 Impacts of habitat modification

The impacts of habitat modification on fisheries production can be determined directly from observing changes in fish numbers and distribution following modification. This was the approach used on Australia's northwest shelf where large areas were closed to trawling in an adaptive management experiment so that the response of the fish populations to habitat recovery could be observed (Sainsbury 1991). A sequence of trawl fisheries from 1959 to 1991 had taken first the higher-valued, long-lived species (lethrinids) associated with sponge and gorgonian-dominated habitat and second, following the decline of these higher valued species, the lesser-valued, shorter-lived species (nemipterids and saurids) associated with mud and sand substrates. Recovery of the habitat-associated lethrinids in the decade following the closure of previously trawled areas that led to recovery of the sponge habitat favoured by these fish, showed that there was a direct relationship between the production of these fish and undisturbed habitat. It is worthwhile to note that there were winners and losers from habitat modification – removal of sponge and gorgonian habitat had left more area available for production of the shorter-lived, less-valued species associated with sand and mud habitats.

A similar adaptive management approach could be used in the SESSF to determine the response of fish populations to habitat recovery, and the ongoing development of a CAR system of MPAs in the southeast may provide an opportunity to do this. However, while in the tropics, results were available after 10 years, it would likely take much longer to detect similar changes in the cooler deeper waters of the SESSF. And with the area trawled increasing by 4% per year between 1996 and 2001 (and possibly higher rates since 2001), while at the same time non-trawl effort increases with the expansion of auto-longline fishing, a decade or two may be too long to wait for answers. Some specific management to reduce the expansion of fishing into increasingly targeted upper slope habitats composed of productive but vulnerable habitat is required now. Any adaptive management would have to be at a sufficiently large scale to provide interim management benefits while including the long-term evaluation of alternative management approaches.

The impact of habitat modification on fisheries production can also be determined indirectly by observing the association of particular species with habitat and inferring that the loss of this habitat is likely to reduce the population fitness. The integration of scientific survey techniques (multibeam swath acoustics and towed videos) with industry maps provides a powerful approach to studying this association and we illustrate this with respect to pink ling, a species for which spatial management is being considered by AFMA.

Pink ling occur in the depths associated with the largest increase in fishing effort (200-700m), and because pink ling are targeted by both trawl and non-trawl fishers on all habitat types, ling now have no refuge from increased fishing effort. Increasing the spatial extent of fishing effort is not taken into account in stock assessments. It seems probable this will have led to underestimating effective fishing effort and underestimating the decline of the stock. In addition, ling-preferred habitat may have been changed to one less-preferred by ling. Fishers maps were used to identify the level 3 habitats 'Features' where ling are found, including the 'Second Howe ground' and the 'Ling Hole'. Multibeam swath mapping showed the distribution of level 4 'Terrains' within these areas, and ling were found closely associated with rough terrain at the canyon margin on the 'Second Howe'. Ground-truth sampling at level 5 'Bottom types' showed ling primarily associated with sedimentary claystones. Within this bottom type, ling were most clearly associated with the level 6 biological facies associated with the densest epifauna, the largest individuals and possible the greatest biodiversity. These were beds of small and large sponges associated with subcropping and outcropping claystone rock at the canyon margin. In fact, even within this biological facies, ling were associated with level 7 microhabitats – crevices, cracks, edges and ledges resulting from the combination of high seabed slope (to 15°) that exposes claystone elsewhere buried in sediment on flatter bottom, and the pronounced up-slope tilt angle or 'dip' in the rock that results in the down-slope rock faces being slightly elevated.

This rock claystone (or slabby) bottom is targeted by fishers, but it is vulnerable to being moved, turned and broken when bottom trawls hook-up as has been observed through towed video (Plate 14, images 168 and 182). The key attribute for understanding trawl impact on rocky claystone habitats is that these rock types are sedimentary and therefore friable, forming loose claystone boulders ('slabs'), many of which are only partially embedded in sediments. A reduction in this habitat type has been a necessary historical part of forming trawl grounds to develop the potential of the fishery, but now the key question for the long-term health of the fishery is, how much needs to be left in natural condition to sustain the productivity of the species such as pink ling that use it? Increased targeting of all habitat types by the combination of trawl and non-trawl methods can only serve to increase the sensitivity of fished stocks to habitat modification. To answer this question will require a targeted field survey using the integrated approach of combining fishers' knowledge with scientific methods.

6.4 Habitat and spatial management

The CAR system of MPAs is designed to protect representative areas of the marine ecosystem presumably so that biodiversity and other ecosystem services are maintained. While they could have some benefits to fishery production, this is not their purpose. In contrast, the spatial management options being discussed by AFMA (and associated experts) are designed to protect or improve existing fisheries production for the SESSF in the face of continually increasing fishing effort in a fishery that already produces an exploitation rate that is five times too high in some areas for maximum fisheries production (Bax and Knuckey 2004).

The objectives of spatial management cannot be achieved by focussing only at the scale appropriate to drawing lines on maps and enforcing those decisions. Spatial management objectives are nested in higher order processes – biodiversity conservation, preservation of ecosystem services, and maintenance of fisheries production – that can only be managed at higher scales. Spatial management by itself is not a panacea, unless the spatial closures cover a sufficiently large fraction of the SESSF to ensure that species in closed areas are self-sustaining, that ecosystem services are independent from external factors, and that fish stocks (and their preferred prey species) can not be fished down to unsustainable levels outside managed areas.

MPAs, fishery spatial management, and habitat exist in a hierarchy, which for the purposes of the SESSF has been defined to consist of 7 levels ranging from level 1 (provincial scale), through intermediate scales (3-5) that represent habitat as features, terrains and bottom types, down to lower levels that represent biological habitats (facies), and microhabitats – cracks, ledges, crevices – used by individual fish (6 and 7). Information available to the MPA process covered levels 1-3; information available from fishers covers levels 3-5; information available from scientific sampling covers levels 4-7. The MPA process suffered from only considering information at levels 1-3. For example, the combination of fishers' information at level 3-4, and scientific information at level 4, illustrates this in the case of the Zeehan MPA. Inadequate definition of fishing activities led to non-pristine areas being selected for the MPA, while adjacent pristine areas were omitted. More recent swath mapping data showed that the initial interpretation of canyon locations from coarser and deeper swath mappings was incorrect, but fortunately this led to more rather than fewer canyons being included in the MPA.

For spatial management to be effective, it must be nested in the hierarchy of scales that habitat exists at. MPAs and other spatial management options that do not cover large proportions of the SESSF will need to be part of a comprehensive management response that controls factors external to the MPA or managed area that would directly influence its success in achieving stated objectives. We doubt that MPAs and spatial management can provide effective management tools if external factors such as increasing fishing effort (increasingly targeted at productive habitat) and effective fishing power (larger vessels with greater capacity for serial habitat modification and depletion) are not addressed.

We will only know if management objectives for MPAs or spatial management are being achieved by monitoring the response of managed habitats (preferably in comparison to 'similar' unmanaged habitats). Robust and efficient monitoring will require knowledge of habitat at levels 5-7 to control for high variability in habitat types and distribution at the scales that influence the behaviour of individual fish. The integrated mapping approach developed in this project has shown one way to address this. The availability of new technologies in Australia to swath map large areas of the seabed will soon provide another.

BENEFITS

There are two main groups of beneficiaries for this project. Primary beneficiaries are the operators and managers of the SESSF. Secondary beneficiaries are at the national level, where we have added to the knowledge base on what is required for effective spatial management.

We have worked extensively with individual operators and their representative organisations to provide a comprehensive map of fishing grounds, habitats and their attributes in the SEF. Industry information was quality controlled through an iterative process with the individual operators, while scientific survey information was used (where possible) to demonstrate the accuracy of fishers' observations (swath bathymetry) and provide visual demonstration of their fishing ground classifications. Confidential industry information is maintained on a secure database, and map products can only be released with the permission of the individual operators who provided the information. The integration of industry and scientific information enables maps of area, fishing effort, habitat type, catches, and dollar values to be produced. These maps were used in a minor way in providing information to fishers' representatives involved in the CAR MPA process, but are presently informing AFMA's planning process for future fishery arrangements. However, the full value of this information base is yet to be taken advantage of. The detailed mapping products now available through this project will hopefully convince future spatial management processes, that proceeding without using the best available data is unlikely to generate the best outcomes for either conserving biodiversity or sustaining fisheries.

The process of gathering the information and maintaining productive dialogue with operators has led to increased appreciation on behalf of both scientists and fishers of what is "habitat" in the SESSF. While many operators need no prompting to recognise the value of habitat to fisheries production, we hope that by collating, interpreting and communicating their knowledge in a scientific approach we will promote a broader appreciation of the potential value to be had by managing habitat use in the SESSF.

Six years ago, we identified habitat as one of the main drivers of fisheries productivity in the SEF (Bax and Williams 1999; FRDC Report 94/040), and initiated a cooperative program with SESSF fishers to map and understand that habitat. We have here built on that earlier project to extend our collaboration with SESSF fishers to map all demersal fishing grounds and habitat in the SEF from the 3nm to 1300m depth (excepting offshore features distant from the mainland or Tasmania). In doing so we have added detailed knowledge on the kinds of fish that are associated with different habitats, what features of different habitats attract them, and how vulnerable those features are to physical disturbance. We have identified the subregions, depth zones, terrains and bottom types that are under most pressure from commercial fishing and suggest interim measures to protect limited and vulnerable habitats on the upper slope used by pink ling and a variety of other species.

This project provides habitat information on levels 3-7 in the habitat classification scheme used in the CAR MPA process. Previously, decisions have been made only on information from levels 1-3. We have shown the inadequacy of this approach from two aspects. First, because habitat exists in a hierarchy it is insufficient to manage at one level without managing external drivers at a higher level. Second, and again because habitat exists in a hierarchy, robust monitoring of performance measures resulting from spatial management at one scale requires detailed knowledge of at least one lower level to control for high spatial variability.

The analyses to date merely scratch the surface of the information collected in this project and it is important to note the enduring significance of projects like this one that have a strong commitment to data collection. Two earlier FRDC projects (Bax and Williams 1999; Bax and Knuckey 2004) have made similarly strong commitments to data collection. The data from these earlier projects has since been used extensively in stock assessments, ecosystem modelling, ecological risk assessment, and most recently the development of strategic options for the SESSF. While limitations on use of the confidential industry data archived in this project may restrict its direct use, we are confident that it will play a similarly large role in the sustainable development of the SESSF. The value of legacy projects such as these that provide extensive data collections (or baseline surveys) for future projects, assessments and management evaluations is insufficiently acknowledged when prioritising research.

FURTHER DEVELOPMENT

In this project we concentrated on the collection of industry knowledge of the seabed terrains and bottom types, value added these data with logbook and scientific data (swath mapping and photographic transects), and archived these data in a secure spatially explicit database that can be accessed for future research and industry development purposes. We have summarized the information in the database and answered some key questions with regard to the distribution of trawl effort between 1996 and 2001, the particular areas, depth zones, terrains and bottom types being targeted, and hypothesized the effects of this expansion on the fish species associated with targeted habitats.

One direct use of the information collected in this project, is an extension of results to inform both industry and the general public of the diversity of habitat types in the SESSF noting the fraction being fished commercially and the larger fraction lying undisturbed. While commercial fishers have fished areas for many years, and formed a picture in their minds of the terrain and bottom types of fished grounds, this is not the same as seeing high-definition videos of the seafloor. The process of scientists and fishers working together to see for the first time the terrains and habitats of fished and unfished grounds contributes to their appreciation of the complexity and vulnerability of seabed habitats and raises their awareness of each other's system view. This can only lead to more productive dialogue and ultimately improved ideas and options for future development of the fishery. We recommend that an extension project be developed using the information from this project to inform industry and the general public. Further video transects from industry vessels using the camera system developed for this purpose should be encouraged.

One way in which data from this project can be used is in stock assessment for the interpretation of catch per unit effort. Catch rates for species such as the blue warehou that are associated with hard bottom will vary depending on how near or how far to hard bottom gear is fished. Maps of bottom type from this project have been discussed in an *ad hoc* manner to assist the interpretation of catch per unit effort data for blue warehou in 2004. We have raised our concerns that the pattern of the fishing fleet extending their fishing grounds to previously unfished habitat with no noticeable increase in catch rate, suggests the serial depletion of fish on productive habitat. This serial depletion will mask a downward trend in the overall stock abundance, leading to non-sustainable fishing practices. We suggest that a formal process be developed to incorporate spatial expansion of effort into the estimates of relative stock abundance from commercial catch data.

The mapping database developed in this project provides an inventory of one of the SESSF's capital assets – benthic habitat. Capital assets do not need to be locked up, but rather used to the benefit of the various ecosystem outputs desired by society. At the same time, habitat as a capital asset is something to be preserved to provide continuing benefits (biodiversity, fish production) for future years and generations. The CAR MPA process has started the process of managing use of some small areas of the SESSF; AFMA is considering how spatial management of fishing effort could enhance long-term stock productivity for the fishery. Further analysis of the data collected in this project, together with an improved understanding of how fish use and move between preferred habitat, would provide a means to determine the benefits of different spatial management options to fisheries production and through the proxy of habitat, biodiversity. As a first step in this direction we have proposed a FRDC project concentrating on the upper slope species – pink ling, blue eye trevalla, ribaldo and gulper shark – species that appear to be associated with distinct depths and habitat types, and in particular habitats that appear to be susceptible to modification from commercial fishing.

The highly structured seabed in the SESSF influences fisheries catches, production and the interpretation of data collected during fishing. We suggest above that habitat distribution should be used in the interpretation of fisheries catch per unit shot data. Habitat, and its discontinuous distribution, will similarly affect the design of scientific studies on the fish stocks. Data from this study should assist the development of future scientific studies in the SESSF.

The westward extent of the data collected in this project was the boundary with the GAB, and the shoreward extent limited to 3 nm beyond the coast. Collection of mapping data for the GAB and to shallower depths would provide similar benefits for other components of the SESSF, but require the cooperation of fishers that fish in the GAB and inside 3 n.m., primarily the rock lobster and inshore non-trawl sectors.

PLANNED OUTCOMES

The planned outcome of this project is that the SESSF fishing industry will pro-actively respond to the challenges presented by AFMA and DEH's policies on sustainable fisheries management. It is planned that this project will provide both the process by which industry developed policies on spatial management, and provide management agencies with the information needed to evaluate industry proposals for spatial management. The aim is to avoid the SESSF industry losing control of this process, and the possibility of inappropriate spatial management measures being imposed.

It was our hope at the start of this project that our interactions with the fishing industry would prompt pro-active measures by the industry to manage their capital asset – habitat – in a fashion that would assist the long-term sustainability of the SESSF. While individual operators and industry representatives have acknowledged the potential benefits of and, in cases, the need to manage productive fishing habitat, the industry as a whole has not embraced this concept. There are many reasons for this, only some of which we can guess at. However, it is clear that the fishing industry in the SESSF is an organisation of individuals with many different objectives. Over the course of this project, operators in the SESSF have had to face many threats to their livelihood – falling quotas, an inadequately-informed CAR MPA process, environmental concerns over the effects of trawling, and increased competition for limited resources from new fishing effort, such as auto-longliners and larger trawlers. Industry has had little opportunity (or resources) in this changing environment to develop a broad industry position on the sustainable use of habitat in the SESSF. However, through this project, we have raised industry awareness of the importance of habitat to fisheries production at the individual and association level. The estimates of a 17% increase in area trawled between 1996 and 2001, together with an unquantified change in non-trawl effort, will hopefully convince more operators of the need to protect this capital asset. It remains to be seen how industry will engage in AFMA's spatial management ideas for the SESSF.

The maps developed by this project will provide the basis for managing the seabed of the SEF. They will document where different habitat occurs and establish industry's role in managing those habitats.

Maps developed in this project had minimal use in the CAR MPA process, although they made a contribution to the design of the main Zeehan candidate MPA that protects some of rocky upper slope seabed that is scare on the west coast of Tasmania. Post-analysis of the Zeehan candidate MPA has illustrated where available map products could have improved placement of the candidate MPA that would have increased the pristine habitat protected and reduced the impact on working fishing grounds.

The database contains extensive information on the location and attributes of fishing grounds including habitats (depth zone, features, terrain, bottom type) and those derived from logbook data (catches, effort, dollar value of catch). Much of this data is also available on a 1 sq km grid. Maps can be produced that summarise some or all of this information at various levels – including by species. The increasing emphasis by AFMA on spatial management of fishing in the SESSF provides an excellent opportunity to use these detailed data to provide outcomes benefiting the fishing industry over the long term. However, if these data (especially confidential data) are to be used, an appropriate process will need to be put in place that protects individual contributor's commercial information and provides industry as a whole that release of their detailed information will not be used to their disadvantage.

The project will reduce the vulnerability of SESSF industry to criticism through demonstrating a pro-active stance on ESD principles, as will as encourage industry's uptake of research outputs. In particular, the project outputs (such as video imagery of a range of fishery seabed habitats) will provide the means for the fishing industry to publicise its pro-active and collaborative stance on habitat and ESD related research.

This project has achieved astonishing support from individual operators who have provided their confidential commercial information to develop maps of seabed habitat in the SESSF. While the project has had its critics within industry, the level of support from individual operators is demonstrated by the fact that we have been able to obtain complete coverage of the SEF from 3nm to 1000m. Operators from the ports of Beachport, Portland, Melbourne, Hobart, Lakes Entrance, Eden, Bermagui, Ulladulla, Wollongong and Sydney contributed their personal electronic trackplotter data and interpreted, corrected and reviewed the resulting map products for their areas. The project has had high visibility at industry meetings, despite the many pressing concerns faced by industry at the present time, and we have been able to present the data in many forums (with the permission of the contributors). This high visibility also led to concerns over whether contributor's data remained confidential. However, the agreements and measures put in place to preserve data confidentiality and security have been strictly observed, and no unauthorised release of industry information has occurred.

The collection of video imagery was delayed by technical problems during the fabrication and testing of the mechanical components of the winch, especially the spooling mechanism. Despite this delay, we ended up with over 50 photographic transects for SEF fishing grounds from a variety of vessel platforms and have an ongoing capacity to film the seabed with a world-class portable camera system. The many plates throughout in this report show the value of photographic records of the seafloor and have been used to illustrate: a variety of fishing grounds off Beachport; 9 substrata types (soft and boggy mud, compact mud, mud boulders, sand, gravel, rubble, slabby boulder, heavy low reef, heavy high reef) from 25 to >1500m; physical impacts of fishing gear; untrawlable bottom; epifaunal communities; and fish sometimes associated with microhabitats, e.g. pink ling with rocky claystone at 400 m depth.

It remains for the fishing industry to determine how they want to use these images (still photographs and videos) to educate colleagues, managers and the general public about the complex environment that fishing operates in, and the actions that they take to promote ecologically sustainable development of this resource. In the further developments, we recommend that a project be initiated to assist the extension of the results of this project to industry, managers and the general public.

CONCLUSION

Science-industry collaboration

The outputs from this project demonstrate a highly successful collaboration between scientists and the fishing industry, and highlight the advantages that come from an active collaboration, as well as the commitment of working skippers to the long-term sustainability of the fishery. Fishing knowledge was contributed primarily by 33 working skippers – most of whom had more than a decade of experience at sea – and contributions were made by individuals from all the major southeastern ports (Beachport to Sydney). Skippers provided their confidential electronic trackplotter data, and worked with the scientists in an iterative fashion to ensure that their data were accurately represented in maps produced for the project. The combined map of over 500 fishing grounds is linked in a spatial database to a variety of information including logbook data, scientific data on habitats, and a habitat classification scheme. The integrated map is superior to either industry or science data in isolation because it combines the strengths of industry knowledge – mapping, naming and repeated sampling of large areas over long periods – with detailed scientific observation of relatively small areas during infrequent surveys using novel samplers such as cameras. In addition, by combining the information from many skippers in a common format, we were able to provide an overview of habitat use at the scale of the entire fishery, which does not depend on individual skippers extrapolating from their own experience.

Habitat in the SEF

Between January 2001 and January 2003, data were collected from contributors in the ports of Beachport, Portland, Melbourne, Hobart, Lakes Entrance, Eden, Bermagui, Ulladulla, Wollongong and Sydney. These data were used to map 452 fishing grounds and an additional 64 areas were added based on published scientific data, unpublished CSIRO data, and data from other fishing sectors. This is the project data set. Non-trawl data covered only ~5% of the SEF and while not useful for synoptic maps did provide detailed information of particular areas. As defined here, fishing grounds are highly variable in size, ranging from 1 sq km to 13,000 sq km, with the size range of non-trawl grounds small relative to that in the project data set. Both ends of the size distribution in both data sets contain a mix of realistic and anomalous cases, and the vast majority of grounds are relatively small; for example, in non-trawl data 85% are smaller than 100 sq km, and 75% of trawl (and other) grounds are less than 200 sq km.

There was enough overlapping coverage (provided by more than one operator for an area) to corroborate a large fraction of the information provided and generate a moderate to high quality data set for bottom types and boundaries over the often complex area of seabed used by the offshore fishery. In areas where validation with swath acoustic was possible, we showed the quality of industry's data could be extremely good.

The overall make-up of the SEF seabed in terms of terrain types (estimated from the project data set) is about half 'sediments with many reef patches', ~30% 'sediments with few reef patches', and ~20% clear sediment. Although there are 45 grounds classified as 'heavy reef', they make up less than 2% of the total area.

Overall, plains of mixed sediment and reef patches comprise virtually all the shelf, which makes up nearly 73% of the study area. Terraces and scarps (escarpments) make up most of the continental slope; the presence of numerous, relatively small features (terraces and scarps) on the upper slope compared to the mid-slope reflects both their importance to the fishery (many developed grounds) and the topographic complexity of that depth zone. Other features – rocky banks, canyons, hills and fans – form relatively small areas and are relatively scarce. Slabby and heavy reef bottom habitats that provide key fishery habitat for several key species are concentrated on the deep shelf and upper slope, while mud boulders are concentrated on the mid-slope. Relatively large areas of slabby bottom and heavy reef occur in the Babel and Eden/Smithys subregions, associated with the massive deep shelf and upper slope escarpments of Bass Canyon.

In the west, the relatively wide continental shelf is a series of massive plains of mixed sediments and rocky reef (mostly terrains of sediments with many reef patches). In contrast, the east has a generally relatively narrow shelf (except off eastern Victoria) with large areas of terrains of clear sediment or sediments with few reef patches, but most of the region's continental shelf rocky banks (between Babel and Wollongong). The west has a broadly similar sized continental slope to the east but differs by having virtually all the area containing hills (although the vast majority are scattered in two large areas of mid-slope in South Tasmania), nearly three times more upper slope terrace, and less than half the upper slope scarp.

Distribution of fishing effort in the SEF

Logbook catch and effort data (resolved to a 1 sq km grid) were overlaid on the map of fishing grounds, reflected off untrawlable ground, and analysed with respect to fishery subregion, major depth zone, seabed terrain type and fishing ground. The area trawled in 2001 is estimated at 26,469 sq km, or about 19% of the SEF fishery region as defined here (3 n.m. to 1,300 m depth contour) or 37% of the trawlable area.

Trawlable grounds are as defined by operators based on their current state of knowledge and equipment. Previously untrawlable ground is likely to be gradually opened up as operators' knowledge increases, especially if there is no limit on fishing power and trawl design. There is a far more untrawlable ground in subregions to the west of Tasmania (76% untrawlable ground; range 52-86%), compared to subregions east of, and including, South Tasmania (15% untrawlable ground; range 0-48%). Of the 68,410 sq km of untrawlable ground in the SEF region, 58,903 (86%) of it is west of South Tasmania. This is due primarily to very extensive areas of patchy reef ('sediments with many reef patches') on the broad sections of continental shelf. Southern Tasmania and all eastern seaboard subregions, with the exclusion of Babel to Wollongong are made up of grounds that are mostly trawlable in some part. The relatively large areas of untrawlable seabed in Babel to Eden/Wollongong are made up by several large rocky banks (reefs) on the shelf (e.g. the "Northeast Babel Reef" and "Gabo Reef") together with extensive rough areas on the upper and mid-slope, much of it associated with tributary canyons that run into the massive Bass Canyon that dominates the geomorphology of eastern Bass Strait.

The method for estimating changes in trawl effort distribution over the period 1996 to 2001 underestimates the spatial extent of fishing because only the size of each annual 'footprint' within a fishery subregion/depth combination could be compared rather than their overlap, and movement of effort between grounds within subregion or depth could not be accounted for. This method estimated a net expansion of 4,057 sq km (or 17%) with an increase in all depth zones except for the shallowest (which is inside 50 m depth and mostly not covered by SEF1 logbooks).

Overall, area trawled increased most in the upper slope depth zone (200-700 m), from 54% of trawlable area in 1996 to 63% in 2001, a 9% increase. Increases were evident in all subregions except Eden/Bermagui (-2%). The largest percentage increases were off the Coral Coast, West Tasmania, SW Tasmania, Maria, and Wollongong (19, 19, 28, 30 and 15%, respectively). The largest increases in area trawled were West Tasmania, SW Tasmania, Eden/Smithys and Wollongong (330, 180, 170 and 130 sq km, respectively).

The other depth zone showing a relatively large increase in percentage of trawlable area trawled was the deep shelf (150-200 m), which increased from 28 to 33% (or 5%) between 1996 and 2001. Increases were mostly in the western seaboard: Beachport, Portland, King Island, West Tasmania and SW Tasmania (79, 19, 15, 27 and 16%, respectively), with Wollongong also showing a 15% increase. The increases were steady off Tasmania over the six year period, but were recent and rapid between 2000 and 2001 in Portland (43%, or 58 sq km) and Beachport (250% or 136 sq km). This change in Portland was accompanied by a smaller scale, but equally rapid increase on the outer mid-shelf (100-150 m) from 10 to 16% of trawlable area trawled between 1996 and 2001. During this period, trawled area declined in the deep shelf zone in the NSW subregions.

The largest decline overall in percentage trawlable area trawled, in the Ulladulla subregion (minus 18%), stemmed mostly from reduced trawled area on the outer mid-shelf (100-150 m) early in this period. Elsewhere, the outer mid-shelf zone experienced expanded effort in several subregions but particularly Babel, Eden/Smithys and Maria. In Babel, the increase was steady over the period: it fluctuated in the relatively massive Eden/Smithy subregion, and the relatively small Maria subregion. With the exception of Portland (63% or 29 sq km), increases on the shallow mid-shelf (100-150 m) were confined to the eastern seaboard with the largest increase off Sydney (76% or 61 sq km), consistent with the dominance of untrawlable patchy reef over most of the continental shelf of the western seaboard.

Patterns were most variable in the deepest zone, the mid-slope (700-1300 m), with several increases and decreases of trawled seabed > 100 sq km. These are thought to reflect changes of effort moving away from targeting orange roughy concentrations towards less targeted fishing for other mid-slope species such as deepwater dories and deepwater dogsharks. The net positive increase over all subregions of 885 sq km (27%) was due to increases on the western seaboard between SW Tasmania and Portland, where steadily expanded effort covered an additional ~760 sq km in 2001 compared to 1996. Declines were in the traditional orange roughy fishery subregions off Beachport, southern and eastern Tasmania, as well as off Eden/Smithys, but the patterns were different and unstable over the six year period.

Serial depletion

The 17% increase in area trawled between 1996 and 2001 would have been expected to lead to higher catches or higher catch per unit effort, unless either overall fish abundance declined, or fish abundance on particular grounds declined once they were opened up.

Catch rates are higher on the most structured bottom type (sediments with many reef patches) than either sediments with few reef patches or clear sediments. These findings are consistent with data showing increased fish density on hard bottom (e.g. pink ling, Williams et al., in press). Collectively, this finding, the expanded use of structured bottom types in some subregions, the anecdotal reports from many fishers of increased targeting of 'hard bottom', and the ability of the fleet to achieve more precise targeting through the rapid adoption of advanced navigational technology, raise the possibility that serial depletion of fishing grounds is occurring. However, the degree of serial depletion occurring from trawl fishing is likely to be considerably lower, at least for species with strong 'hard-bottom' affinities such as ling, than with some non-trawl fishing methods. Ironically, data for these methods – especially autolongline and trap – were not amenable to analysis during this project because they are recorded in logbooks at coarse-scale (half-degree grid cells). Investigating the likelihood of serial depletion, and its possible effect on masking downward trends in CPUE estimates, is an important question for future research.

Habitat used by fishing

Photographs, multibeam acoustic maps and physical samples of the seabed from many different areas and fishing grounds were accumulated during the life of the project. These have enabled the habitat attributes described by fishers and recorded in the questionnaire (what the bottom is 'made of' and 'looks like') to be illustrated and visualized. Images also provide evidence of fishing gear directly modifying the seabed in the form of drag marks, removal of epifauna, dislodged boulders, discarded catch and lost gear.

Images from 'unfishable' areas, mostly reported by trawl fishers as untrawlable, showed these are high relief reef, low rocky features that are undercut or with raised outcrops, and flows of rocky debris including large boulders – predominantly on the continental slope. There is no clear distinction between trawlable and untrawlable seabed, since trawling may be prevented by small, isolated, features in an otherwise trawlable terrain, while comparatively small terraces on an otherwise untrawlable slope can be targeted. Small hard bedrock outcrops in otherwise clear sediment plains or terraces may halt the progress of a trawl (stoppers) and damage or entangle gear, while shelf edge features, especially scarps, may be steep with high relief rocky banks that are not sufficiently flat or large enough to set the gear on. Rock hardness also influences what is trawlable, since gear may be winched off softer rock types without damage to the gear but remain attached to, or be severely damaged by, harder types. Trawl 'access' is also strongly related to gear type: in particular vessel power, features of ground gear including the sizes of bobbins and/or rubber discs, and accurate positioning and mapping technologies. For example, heavy low sedimentary reef may be trawlable in particular directions, or using certain gear configurations including larger and more robust ground gear and with sufficient vessel power, but may also be inaccessible to some trawl types or smaller vessels.

In contrast, most terrains/ bottom types, including many heavy reefs, are accessible to all non-trawl gears. In many, if not most situations, high heavy reef can be fished by, and is targeted by, drop line and traps, and possibly all non-trawl gears. Locations where non-trawl gears could not be used on high heavy reef would be linked more strongly to the risk of water currents moving and tangling gear around rocky outcrops or under ledges, than to the inability of fishers to set gear over such features.

Fishing impacts on habitat

Modification of habitat by fishing activities is a key issue to both sustainable fishery development and biodiversity conservation. This is being formally examined in the SESSF through, respectively, the Ecological Risk Assessment project (Wayte et al., 2004) and a Fishery Risk Assessment for southeastern Commonwealth MPAs by the DEH. In these processes, the risk of impacting seabed habitats is assessed by first considering habitat vulnerability based on assessing its susceptibility (resistance) and productivity (resilience) to modification, and second by considering the likelihood of habitats being used by each fishery sector. Using these criteria, inner shelf sediments with no large attached fauna, or small or encrusting epifauna, are least vulnerable, while sediments and boulders supporting large epifauna are most vulnerable. Rocky reef with large epifauna has high resistance but low resilience and is therefore of intermediate vulnerability.

Evaluating risk involves considering the likelihood of habitats of different vulnerability being used by each fishery sector, as well as the extent of modification and the area of each habitat type in the fishery. For example, there is a low likelihood of encounter between bottom trawls and high relief reef, low relief reef with undercuts or raised outcrops, or flows of rocky debris including large boulder, hard rock types such as cemented (indurated) limestones and volcanic igneous rocks, or steep and complex bottom topography. In contrast, most habitats are accessible to non-trawl gears, particularly drop line and traps, including many types of heavy reef. However, areas of high water currents may be avoided to reduce the risk of tangling gear around rocky outcrops or under ledges.

Understanding how fishing effort can affect fishing through its effect on habitat, requires knowledge of the types of habitat present in the fishery, their amount and distribution. Maps of fishing grounds from commercial fishers' data provide boundaries, areas and names for a mosaic of patches across the fishery, mostly at scales of 10s to 100s of kilometres. Each ground is provided with fishers' coarsely resolved habitat information, and importantly with fishers' ecological interpretations (Williams and Bax, 2003a). These features permit a fishery-wide understanding of habitat type and distribution by providing a template on which to overlay more finely resolved data from logbooks and scientific survey. Scientific habitat data add to, and can be extrapolated over, industry data at finer scales.

Integrated science and industry data enable the types, distributions and quantities of seabed habitats to be estimated at intermediate levels over the scale of the fishery. Habitat has been described and mapped at the scales of Depth Zones, Features, Terrains and Bottom Types for the whole fishery and by fishery subregion. Features and bottom types are illustrated with a set of photographic and multibeam images in Plates 1-13. However, defining the goals of habitat related management (for fishery health or biodiversity conservation), and assessing the effectiveness of management intervention, also requires an understanding of habitats at the finer scales. Information is needed on the biological component of habitat to estimate biodiversity and to understand how larger attached epifauna such as sponges contribute to habitat structure, and on the fine scale physical features (e.g. cracks and crevices) that provide microhabitats in which individual fish live.

Spatial management of fishery habitat

Visual examination of the trawl effort distribution in the last two years (2003-2004) shows trawl effort has continued to expand in every fishery subregion – in some subregions this appears to be above the 17% that we observed between 1996 and 2001. We suspect that this is partly due to improved navigation in structured habitat using enhanced 3-D topographic maps developed from depth sounder data. At the same time, larger trawl and non-trawl vessels that have a greater capacity to fish down resident populations including ling, blue eye and ribaldo in a relatively narrow depth range on the upper slope, have entered the fishery. These vessels have more ability to fish the hard bottom that previously provided a refuge from trawling for these upper slope species. All, or almost all, upper slope habitats can now be fished and hard bottom habitats are being increasingly targeted, especially by non-trawl methods. These two developments represent a potential increase in the serial modification of habitat, and the serial depletion of habitat-associated fish populations, and support the concept of incorporating spatial management options into integrated management planning, e.g. through the Alternative Management Strategies project. Planning will need to consider locations, areal extent, time periods and gears types for the different goals of stock protection and habitat conservation.

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APPENDIX 1 – MOU AND DATA SECURITY

Document 1: CSIRO-Industry SEF mapping project: MOU

Document 2: Annex to MOU with SETFIA and SENTA: internal CSIRO data security for SEF mapping project

CSIRO – Industry SEF mapping project

Memorandum of Understanding [signed separately with each Association]

Memorandum dated: , 2001

BETWEEN [SETFIA/ SENTA]

AND CSIRO Marine Research, Castray Esplanade, Hobart, Tasmania, 7000

The purpose of this Memorandum of Understanding is to set out how CSIRO Marine Research will inform [SETFIA/ SENTA] and individual fishers about results from the project, how [SETFIA/ SENTA] will be incorporated into the project and provide support for it, and how project results will be released to a broader audience.

CSIRO Marine Research shall:

1. Maintain regular communication with [SETFIA/ SENTA] (principally through its Executive Officer), including providing updates on progress of the project for [SETFIA/ SENTA] meetings
2. Include a representative of [SETFIA/ SENTA] on the project Steering Committee, and cover the costs of their representative to attend the meetings
3. In the planning stage of the project, seek advice from key members of [SETFIA/ SENTA], particularly working skippers, on the mapping method and questionnaire used for collecting information
4. Release map outputs in stages, seeking authorization for release as follows:
    - provide **initial** maps to contributing individual fishers to check and to authorize any further release
    - provide **revised** maps based on trawl data to [SETFIA/ SENTA] and the Steering Committee for examination before any further release (the Committee is bound to keep information confidential until its general release is approved through CSIRO and [SETFIA/ SENTA])
    - release **interim** maps more generally (initially to SETMAC/ SENTMAC)
5. Present **composite, interpreted** maps from trawl fishers (and including scientific data) to [SETFIA/ SENTA] at two workshops:
    - a [trawl/ non-trawl] sector workshop towards the middle of 2002
    - a cross-sector (trawl and non-trawl) workshop towards the end of 2002
6. Formally acknowledge industry and CSIRO as the sources of information for maps
7. Provide [SETFIA/ SENTA] with a draft of the project final report for comment

8. Ensure [SETFIA/ SENTA] are fully aware of the final report, its content and presentation prior to its public release
9. Develop a public relations strategy for the project and its outcomes

[SETFIA/ SENTA] shall:

1. Provide public endorsement and support for the project
2. Authorise use of the [SETFIA/ SENTA] logo on project updates, such as those distributed to Association members through SEANET
3. Participate in a cross-sector workshop with [SETFIA/ SENTA], project scientists, fishers and steering committee members and in particular provide a formal contribution addressing the stated project objectives and helping lead discussion on future options for the fishing industry's involvement in the development of management recommendations on habitat issues.*
4. Provide comment on the draft final report and published material for consideration by CSIRO
5. Contribute to developing the public relations strategy

*CSIRO recognizes that the meeting will be most effective if held independently of other Association or management meetings and will undertake to source funds to cover the cost of industry members attendance.

Executed as a Memorandum of Understanding

Signed on behalf of [SETFIA/ SENTA] and CSIRO

Annex to MOU with SETFIA and SENTA:

internal CSIRO data security for SEF mapping project

Purpose

The purpose of this Annex is to set out how CSIRO Marine Research will arrange internal security for fishing industry data during and after the 2-year term of the project. The key issues are to:

- specify how the data will be protected during and after the project, and
- how to protect industry's IP in regard to the contract with FRDC .

Data types

The data types in question are derived from fishing industry information on fishing locations and related observations recorded in track-plotters, in personal logbooks and on paper charts. Data exist in electronic form in GIS maps and database records, and in paper form as a series of maps produced by CSIRO.

Security measures for data

The following security measures are in place:

- every map printed as a paper copy is labeled with a code that records the contributor (by code number not name), the type of map, the area covered, the purpose of the map, and importantly, the copy number (i.e. the number of copies in circulation, usually 1 or 2)
- paper copies are stored at the CSIRO Marine Labs in Hobart in a locked cabinet and locked office
- every paper map copy is registered and tracked in the project database
- firewalls and passwords protect the two existing copies of the electronic data (on the project computer and the backup on the central server, both in the CSIRO Marine Labs in Hobart)
- confidentiality of derived data (maps) is assured by the approval procedures detailed in the MOU

Access to data

Industry has agreed to provide their data on the understanding that access to data is restricted to the project team and that release of data or data products at various levels of resolution is contingent upon approval by data contributors that own the data and/ or approval by the industry associations (SETFIA and SENTA) according to a proforma as laid out in the MOU.

Here we agree formally that:

- during the project, access to data will be strictly limited to the CSIRO members of the FRDC project team (Alan Williams, Nic Bax and Bruce Barker)
- at the end of the project, the contributors and Associations will be formally approached to consider options for storage, management and access to data. We anticipate that these data will be a valuable source of information for industry and researchers well beyond the life of the project.
- the default arrangement will be that the master copy of the industry data is lodged in a secure area of the CSIRO Marine Research 'data warehouse' – but individual contributors and/or the Associations can specify an alternative arrangement. In the CSIRO data warehouse, access to data is available only to individuals with a personalized access code that is provided by the database administrator; access will remain restricted to the project team.
- these data security arrangements are guaranteed by the senior manager of the project team, Dr Keith Sainsbury
- changes to data access arrangements, such as the extension of access rights beyond the project team, requires the written approval of the relevant Association (SETFIA or SENTA) and Dr Sainsbury's authorization; delegation of Dr Sainsbury's authority requires the written approval of the relevant Association (SETFIA or SENTA).
-

IP agreement with FRDC

The brief and unspecific wording in the IP section of the existing contract will be reviewed and reworded, sent to the Associations for comment, then forwarded to FRDC with a formal request to incorporate it into the contract.

Signed on behalf of CSIRO Marine Research

In the present of:

Signature of Witness	Signature of authorized representative
Name of Witness (print)	Name of authorized representative (print)

APPENDIX 2 – QUESTIONNAIRE

Details of fisherman, boat and fishing gear

Name

Fisherman code

Job	Owner/ skipper	☐	from (year)		to
	Skipper	☐	from (year)		to
	Ex-skipper	☐	from (year)		to
	Boat owner	☐	from (year)		to
	Other	☐	from (year)		to
Fishery	Trawl	☐	from (year)		to
	Danish Seine	☐	from (year)		to
	Dropline	☐	from (year)		to
	Bottom longline	☐	from (year)		to
	Mesh net	☐	from (year)		to
	Trap	☐	from (year)		to
	Other	☐	from (year)		to

Home port

Main areas fished

Main target species

Mainly working

on top (<70 fm) ☐

on the shelf (70-80 to 120-140 fm) ☐

over the edge (120-140 fm) ☐

deep (> 150 fm) ☐

deep-deep (>300-320 fm) ☐

How many days to you average at sea per year?

What's the average length of a trip (in days)?

Vessel

Vessel name

Vessel length (m)

Vessel power (HP)

Nozzle fitted

Main sounder

Main plotter

C-plot or computer system?

Net link/ net monitor

Your comments on boat and electronics, e.g. meet demands of the fishery? a good setup? When do you use monitor? Big impact on fishing capability?

General details of fishing gear

Especially mesh sizes, ground gear

1. Areas of the bottom: grounds and features

Area code ☐ **Depth range (fm)** ☐ **Fisherman code** ☐

Area name ☐

Alternative names ☐

General use

☐ Trawl ground
☐ Non-trawl ground
☐ Fished in part: few shots/ little used
☐ Fished in part: detail undisclosed
☐ Untrawlable
☐ Unfished
☐ Unknown

Boundaries

CSIRO comments on boundaries (DD, depth distinct; DI depth indistinct; PD, physical distinct; PI, physical indistinct; A, Arbitrary; P, political; U, unknown)

North ☐
South ☐
East ☐
West ☐

Notes on boundaries:

Boundary confidence level (1-5): ☐

Bottom type

Mapping category

1 ☐ **Heavy reef**
2 ☐ **Reef patches (many)**
3 ☐ **Reef patches (few)**
4 ☐ **Sediments**
5 ☐ **Unknown**

Bottom type confidence (1-5) ☐

What it looks like overall

☐ Flat
☐ Sloping
☐ Steep
☐ Undulating
☐ Rugged
☐ Bank
☐ Valley
☐ Canyon
☐ Hill
☐ Seamount

What its made of (%)

☐ Mud - soft & boggy
☐ Mud - compact
☐ Sand
☐ Gravel (pebbles/shell)
☐ Sandstone (compact)
☐ Rubble/ boulders
☐ Slabby
☐ Mud boulders
☐ Heavy low reef (less than 0.5 fm)
☐ Heavy high reef (more than 0.5 fm)
☐ Unknown

General description

General description of area including features, eg cliffs, pinnacles, and anything unusual ?

APPENDIX 3 – REPORTS TO SPECIAL MEETINGS

Reporting to special meetings showing dates, locations and aim of meetings

Date	Location	Meeting or group
August 3, 2001	Hobart	Project update presented to project Steering Committee
May 7, 2002	Canberra	Project update presented to SETFEAG spatial workshop
February 3, 2003	Canberra	Project update presented to AFMA Board
March 5, 2003	Melbourne	Project update presented to SENTMAC
March 6, 2003	Canberra	Project update presented to SETFEAG meeting
April 4, 2003	Portland	Project update presented to AFMA Board during port tour
June 26, 2003	Hobart	Project update presented to project Steering Committee
July 1, 2003	Hobart	Project update presented to National Oceans Office
July 4, 2003	Canberra	Project update presented to AFMA Environment Manager

APPENDIX 4 – CONFERENCE PAPERS

Paper 1.

INTEGRATING FISHERS' KNOWLEDGE WITH SURVEY DATA TO UNDERSTAND THE STRUCTURE, ECOLOGY AND USE OF A SEASCAPE OFF SOUTHEASTERN AUSTRALIA

Paper 2.

INVOLVING FISHERS' DATA IN IDENTIFYING, SELECTING AND DESIGNING MPAs: AN ILLUSTRATION FROM AUSTRALIA'S SOUTH-EAST REGION

Paper 1
also available at:
http://fisheries.ubc.ca/publications/reports/report11_1.php

Proceedings from the first international conference on 'Putting Fishers' Knowledge to Work'.
UBC Fisheries Centre Research Report

INTEGRATING FISHERS' KNOWLEDGE WITH SURVEY DATA TO UNDERSTAND THE STRUCTURE, ECOLOGY AND USE OF A SEASCAPE OFF SOUTHEASTERN AUSTRALIA

Alan Williams and Nic Bax

ABSTRACT

Australia involves fishers at all stages of the fishery assessment and management process. A key factor in the success of this approach is using fishers' information to supplement and interpret standard fisheries data. From 1994, we collected fishers' information on fishing grounds and habitats as part of a 5-year study of a continental shelf fishery. We met regularly with experienced fishers during port visits, commercial fishing operations at sea and in formal (management) meetings. This pattern of liaison enabled us to build relationships and a level of trust that facilitated a two-way sharing of knowledge. We integrated the ecological knowledge of fishers with scientific survey data to map and understand the seascape (seabed landscape) in a way that would not have been possible from scientific data alone. Fishers provided detailed information on the fishery, navigation, fishing effort distribution, individual species, fish behaviour, productivity, seabed biology, geology, and oceanography. A key result was an interpreted seascape map incorporating geomorphological features and biological facies at a variety of spatial scales of resolution from 10s to 100s of km. Supported by industry, we are now extending the mapping project to the entire shelf and slope of the South East Fishery region. Fishers believe the project provides them with the opportunity for input to developing spatial management under Australia's 'Oceans Policy', and guaranteeing their involvement in a developing program of 'regional marine planning'. However, they also fear that their information will be used against them - especially for closing off valuable fishery areas. We discuss the importance of fishers' knowledge to interpreting scientific data, and the need for an ongoing dialogue between the fishing industry, scientists and managers. Only this ongoing dialogue will ensure that fishers' knowledge is used appropriately and, as

importantly, that fishers' concerns are addressed in developing management options for this area.

INTRODUCTION

Management of the world's oceans has typically been driven by single issues – for example, how many fish to catch, where to discard waste, where to mine, dredge, or drill for oil, and more recently which areas to protect (Allison *et al.* 1998; McNeill, 1994). At its simplest, single-issue management can be achieved with specific and limited information and by ignoring many of the potential interactions with other issues or aspects of the marine environment. However, coincident with our increasing awareness of the ecosystem services provided by the marine environment (Norse, 1993), is an increasing recognition of the limitations of single-issue management (Sainsbury *et al.* , 1997), especially as our use of the oceans continues to increase.

It is no longer sufficient to manage a fishery solely on the basis of the number of fish removed; instead, where and how fishing occurs, and with what impacts, have become equally important questions. To answer these questions requires first that we define the management units we are dealing with (Langton et al. 1995). In particular, and as been the case on the land for centuries, spatial attributes of the marine environment have become increasingly important for effective management. This requires that we understand the ecological patterns at regional and local scales, and integrate over these scales to provide a 'seascape' perspective (Garcia-Charton and Perez-Ruzafa, 1999).

Australia is developing integrated management of its marine resources through *Australia's Oceans Policy,* launched in December 1998. Principal drivers for the policy are: ecosystem-based management; integrated oceans planning and management for multiple use; promoting ecologically sustainable marine-based industries; and managing for uncertainty (Commonwealth of Australia, 1998). It is recognized that real success of the plan will depend on all Australians gaining an appreciation and understanding of both the complexity of the ocean environment, and the interaction of humans within that environment (Sakell, 2001).

The marine environment off southeast Australia is the test case for 'regional marine planning' in Australia as it forms the first of 13 'large marine domains' (LMDs) that will eventually be covered by management plans. While there are some spatial data relevant to fishery management available for this area, in general it is either of low resolution (e.g. the start and end positions of commercial fishing operations from fishery logbook records), or lacks ecological interpretation (e.g. bathymetric and geological maps from geoscience sampling). Until recently, little was known about the spatial organization of habitats (substrata, biota and adjacent water column) or the ways in which the seabed is used as fishing grounds. Seabed habitat in the South East Fishery (SEF) was mapped for the first time as part of a five-year study to interpret the ecological processes contributing to the productivity of the shelf fishery ecosystem – 'the ecosystem project' (Bax and Williams, 1999). The SEF is a complex, multi-species, multi-sector fishery (Tilzey and Rowling, 2001) that operates in a large fraction of the South East LMD adjacent to mainland Australia. The mapped area was ~24,000 sq km of the continental shelf (~25-200 m depths) adjacent to the coastline between Wilsons Promontory in eastern Victoria and Green Cape in southern NSW – the south-eastern point of the Australian continental margin where east and south coasts meet (Bax and Williams, 2001: Fig. 1). In that study, survey data provided the means to determine the structure of the seabed and its association with biological communities and environmental factors at particular scales in space and time (Bax and Williams, 2001; Williams and Bax, 2001). The addition of fishers' ecological knowledge aided the interpretation of those associations, as well as enabling an understanding of the ways in which the seabed is used by the commercial fishing fleet. As it turned out, fishers' information was so useful that we developed a second study – 'the mapping project' – using fishers' information on habitat types and distribution (interpreted through scientific knowledge and ground-truthing) as the primary data source to develop fine-scale maps of the southeast Australian seascape.

In this paper, we first describe how fishers' knowledge contributed to the ecosystem project and explain why this provided a better understanding than a study based on scientific survey data alone. Second, we provide an overview of our methodology for collecting and integrating fishers' knowledge in the follow-up mapping project. Finally, we draw attention to the benefits of combining fishers' ecological knowledge with scientific survey data to provide a seascape perspective of the marine environment, and stress that this combination requires an ongoing dialogue between the fishing industry, scientists and managers. The direct benefit of combining our knowledge in this way is an improved understanding of the seascape. An indirect benefit is that it empowers fishers with the opportunity to be actively involved in developing management options for the marine environment that they are most familiar with.

THE SOUTH EAST FISHERY

The continental shelf and slope off south-eastern Australia is the area of greatest fishing effort within the South East Fishery (SEF) – Australia's largest scalefish fishery, and the most important source of scalefish for domestic markets. Trawling started in the early 1900s, and by 1999 the SEF fleet was made up of 89 operating otter-board trawlers (draggers) and 20 Danish seiners (the 'trawl sector') (Tilzey and Rowling, 2001), as well as a smaller number of demersal longliners, dropliners, mesh-netters and trappers (the 'non-trawl sector'). More than 100 species form the commercial catch of the fishery, but 18 species or closely-related species-groups managed by a system of catch-quotas make up the bulk (> 80%). Annual total allowable catches of individual species range from a few hundred to a few thousand tonnes generating a total value for the fishery of about A$70 million.

OVERVIEW OF THE 'ECOSYSTEM' AND 'MAPPING' PROJECTS

The ecosystem project was designed to consider the ways in which management intervention, beyond the established single-species fisheries management, could have a direct effect on the long-term productivity of this fishery ecosystem (Bax *et al.*, 1999). Production was taken to mean both the production of fish and the factors that determine their availability to the fishery, while our concept of "ecosystem management" was tied strongly to the notion of needing to manage peoples' interactions with ecosystem components (Bax *et al.*, 1999). Engagement with the fishing industry was desirable to understand how fishers viewed the ecosystem, how they interacted with it, and how to best target our limited survey time. Accordingly, we initiated a two-pronged industry liaison program when the project started. Depending on individual skills and experience, members of the project team became involved in formal fishery management and assessment meetings, and/ or spent time in the two big ports in our study area (Eden and Lakes Entrance) and did trips to sea on fishing boats (several trips in the first year, then only 1-2 per year). A particularly useful feature of our sampling program was using industry vessels for specialized fishing. Collectively, these interactions enabled us to establish contact with a range of industry personnel from the working skippers to the association executives. This gained us the support (and data) of individual operators and, in addition, the endorsement of the executive to further develop the project.

We maintained fairly regular contact with a core group of operators and were able to build up a level of trust and dialogue with this core group as the project developed. Our findings were reported back to individuals and the peak industry associations on an ad-hoc basis during the course of the project. So, in summary, our approach to industry involvement evolved naturally during the ecosystem project – importantly, it lacked systematic planning or protocols, and there were no obvious benefits for industry.

The contacts with industry members and associations that we developed during the ecosystem project proved crucial in garnishing support for the second project – the mapping project – that makes extensive use of industry information and has explicit benefits (and risks) for industry. In this partnership project, we are extending the seascape mapping to the entire continental shelf and upper slope (to ~ 1000 m depth) of the SEF region. In contrast to the ecosystem project, the mapping project has a planned methodology for collection, review and release of industry data. However, our approach is necessarily adaptive as the scale and detail of outputs are realized, and as industry responds to a rapidly evolving environmentally-focused fishery management regime. Key elements of the methodology are discussed in the final part of this paper.

VALUE OF FISHERS' KNOWLEDGE FOR NAVIGATING AND MAPPING

When we started the ecosystem project our means of navigating around the fishery seabed was limited to what could be gleaned from third-party, coarse-scale bathymetry data and navigation charts – primarily point-source depth soundings, the approximate positions of key depth contours including the continental shelf edge at ~ 200 m, and the positions of some near-surface rocky banks identified as shipping hazards (Table 1). This information, in combination with some prior survey data and some rapid exploration by echosounding during survey, enabled us to fix a set of transects and sampling sites, stratified by depth and latitude (Bax and Williams, 2001: Fig. 1). These were used for a broad-scale coverage of the area during 4 seasonal trawl surveys – by definition on sediment substrata. But to meet the core aim of the project, which was to understand the importance of habitat to fisheries productivity, we needed both to survey a range of characteristic rocky reef habitats in the study area and understand the spatial context of habitats, e.g. patch sizes, boundary types and distributions.

This is where we really started to benefit from our dialogue with fishers – they told us where to look. At an early stage we were able to build a focused study of habitats into the field surveys to intensively sample at a relatively small number of sites (Bax and Williams, 2001: Fig. 1). This enabled us to understand the ecological roles of particular features, and their often small spatial scales (100s of meters to a few kilometers), for example the use of prominent reef edges by commercially important semi-pelagic, feature-associated species. Fishers' knowledge (Table 1) enabled us to progressively build a spatial framework on which to interpret the range of information we were collecting during our surveys. For example, by providing information on the boundaries of rocky reefs we were able to produce thematic maps of underlying geology (Bax and Williams, 2001: Fig. 3). Over the course of the project we collected sufficient spatial information from fishers to put together what we called our 'fishers map' (Bax and Williams, 2001: Fig. 4). In many ways it is a coarse-scale map of habitats, although its units – fishing grounds – are actually a hybrid mix of geomorphological features such as sediment plains and rocky banks, together with biological facies or biotope types – patches of substratum dominated by one particular community or animal. In summary, fishers contributed unique mapping knowledge, such as ground types, boundaries and names, that enabled us to understand the make-up of the seascape at variety of spatial scales – from small-scale features through to a regional overview

VALUE OF FISHERS' INFORMATION FOR UNDERSTANDING SPECIES' ECOLOGY AND THEIR ENVIRONMENT

Two fundamental differences between observations made by fishers during commercial fishing and by scientists during survey are related to the timing and frequency of sampling - the temporal and spatial resolution (Table 1). While time spent at sea by skippers varies considerably, some average over 200 days per year and sustain this for many years, building on the experience of their parents or other older skippers. In addition to learning where to fish, their mode of operation often includes searching and watching to enable precise target-fishing of fish "marks" seen on echosounders. For example, the first shot of the day is often delayed until the 'feed layer' (or acoustic scattering layer) descends to the bottom – around first light (Prince *et al.*, 1998).

In contrast, our survey samples (a combination of randomly directed and targeted) were fixed on the calendar, but essentially random in time as they took no account of the annual variability in seasonal progression (Bax *et al.* 2001) or of fine-scale patterns of fish movement. Sampling was only regulated (standardized) to either day or night, but not by season, or by considering a site-season interaction. Relative to the high number and frequency of commercial sampling, surveys represent very brief snapshots in time and space. In the year when we sampled most intensively (2 surveys in 1996) we completed less than 100 trawl tows on the continental shelf (< 250 m depth) while the trawl fleet completed over 10,000 – a two orders of magnitude difference in intensity spread widely across the fishery.

What differences in knowledge of species ecology and the fishery ecosystem resulted from these differences in sampling? One of many species examples is illustrated by the morwong (or sea bream), a mainstay quota species on the domestic market. Our survey sampling – including targeted sampling based on prior information from fishers – showed that morwong were associated with limestone reef and sediment substrata, and had high abundance on reef edges. It is primarily a benthic feeder, and presumably moves away from the shelter of reefs to forage on sediments plains. It had a generally higher abundance in the southern part of the study area (consistent with its broad temperate distribution) and was most abundant (in our seasonal trawl samples from sediment plains) in spring and autumn. Catch rates were higher during the day than at night in diel gillnet samples. Local trawl fishers report that movements of morwong are linked to season, depth, habitat type and time of day in a more complex way. Thus, in autumn, they catch this species in the south of the area, but catches are taken progressively shallower and northwards over a period of weeks, during which time it is caught only at night (i.e. it is not available to trawl during the day). Through winter and spring, with a peak in September, morwong move onto the elongate banks of limestone reef to the north where they are caught in what are called the "gutters" between reefs, but now *only during the day.*

Our scientific data show this is not a spawning movement, and while oceanographic data indicate a general correlation between the horizontal movement of fish and opposing seasonal flows of warm and cool currents, the processes that drive the depth-related, substratum-associated and vertical patterns (the latter inferred from variable availability to trawl) remain unexplained. Irrespective, the distinct patterns known to fishers would be very unlikely to be detected by a typical scientific survey or by analysis of logbook data, and this is just one of the many examples for individual species. Information at this fine spatial and temporal resolution, unless provided by fishers, is not available to survey design, for the interpretation of CPUE or other fishery statistics, nor to assist an understanding of individual species' ecology such as habitat utilization.

Although fishers tend not to talk about their knowledge of the fishery "ecosystem", it is the environment in which they conduct the business of catching fish. For example, successful fishers have considerable insights into structures and processes that affect production – the availability of particular species or species-groups, of the right size, and in commercial quantities. In our region, fishers know that production is concentrated at the shelf break and on the upper slope (~150-700 m) particularly around canyon heads. Successful fishing depends on knowing when and where the right combinations of depth, bottom types, currents and good feed marks occur together. There are hot-spots, but they are dynamic over periods of days, weeks or years – for example, with hydrodynamic climate being influenced by daily tide, episodes of upwelling, wind-driven currents, and the moon, as well as 'long-term' seasonal events. Fishers may not be aware of the movement of the eddies of the East Australian

Current onto the shelf, but their observations of how fish catchability changes with 'clean' or 'dirty' water matches the movement of these eddies. The extent to which hot-spots can be detected or predicted is closely linked to the degree of success in fishing over time.

We were able to explain some of the patterns known to fishers by identifying food webs and sources of primary production from analysis of diets, stable isotopes and pigment breakdown products in survey data (Bax and Williams, 1999; Bax *et al.*, 2001). Oceanic production (food) is highly important whereas terrestrial or nearshore inputs are relatively trivial. Commercial shelf fishes– including many traditionally viewed as demersal or 'bottom dwelling'– prey heavily on the animals that form 'feed layers' in the oceanic water column (pelagic prey) as well as those in local sediments (benthic prey) (Bulman *et al.*, 2001). As a consequence, the seabed at the shelf-break is productive because it is bathed with upwelled slope waters containing high levels of nutrients, particulate organic matter oceanic pelagic prey, and particular elements of oceanic micronekton at their near-shore limit of distribution (e.g. lanternfishes) (Bax and Williams, 1999). Fishing is especially productive in the first few hours of daylight, the time at which this feed layer intersects with the bottom. Thus, because fishers and scientists tend to observe the fishery ecosystem at different spatial and temporal scales, their observations are often complementary. Fishers' knowledge may permit scientific observing to be better targeted, and more insightful, while survey data can provide the detail that leads to a more rigorous interpretation of fishers' knowledge.

ROLE OF FISHERS' INFORMATION IN UNDERSTANDING SEASCAPE USE

The ways in which the seascape of this area is being used and impacted by fishing is the subject of developing interest by fishery mangers, environmental and conservation agencies, the general public, and by industry itself. Management of the seabed is being considered more actively, but whereas spatial management (or zoning) is universally accepted on land, it has only recently been considered as an option, or even necessary, in the ocean (Bohnsack, 1996). Spatial management on the land has benefited from numerous datasets available from visual observation of the landscape – in person, from the air, or via satellite. Similar information is not available for the seascape because it cannot be observed directly (except at the shallowest depths). Increasingly, scientific surveys can be used to provide detailed 'pictures' of the seabed with single beam acoustics (Kloser *et al.*, 2001a) or multibeam acoustics (Kloser *et al.*, 2001b), but even the most modern techniques are very time consuming and therefore expensive, especially at shallower depths where the acoustic sampling footprint is comparatively small. Only large-scale undersea features such as upwellings of colder water driven by topographic features or sea level rises over submarine ridges can be observed from satellite. What is needed for spatial management, at anything less than the coarsest scale (bioregion and depth), is an information source of sufficient resolution to detect seabed features at the scale where management is possible (less than 1 km for fisheries where satellite transponders are fitted to vessels). Fishers operate below this level of resolution, and we suggest that their information has the potential to provide information on the seabed at a scale suitable for spatial management.

In the SEF, the distribution of trawl tows has been used as an index of disturbance (Larcombe *et al.*, 2001). However, interpretation of the resulting maps is limited because fishing is highly targeted at specific seabed features that occur at scales less than the typical 3-hour trawl tow. Even unaggregated trawl start (or end) positions are poor representations of tows that are, on average, three hours in duration and therefore up to ~10 nautical miles in length. Analysis based on shot mid-points provides a closer spatial approximation of effort by considering both end-points, but suffers from the introduction of unknown errors because trawl tows do not follow straight lines. They most often follow physical boundaries and may involve several directional changes, for example to navigate through 'broken-ground'; the ~12-nautical mile 'Snake Track' through the Howe-Gabo Reef complex is one aptly-named example. We conclude that logbook data (start and end positions) enable interpretation of effort distribution at the scale of fishing grounds (10s-100s of sq km), but provide limited insights into impacts of seabed use because most significant habitat features occur at a finer spatial scale (10s-1000s of sq m) (Bax and Williams, 2001).

In the SEF, the vulnerability of seabed types to fishing impacts is highly variable. Fishers have shown us that when areas of low-relief limestone slabs are fished, benthic fauna and some of the actual substratum can be removed. On the other hand, high-relief and heavily cemented limestones will never be trawlable and these are regarded as 'natural refuges' by trawl fishers. However, these same 'natural refuges' are often the prime fishing grounds of the non-trawl sector that fishes with static gears such as gillnets, traps, and hook and line. This is a potential source of conflict between industry sectors when spatial management is introduced to the fishery. Habitat features at the scale at which the industry sectors operate will need to be considered if equitable management arrangements are to be introduced, although actual management regulations may operate at a coarser scale. The only feasible way to map the seascape at a resolution similar to that at which fishers operate, is to use the information collected by the fishers themselves. However, this information is sometimes highly confidential, being the commercial advantage that one fisher may have over another. In the following section we describe how we set about accessing this confidential information.

Integration of fishers' knowledge in the mapping project

"Integrating fishing industry knowledge of fishing grounds with scientific data on habitats for informed spatial management and ESD evaluation in the SEF" – the official title of the mapping project – has the explicit aim of incorporating fishers' knowledge of the seascape into strategic management planning. We have broad support from industry because the project is viewed as a mechanism to have industry information considered in decision-making processes for the fishery, and that *informed* decisions will result. However, support is not unanimous and this is due, in large part, to many fishers remaining sceptical that their information will not be used appropriately. Moreover, fishers are not a single cohesive group, and have different views of the system they fish, and short- or long-term approaches to sustainability – based, at least in part, on their level of tenure in the fishery. Some fishers are unwilling to share their commercially confidential information with us. Many fear that their information will be used against them, especially for closing off valuable fishery areas – they are well aware of the link between areas of high fishery productivity and areas of high biodiversity. Our approach to gathering, storing and releasing industry information needed to address these concerns to the extent possible; we needed maximize our support from industry, while also retaining the option to release aggregated industry knowledge to a broad audience in the form of map products.

We argued the benefits of the project aims to individuals and the peak bodies for several years (including through several failed proposals) before we gained support and funding. Our key argument was that the project would provide a tool to help industry respond to the raft of upcoming environmental legislation soon to affect the fishery. Legislation includes spatial management of all marine industries under Australia's Oceans Policy – a developing program of Regional Marine Planning that includes a National Representative System of Marine Protected Areas – as well as fishery specific "strategic environment impact assessments" that aim to support ecological sustainability. With their information systematically collected and rigorously evaluated, fishers would be positioned to critically evaluate proposed spatial management plans, such as the placement of MPAs, and require management agencies to have clearly defined and measurable aims for their proposed management options.

Interestingly, the peak industry bodies supported the project, at least in part, because they saw it as a mechanism for industry to be actively engaged in the process of management planning, rather than just reacting to it. Our hope is that the project, by broadening industry understanding of the seascape they rely on, will encourage proactive thinking and actions from industry to enhance the sustainability of their fishery. In addition, the project provides industry with a tool for improving its public image. Presently, there is discontent and concern about what fishers see as poorly-informed and often misleading media and scientific reporting on interactions between fishing and the environment. This project will provide industry with some hard facts that they can use to demonstrate their real level of impact on the seascape – the trawl sector is particularly keen to be able to demonstrate that large areas of the fishery are untrawlable or untrawled.

The project is structured in a very transparent way to give fishers a high degree of control over the form in which information is released and the timing of various outputs. We have agreed that habitat maps of the area will be released following review by individual contributors and the relevant associations, and that these maps will include summary detail from commercially confidential information. Higher resolution maps of specific areas of interest, showing precisely the trawled and untrawled areas may also be released but these will require the approval of individual fishers.

The key processes and infrastructure of the project include:

- Project staff that are known and trusted by fishers - including consultants who have history and regular contact with the trawl and non-trawl sectors
- Data collection in ports and at sea
- Registration and strictly controlled storage of industry's information
- Rapid data acquisition and map-making by using raw track and mark data from fishing vessel trackplotters in conjuction with a GIS
- Collection of habitat attribute data (including terrain and bottom types, species mix and fishing patterns) using a questionnaire that was developed with industry help
- Verification and validation procedures to ensure data are scientifically rigorous
- Data management (spatial and attribute) and map production facilitated by a custom-designed spatial database
- A step-wise release of map products with clear arrangements for industry review and approval of maps prior to release
- A statement of arrangements and responsibilities of CSIRO and industry set out in a memorandum of understanding
- Field sampling from industry vessels - including photography with a high-tech camera system designed and built as part of the project
- Value adding with scientific survey data (geology/ oceanography/ video)
- Continued involvement of industry through the associations, and
- Involvement of a Steering Committee with cross-sector industry representation

Our approach is adaptive to a degree for two main reasons. First, it is difficult to determine what level of spatial scale and detail is acceptable for map outputs until data are collected and mapped. We have an explicit step-wise protocol for making, reviewing and releasing maps – but this has the flexibility to release maps at various resolutions depending on the specific needs and concerns of ourselves and industry. Secondly, the implementation of the new legislation for this fishery is evolving rapidly: the transition from conceptual to operational objectives may make demands on information that we have not anticipated. For that reason we have developed a comprehensive questionnaire, requiring the repeated involvement of active fishers. The resulting data will be available as new management approaches develop, thus allowing industry to have an input in their development, and managers to access information in a form that best addresses their specific management objectives.

Conclusions

Management for conservation, multiple-use or fishery goals will benefit from collaboration with the fishing industry because fishers know the seascape considerably better than other stakeholders, and they have a broad understanding of the processes that influence fishery productivity. As concisely stated by Neis (1995), "fishers deal regularly with a landscape that no one has seen". In addition, fishers potentially provide the means for cost-effective acquisition of mapping data over large areas, and they have an important stake in ensuring that any spatial management of the seabed is based on reliable information interpreted appropriately. Acquiring reliable data requires a structured, verifiable collection process, and methods to resolve conflicting information.

However, collaboration with industry is not limited to acquiring their data, but requires an ongoing dialogue if the data are to be interpreted judiciously, and industry is to understand the value of any proposed management measures (Neis, 1995). Developing maps of the seabed is one thing, but interpreting them to provide the basis for improved management of the fishery that accounts for the diversity and specialisation of fisher's daily activities is another. This is where the ongoing dialogue between the fishing industry and scientists really begins.

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Table 1 Sources and types of information used to describe the continental shelf seascape in the south-eastern South East Fishery during the 'ecosystem project'

	Project surveys	Fisher's knowledge
Navigation over seabed	Navigational charts, depth contours	Accumulated maps in charts and plotters; names for features
Fishery	Fish species and size composition (quantified seasonal catches– trawl, trap, mesh-net)	Fish species and size composition (unquantified daily catches– trawl, mesh-net)
Fish behaviour (use of grounds)	Seasonal, diel (at times of surveys)	Time scales from days to decades
Fishing effort distribution	Logbooks (aggregated start position data)	Detailed tracks and marks of individual vessels
Productivity	Detailed energy flows at set points in time	Dependability of fishing grounds over decades
Seabed biology	Fish and invertebrate communities (quantified, but few samples from nets, sleds, and photography); detailed species information	Dominant fish and invertebrate types (unquantified, but numerous net catches); local species-mixes or 'taxonomies'
Seabed geology	Rock type and geological history (dredge rocks); sediment classification (grab samples); depth contours (echo soundings from survey track lines)	'Ground-type' classification (gear damage/ wear, by-catch of rocks, mud etc.); depth contours (echo soundings accumulated over years of exploration)
Oceanography	Regional surface currents (SSTs; sea surface height) and local vertical structure (CTDs); bottom currents (sediment modification in photographs)	Local surface and bottom current direction and speed (gear/ vessel behaviour)

Paper 2

INVOLVING FISHERS' DATA IN IDENTIFYING, SELECTING AND DESIGNING MPAs: AN ILLUSTRATION FROM AUSTRALIA'S SOUTH-EAST REGION

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Abstract

Commercial fishers are the most frequent observers and users of many marine environments – especially in offshore regions. They have mapped, named and sampled many features of the continental shelf and slope that the rest of the community is unaware of, and collectively have knowledge for large areas. Scientists use relatively sophisticated equipment and methods for mapping, but usually over relatively small areas because they do not have the resources to do more. Scientific observation using hydroacoustics, cameras and physical samplers can provide fine spatial scale resolution of the environment, while larger scale information is provided by archival data on biota and geology together with remote-sensing. Fishers' information, based on repeated observations over long periods, charts the environment at an *intermediate* level of resolution. At this intermediate level, the types and boundaries of habitats are defined at scales of 10s of km – 'megahabitat-scales' – over large areas of the seabed, and are complementary to scientific data. CSIRO and sectors of the offshore fishing industry are working together to map the seafloor of southeast Australia. Prospectively, information gathered in this way will contribute to understanding representativeness and adequacy at the broad-area identification phase, and MPA selection and design phases during the development of a CAR system of MPAs in the South-east Region currently being undertaken. The data also provide a first means of identifying both the fishery implications of MPAs, and the links between conservation and fishery management goals that are unclearly specified for this region at present. As importantly, the process of involving the fishing industry at all stages of the map development provides them with the information to require that proposed spatial management of their working environment is appropriate and based on sound environmental principles.

KEY WORDS: SOUTH-EAST REGION, CAR, MPA, FISHERS, SEABED MAPPING

Introduction

Australia is developing integrated management of its marine resources through Australia's Oceans Policy, launched in December 1998. Principal drivers for the policy are: ecosystem-based management; integrated oceans planning and management for multiple use; promoting ecologically sustainable marine-based industries; and managing for uncertainty (Commonwealth of Australia, 1998). Implementation of these planning concepts will be through Regional Marine Plans (RMPs) developed by the National Oceans Office (NOO, 2000a). The development of marine protected area (MPA) proposals under the Commonwealth's component of the National Representative System of Marine Protected Areas (NRSMPA) will be developed as part of the regional marine planning process.

The marine environment off southeast Australia, the South-east Region (SER), is the test case for regional marine planning in Australia – it forms the first of 13 'large marine domains' that will eventually be covered by management plans. Details of the draft operational criteria and process for identifying and selecting a representative, comprehensive and adequate system of MPAs in the SER were released in July 2002.

Commercial fishers are key stakeholders in the SER. Offshore, the largest geographical overlap is with the South East Fishery (SEF) – a complex, multi-species, multi-sector fishery that operates on the continental shelf and slope adjacent to mainland Australia, and on some offshore seamounts and rises (Tilzey and Rowling, 2001). It is Australia's largest scalefish fishery, and the most important source of scalefish for domestic markets.

There are many reasons for involving fishers in the process of identifying, selecting and designing MPAs (Baelde et al. 2001). Most obvious is that MPAs are likely to affect fishers' access to fishing grounds, and, as a single stakeholder group, commercial fishers are often most affected by MPAs (Hall, 1999). However, commercial fishers' are also usually the most informed about the broad structure and condition of the marine environment – they are out there fishing most days of the year – and have the potential to substantially improve the process of MPA selection. The aim of this paper is to examine this second aspect of fishers' involvement in MPA development: the relevance, and prospective contribution, of their data and knowledge to the CAR process of identifying and selecting candidate areas. We start by providing an overview of the process, the data needs and data availability for MPA development in the SER, and illustrate this with reference to one area – the Twofold Shelf bioregion (see also the companion paper, Bax and Williams, this issue). We then show at what level fisher's data can enhance this process, and finish by detailing how we are working with fishers to collate their data and provide them with the capacity to actively participate in MPA design in Australia's 'South east Region'.

MPA development in the SER: ecosystem units

Protection of biodiversity in the Australian marine environment will be implemented partly through a comprehensive, adequate and representative national system of MPAs – a systematic 'CAR' approach. In simple terms this means reserving areas that reflect the biodiversity of particular marine ecosystems (representative), of sufficient size and spatial distribution to ensure their ecological viability (adequate), for the full range of ecosystems (comprehensive). MPA development in the SER has two interactive phases: identifying broad candidate areas based on regionalisations of biological and physical data to differentiate major ecosystems, and selection of reserve sites from, or within, candidate areas based on human and scientific considerations.

The many guidelines and actions needed to implement the NRSMPA (ANZECC TFMPA, 1999) rely on a variety of spatial data to define ecosystems. However, for the offshore seascape, data that are both detailed and wide-ranging are rarely available. Unlike spatial management on the land – which has benefited from numerous datasets available from visual observation of the landscape – similar information is not available for the seascape because it cannot be observed directly (except at the shallowest depths).
Implementation decisions for MPAs will be have to be made using the best information available, which in many instances will be limited in time and space and sometimes based on surrogates (ANZECC TFMPA, 1999). The available information for identifying bioregions and smaller-scale spatial units is usually a combination of broad-scale datasets, such as bathymetry and physical oceanography gathered for the entire region, archival (museum) data such as taxonomic and geological inventories assembled over decades, together with fine-scale data on habitat types and their associated species for a selection of (usually) isolated locations.

Intermediate-scale data that provide habitat and biological community distributions at scales of 10s of km within bioregions are not available for most areas of the Australian shelf or slope. Techniques for using surrogate variables to reliably predict the distributions of habitats and components of biodiversity at intermediate scales based are under active development (Kloser et al. 2001b). These methods are typically based on single-beam or multi-beam acoustics in conjunction with cameras and physical samplers (Kloser et al., 2001a, b, respectively) and are providing increasingly detailed and accurate 'pictures' of seabed habitats and biodiversity. However, substantial resources are required before scientific mapping at intermediate scales can be extrapolated over large areas.

Bioregionalisations have been completed for the SER continental shelf (< 200 m depth) (IMCRA, 1998) and deeper regions (NOO, 2002b). However, intermediate scale habitat distributions have only been mapped for one area – the Twofold Shelf bioregion (Bax and Williams, 2001; Williams and Bax, 2001). In this area, at least six distinct biological communities were identified on the shelf alone.

MPA development in the SER: spatial framework and habitat classification

The multi-scale structures and functions of (marine) ecosystems (e.g. Langton et al. 1995, Garcia-Charton and Perez-Ruzafa 1999, Roff and Taylor 2000) necessitate that a classification scheme for habitats and a spatial framework of habitat or biological community distributions be developed, before spatial management of resource use can be implemented . This is exemplified by the process of bioregionalisation that underpins the development of a network of MPAs, where large areas are sequentially subdivided into units that represent either identifiable ecosystems or areas that are amenable to management (both usually at large spatial scales).

A hierarchal classification of "habitats" is effectively used as a surrogate for the hierarchy of ecological units and processes that are the subject of MPA development. The scheme applied to the SER recognises a series of nested, pseudo-spatial 'Levels' for the structure of habitats, each reflecting the influence of characteristics and processes acting at different scales (Table 1). It is under development (mainly by V. Lyne and P. Last of CSIRO Marine Research) but is presented with illustrations, and examples from the Twofold Shelf bioregion, in Kloser et al. (2001b). The bioregionalisation for the offshore regions of the SER (> 200 m) differentiates bioregions at Level 3, i.e. as a set of biogeomorphological units (Table 1) (NOO, 2002b).

Because different natural systems are not delineated at spatial scales that are either clearly defined or repeated, the boundaries between levels are rarely sharp or unequivocal (Allen and Starr, 1982). Hence, the scheme of Lyne and Last (Table 1) is pseudo-spatial: ecosystems defined at one level may not all be at the same spatial scale, while ecosystems at one level may not be 'smaller' than others at the next higher level. Nevertheless, in most systems there are discontinuities that can be recognised, and these have allowed the development of a number of classification schemes for different purposes. A useful example for classifying deep seabed habitat is Greene et al. (1999). These authors (e.g. Greene, pers. comm.) are not wedded to the fine details; what they stress is the importance of the hierarchical view, and the need for an agreed classification scheme as a working language for their particular purposes.

An illustration for the SER is provided by (Bax and Williams, this issue) from a study of the continental shelf portion (25-200 m depth) of the Twofold Shelf Bioregion (IMCRA, 1998). Several ecosystem features in that region including the distribution of sediments, biological communities, and size classes of abundant fishes, were influenced primarily by latitude, hydrology and depth at 'provincial' scales (sensu Greene et al., 1999) of 100s of km. At a finer scale, biological patterns were due to substratum type, geomorphology and locally modified hydrology at 'megahabitat' scales of a km to 10s of km, or less (Williams and Bax, 2001). Ideally then, the development of MPAs in a marine system would have management objectives, performance measures, indicators, reference points and decision rules that take all spatial scales into account, even if the MPAs will only operate at one particular scale in the hierarchy.

What are fishers' data and how are they relevant to MPA development?

Habitat distributions at megahabitat-scale are not known for the vast majority of the continental shelf and slope seabed around southeastern Australia. Information at this scale is available for the Twofold Shelf region because habitat distributions were mapped and sampled in several surveys over five years (Bax and Williams, 2001). A vital component of that mapping process was to integrate fishers' spatial information on habitat distribution with survey data (Williams and Bax, in press).

Habitat mapping in this way was an iterative process over the life of the study. At the project's commencement, navigation around the bioregion was based on third-party, coarse-scale bathymetry data and navigation charts – primarily point-source depth soundings, the approximate positions of key depth contours including the continental shelf edge at ~ 200 m, and the positions of some near-surface rocky banks identified as shipping hazards. This information was used in combination with limited existing survey data, and some rapid exploration by echo-sounding during surveys, to fix a set of transects and sampling sites, stratified by depth and latitude, for trawl surveys (Bax and Williams, 2001: Fig. 1). These sites provided broad-scale information across the Twofold Shelf, but only for soft-sediment substrata. It was dialogue with knowledgeable local fishers that enabled targeted sampling of consolidated substrata, mostly rocky reefs, to be progressively built into the field surveys. What evolved at the end of the study was an intermediate-scale map of habitats – the 'fisher map' – a hybrid mix of fisher-delineated geomorphological features at scales of 10s to 100s of km (such as sediment plains and rocky banks), ground-truthed with physical samples and photographs from surveys that identified biological facies – patches of substratum and their dominant faunal elements or characteristic community types at scales of metres. The map is reproduced at coarse resolution in Fig. 1, with a zoom view and detail for selected areas in Fig. 2.

Against the hierarchical classification framework being used for the SER (Table 1), the 'fisher map' can be clearly seen to be operating over several of the finer-scale levels, and in fact to be a hybrid of Levels 3-6. Geomorphological features at scales of 10s to 100s of km, such as sediment plains and rocky banks, (Level 3), and details of their primary substrata and biota (Level 4) were mostly defined by fishers (Fig. 1). Ground-truth physical samples and photographs from survey identified secondary biotopes (Level 5), and biological facies (Level 6) (Fig. 2).

A closer look at the nature of fishers' data

Fishers' data – maps and names

Fishers have names for large numbers of a great variety of seabed features at a range of spatial scales, including small scales (10s of meters to a few kilometers). These enable navigation around the spatial framework: visualizing and interpreting patterns in data at a variety of spatial scales and providing a common language for discussing system properties. In contrast, scientists are usually restricted to navigating by a limited range of names from navigational charts – mostly coastal features such as headlands or towns, near-surface rocky reefs identified as shipping hazards, and major features of seabed topography such as the shelf edge and offshore platforms – these may have little to do with the spatial units that describe biological communities. Occasionally, the better-known names given by fishers to features visible only on echosounders are also included in scientists' vocabulary. One example for the SER is the naming of seamounts in a survey (Koslow et al., 1999) that led to the establishment of the Tasmanian Seamounts Reserve. The 'fisher map' exemplifies this for the

Twofold Shelf bioregion: 33 names for major seabed features (megahabitats) can be attributed to fishers while only three (two near-shore reefs and one shipping hazard) are found on navigation charts of the area). At a finer scale, fishers also give names to individual habitat patches or geomorphological features such as rocky reefs and the 'gutters' between them.

Fishers' data – physical sampling

Fundamental differences between observations made by fishers during commercial fishing and by scientists during survey are related to the timing, frequency and coverage of sampling (Williams and Bax, in press). In offshore regions, fishers sample frequently, often targeting particular topographical features, current regimes, or periods of day and night. As a result they gain good, although unquantified, knowledge of local ground types and their species-mixes or 'taxonomies' of fishes and benthic invertebrates. In contrast, scientists tend to gain highly detailed data from a variety of specialized sampling tools, but usually from relatively few samples that are often untargeted. Because fishers and scientists tend to observe marine ecosystems at different spatial and temporal scales, their observations have the potential to be complementary. Unfortunately, and as is usually the case, in the absence of adequate communication and cross validation between scientists and fishers, these different observation scales lead to different system views and the potential for divisive debates.

Fishers' knowledge may permit scientific observing to be better targeted and more insightful, while survey data can provide detail that leads to more rigorous interpretation of fishers' knowledge. The comprehensive scope of fishers' exploration and fishing provide the means to extrapolate the point sampling of scientists to larger scales, and to locate unique areas of biodiversity that may remain undetected by survey or surrogate-based approaches. In the context of MPA development, this means that fishers collectively will frequently have knowledge about biodiversity and spatial structuring of which the broader community, including scientists, is unaware. In this respect, their knowledge is relevant to both systematic (CAR) and to targeted (iconic area) approaches to MPAs in the SER.

Contributing industry data to MPA development in the SER

The need for MPA declaration in the SER, as part of the Regional Marine Plan which is to be completed by 2003, means that lines must be drawn on the water that will, firstly, identify broad areas of interest from which, secondly, draft candidate MPAs are selected before, thirdly, MPA sites are chosen. The utility of 'fisher map' style mapping data, if collected in the right form and to meet the above timetable, becomes obvious. The data set would prospectively provide interpreted habitat information (distribution, boundaries, sizes, generalized geology and community types) at 'megahabitat' scale or finer, with near-complete coverage for the continental shelf and slope (from about 100 m out to about 1,300 m depth), over all SER provinces.

The data are relevant in two ways. Firstly, and with regard to the conservation goals of the NRSMPA, megahabitat-scale data with provincial-scale coverage are a unique contribution to understanding representativeness and adequacy under the CAR approach (Bax and Williams, this issue). Their inclusion is therefore prospectively beneficial (for managers *and* industry) to the broad identification phase by defining the essential fishing grounds, and may be the best available for the selection and design phases by providing megahabitat data – especially the areas, shapes and boundaries of habitats. Secondly, with regard to fishery management goals in the SEF, the data provide a first means of identifying the fishery implications of any area management (such as effort displacement by area closures) and the scope for integration of spatial planning by conservation and fishery managers. Presently, the linkage between spatial management planning for biodiversity conservation and for fishery purposes is not clearly specified (Baelde *et al.* 2002), benefits to fisheries from MPAs are not well established (Ward et al. 2001), and prospects for integration of conservation and fishery management goals in the SER remain largely unexplored.

A joint project between CSIRO and the trawl and non-trawl sectors of the offshore fishing industry (detailed below) was started in 2001 with the explicit aim of incorporating fishers' knowledge of the seascape into strategic management planning. Industry executives supported the project primarily because they viewed it as a way to participate directly in the forthcoming, but then unspecified, spatial management process. It was argued that, with their information systematically collected and rigorously evaluated, fishers would be positioned to critically evaluate proposed spatial management plans, such as the placement of MPAs, and require management agencies to have clearly defined and measurable aims for their proposed management options. In this way fishers could reduce the likelihood of inappropriate MPAs holding little conservation advantage and only a cost to industry. However, support at executive and grass-root levels was not unanimous, and remains that way, in large part because many fishers fear that their information will be used against them, especially for closing off valuable fishery areas.

Nonetheless, at the time of writing, a large volume of data (some 550 separate electronic files) had been contributed and processed, and maps made at various levels of refinement for most of the shelf and slope in the SER. There is momentum to introduce these data in time to contribute to both the initial identification and subsequent selection of MPA sites. However, while involvement of industry data in this way has clear prospects for enhanced conservation outcomes, fishers remain uncertain about the outcomes for them and therefore uncertain about how, or indeed whether, to contribute their data. The consultative process will need to clarify key issues that remain unclear at this stage of the planning process: the likely negative impacts of MPAs on commercial fisheries – particularly those stemming from effort displacement; the links of systematic MPA development defined by conservation goals to spatial management actions defined for fishery goals; and to identify the tangible benefits that will come from sharing their knowledge.

Overview of CSIRO-Industry mapping project

A list of the main project features and structures to address the issues of involving fishers' data in the spatial planning process is shown in Table 2. Importantly, a high degree of transparency gives fishers a high degree of control over the form (spatial scale, information content, overlays of other data sets) and timing of any outputs, and authority is required from individual contributors and the relevant associations for release of information. This is anticipated to be a step-wise and adaptive process because it will be necessary to determine, firstly, what industry is confident to release, and secondly, what specific products are needed for an MPA development process that is evolving rapidly.

Conclusions

Fishers' mapping data, if collected in the right form and to meet the MPA development timetable for the SER, could provide interpreted habitat information (distribution, boundaries, sizes, generalized geology and community types) at 'megahabitat' scale or finer, with near-complete coverage for the continental shelf and slope (from about 100 m out to about 1,300 m depth), over all SER provinces. This is relevant to all phases (identification, selection and design) of MPA development, as well as other forms of spatial management for fishery goals. Spatial management – including MPA declaration – based on coarser levels (bioregion and depth) increases the risk of unnecessarily restricting fishing activity, while not increasing conservation benefits.

Including fishers' knowledge in defining spatial management of a seascape best known to them is perhaps the best way to gain their acceptance and understanding of conservation objectives. Achieving this understanding is likely to provide benefits in the subsequent operational stages of spatial management, e.g. compliance, surveillance, performance assessment and monitoring (Baelde *et al.* 2002). Active and successful participation of fishers in this process for the SER could provide a blueprint for industry participation in future phases of the NRSMPA.

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Tables

Table 1. Overview of the hierarchical scheme used to classify the structure of marine habitats in the South-east Region (under development by V. Lyne and P. Last, CSIRO Marine Research, version 1.2, February, 2001). For more detail see NOO, 2002b)

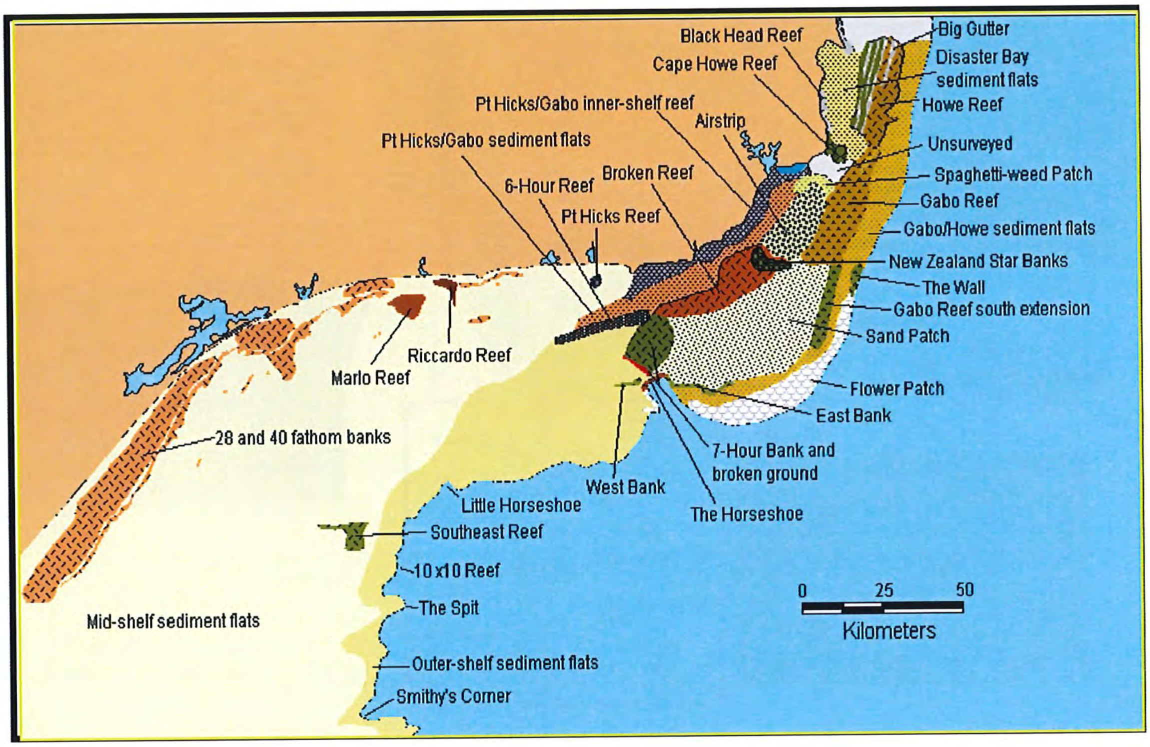
Level	Brief description
1 - Provincial	Biogeographic units
2 – Biomes/ sub-biomes	Large areas with characteristic collections of species: the biotic communities of the coastal region, shelf, slope and abyss differentiated by depth and latitude
3 – Biogeo-morphological units	Easily identifiable geomorphological subdivisions, usually with distinct biotas. Typical units on the continental shelf include sediment plains, rocky banks, and valleys and cliffs at the shelf-break, while continental slope units include canyons and seamounts.
4 – Primary biotopes	Biotic assemblages associated with broadly different substrata (soft, hard or mixtures) and modified by hydrological variables such as wave exposure, turbidity, tidal effects and current speed.
5 – Secondary biotopes	Generalised types of biological and physical substrate within the soft/hard/mixed types (e.g. igneous, calcareous, silts, sands, gravels, seagrasses, sponges) together with geological, biological and ecological interpretation (community structure and composition or biodiversity) provided by biological and physical sampling.
6 – Biological facies	Identifiable biological and physical units defined by a biological indicator, or suite of indicator species, used as surrogate for a biocoenosis or community. They include, for example, a particular species of seagrass, or group of corals, sponges, or other macro-fauna that generally occur together.
7 – Micro-communities	Assemblages of species that depend on member species of the Facies (e.g. communities associated with kelp holdfasts)

Table 2. Overview of CSIRO-industry mapping project in the Australian South-east Region: issues and project structures

Issue	Project structure
Data collection	Collection in ports and at sea by project leader known to fishers
Spatial data and maps	Mainly based on electronic data from fishing vessel track-plotters
Habitat attribute data	Terrain and bottom types, species mix and fishing patterns collected using a questionnaire developed with industry input together with fishery logbook data
Verification and validation	Procedures in place to ensure data are scientifically rigorous
Data management	Storage and map production with a customised spatial database for spatial and attribute data
Formal arrangements	Responsibilities for CSIRO and industry set out in a memorandum of understanding, and data security and IP agreements
Field sampling	From industry vessels with a high-tech camera system designed and built as part of the project
Other data	Scientific survey and other data (geology/ oceanography/ video/ logbook/ socioeconomic) for GIS overlays
Industry consultation	Continued involvement of industry through peak associations, Steering Committee and individual operators
Agency consultation	Steering Committee with multi-agency and cross-sector industry representation
Release of industry maps/ information	Step-wise and adaptive with clear arrangements for industry review and approval procedures

FIGURES

Fig. 1. A coarse-scale map of habitats – the 'fisher map' – made for the Twofold Shelf Bioregion (from Bax and Williams, 2001, Fig. 4). The map combines is a mix of fisher-delineated geomorphological features (mostly sediment plains and rocky banks) ground-truthed with physical samples and photographs from surveys (Fig. 2).



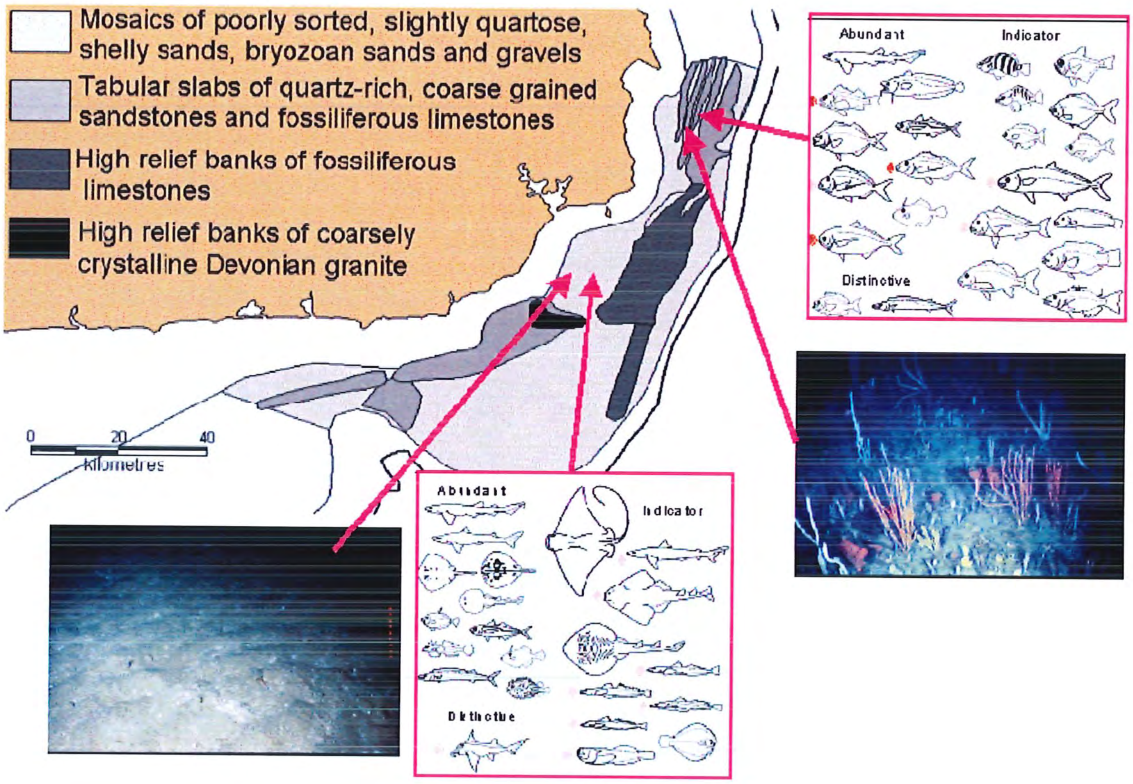


Fig. 2. Zoom view of a section of the outer continental shelf within the Twofold Shelf Bioregion with ground-truth detail for the "Airstrip" and inner "Gabo-Howe Reef complex" 'megahabitats' (see Fig. 1). Data on fish communities and habitats from Williams and Bax (2001) and Bax and Williams, 2001 respectively.

APPENDIX 5 – INTELLECTUAL PROPERTY

Addition to standard agreement:

"Raw data are the property of the individual operators from who they were obtained. Supplementary data on oceanography, geology and other scientific data are the property of the organisation from which they were obtained. IP belonging to the project is restricted to the processes of integrating these data into electronic and the final hard copy habitat maps to be produced in the final report. Project IP has no anticipated commercial value."

APPENDIX 6 – LIST OF STAFF

Dr Alan Williams: Project management, industry liaison, data acquisition, data analysis and interpretation

Dr Nic Bax: data analysis and interpretation

Mr Bruce Barker: geographic information system (GIS), database maintenance, image management, industry liaison, camera operations

Ms Karen Gowlett-Holmes: interpretation of seabed images

Dr Neil Klaer: logbook data processing and analysis

Taz-E (Dr Tim Jones): database development

Biospherics (Dr Jeremy Prince): consulting on project development

SeaMatters (Dr Pascale Baelde): consulting on industry liaison/ data acquisition