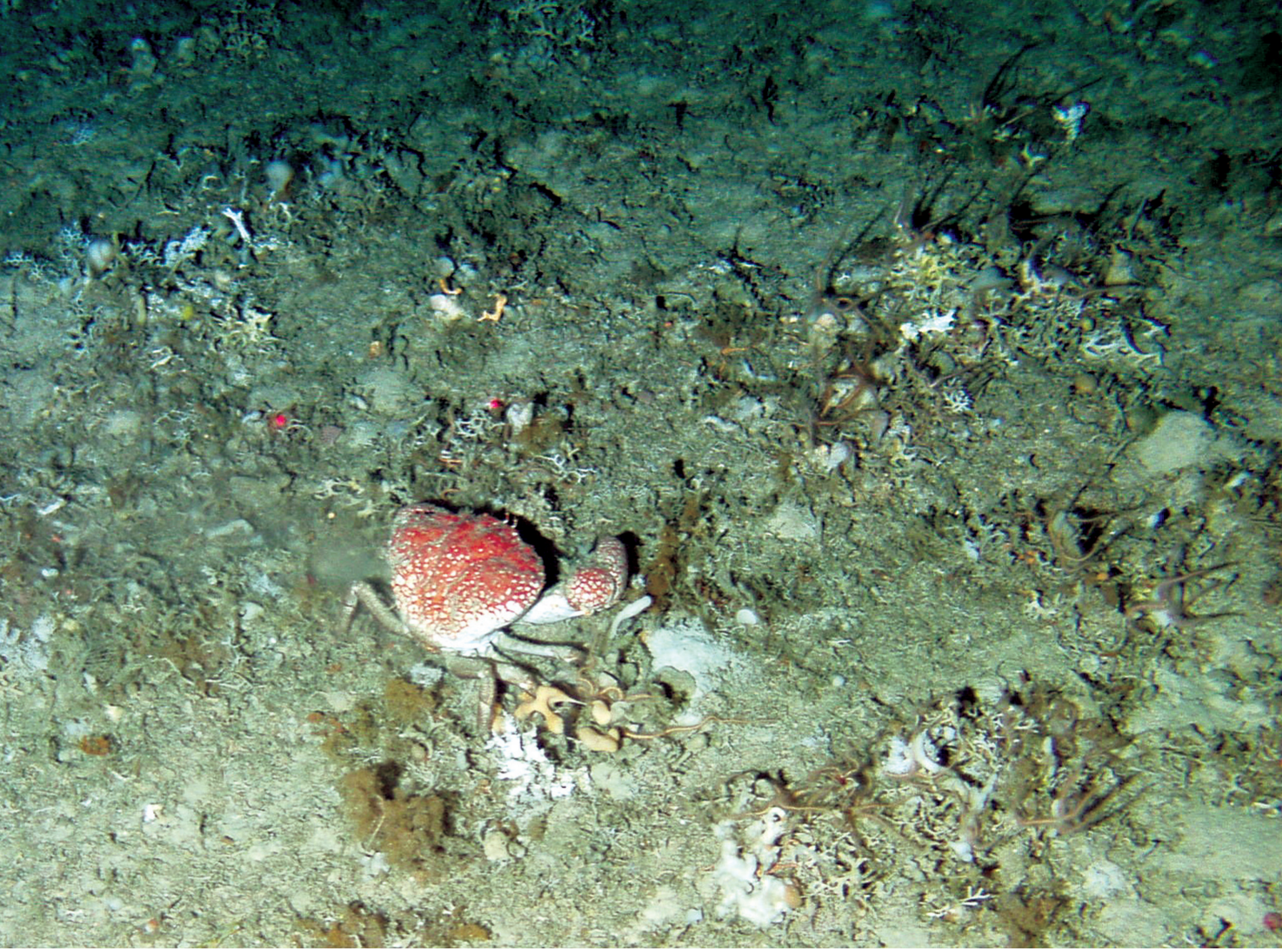

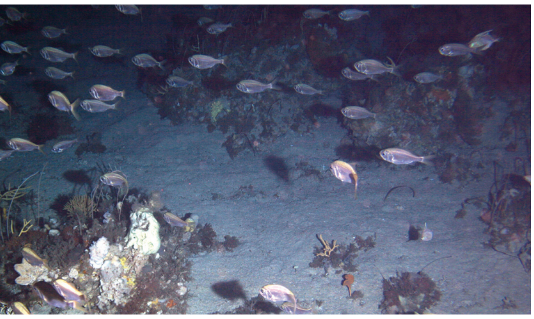

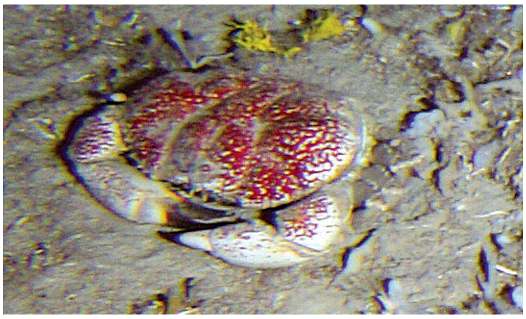

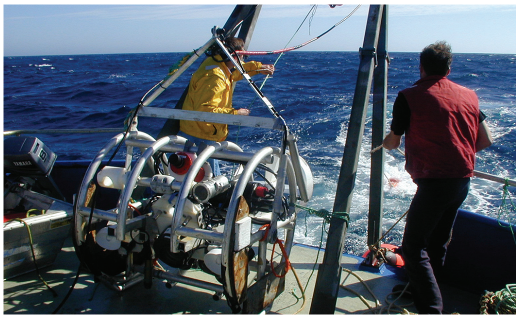

Understanding shelf-break habitat for sustainable management of fisheries with spatial overlap

final report to the Fisheries Research and Development Corporation
PROJECT NO. 2004/066

June 2009

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Title: Understanding shelf-break habitat for sustainable management of fisheries with spatial overlap : final report to the Fisheries Research and Development Corporation : project no. 2004/066 / Alan Williams ... [et al.].

ISBN: 9781921605130 (pbk.)

Series: FRDC project ; 2004/066.

Notes: Bibliography.

Subjects: Crab fisheries--Tasmania--Management.
Menippe--Tasmania--Management.
Continental shelf--Tasmania.
Trawls and trawling--Bycatches--Tasmania.
Bottom fishing--Tasmania.

Other Authors/Contributors:
Williams, Alan, 1958-
CSIRO. Marine and Atmospheric Research.
Fisheries Research and Development Corporation (Australia)

Dewey Number: 639.5609946

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2004/066 Understanding shelf-break habitat for sustainable management of fisheries with spatial overlap.

PRINCIPAL INVESTIGATOR: Dr C. Gardner

ADDRESS: University of Tasmania

Tasmanian Aquaculture and Fisheries Institute

Private Bag 49

Hobart 7000

Telephone: 03 6227 7233 Fax: 03 6227 8035

1 Objectives

1. Define and map key habitats on the shelf edge (~80-180 fm — i.e. 150-330 m) at locations around Tasmania where fisheries using different gear types interact.

2. Evaluate their resistance and resilience to impact from fishing gears using the semi-quantitative 'Ecological Risk Assessment' framework

3. Detail the distribution of exploited shelf-edge species in relation to habitat features

4. Evaluate ecosystem links within habitats based on trophic, temperature and current-flow data

5. Evaluate the use of video to obtain stock assessment information such as abundance, sex ratio, condition and size of target species, primarily the giant crab.

2 *Non-Technical Summary*

OUTCOMES ACHIEVED

The shelf-edge is the region of seafloor where the flat continental shelf drops away rapidly to form the continental slope in about 150 to 400 m depths. Although important to fisheries, shelf edge habitats off Tasmania were poorly known due the difficulty of conducting research at such great depth. This project provided fisheries managers with information to evaluate whether bottom trawling had an adverse impact on the habitats of giant crabs in the area where trawl and giant crab fisheries overlapped.

'Bryozoan thicket' (dominated by emergent bryozoans plus small erect sponges and ascidians) was one of four main habitats identified, and the dominant habitat where giant crabs are fished.

Our risk analysis showed the bryozoan thicket was potentially at risk from trawling but not crab trapping. The primary factors resulting in this difference between gears were: (i) the entire Tasmanian distribution of this habitat being available to the trawl fishery; (ii) very high overlap of trawl effort with its distribution (high encounters), and (iii) relatively high degree of impact of trawls that are heavy and have a large footprint.

There was no evidence that degradation of bryozoan habitat was directly detrimental to giant crabs based on loss of prey because prey did not show a strong association with the bryozoan habitat. However, a distinctive spatial pattern was observed in abundance of undersize crabs, with greatest density off NW Tasmania. This hot-spot appears to be more a function of larval advection than habitat traits. These observations show the need to evaluate habitat use in the context of fishery spatial management, especially since very little of the bryozoan habitat falls under formal spatial management arrangements for ongoing protection.

The shelf-edge is the region of the seafloor where the flat continental shelf drops away rapidly to form the continental slope – the steep edge of the continental margin that continues to the abyssal plains. The depth of the shelf edge is roughly between 150 and 400m. It's an important area for fisheries and is targeted by trawl and trap fisheries around Tasmania. This project was developed to address a need for improved understanding of the benthic habitats in these areas. Prior to this project there was little information on habitats in these areas because sampling at these depths is challenging and requires specialised gear. Management of fisheries operating in the area had no habitat information to inform decision making - and this was especially needed for discussion of interaction of different sectors operating in the region (i.e. bottom trawl and giant crab fisheries).

Objective 1. Define and map key habitats on the shelf edge (~80-180 fm, 150-330 m) at locations around Tasmania where fisheries using different gear types interact.

A range of methods was used to examine habitat along the shelf break including towed video, digital stills, swath mapping, sled tows and current and temperature profiling. Video transect data was emphasised in analyses for the project and provided qualitative information on faunal assemblages plus quantitative information on faunal categories, substratum type and geomorphology.

Key habitats on the shelf break were defined and mapped. Four categories of sessile fauna predominated: (1) ‘thicket or turf’ dominated by emergent bryozoans plus small erect sponges and ascidians; (2) low and/ or encrusting bryozoans and sponges; (3) low microfauna in association with detritus; and (4) absence of epifauna (often with bioturbation). Latitudinal variation in habitat was slight with differences between samples driven by depth, and whether the samples were from within canyons.

Observations of microhabitat use by exploited species were made with video and digital stills data. Although finfish tended to avoid the gear, giant crabs were less responsive and 75 were observed. They were often observed excavating sediment, sometimes partially buried, while many were using small-scale habitat features including ledges and larger sponge for shelter.

Objective 2. Evaluate the resistance and resilience of habitats to impact from fishing gears using the semi-quantitative 'Ecological Risk Assessment' framework

The ecological risk assessment process applied here used the same approach as applied for the Ecological Risk Assessment of the Effects of Fishing (ERAEF). This is a scoring process for potential risk or vulnerability (low, medium or high) against a series of attributes related to ‘availability’, ‘encounterability’, ‘selectivity’ (when multiplied together = susceptibility) and ‘productivity’. Ranks are sub-fishery (gear) specific, with the rank score for each attribute derived via a series of tables and decision rules. A final risk rating is calculated from a 2-dimensional plot of susceptibility and productivity.

Summarising the risk scores for each sub-biome showed that the shelf-break (200-300 m) is the area of highest risk in respect of both trap and trawl fisheries: > 50% of all habitat images on the shelf-break rated as potentially high risk for trawl, and as medium risk for trap. The outer shelf habitats were mostly not vulnerable to either fishing method. Vulnerability of habitats to gear type was mapped along the coast, which provides guidance for spatial management.

This project offered a unique opportunity to examine the physical impact of a heavy towed epibenthic sled on shelf edge seabed habitat over a 1-year time period between two surveys. Photographic observation detected no obvious signs of habitat recovery in this period.

Clearly defined gear marks were identified in 8671 video-frames, or around 3.2% of the total scored. Of these 20% were observed on the outer shelf (< 200 m), 7% on the shelf-break and 73% on the upper slope (54% in the 350-450 m depth range). Thus, the shelf-break, which was identified as potentially at high risk to impacts from trawl gear and moderately vulnerable to traps, showed the least amount of gear marks. Gear marks observed on the seabed appeared to come mainly from demersal trawls. The distribution of observed gear marks showed a good overall correspondence with areas recorded by logbooks as having trawl effort.

Our ERA analysis showed there is one conspicuous vulnerable habitat type, the bryozoan turf /thicket, potentially at high risk from trawling. The primary factors resulting in this outcome were: (i) its entire Tasmanian distribution was available to the trawl fishery (based on the management boundary); (ii) there was a very high overlap of trawl effort with its distribution (high encounters), and (iii) relative to other gears including crab traps, a trawl has a high degree of impact because it is heavy and has a large footprint. In addition, the habitat occupies a relatively small area, it has low physical resistance to this gear, and its fauna is fragile and completely removable. It occurs in deep water meaning it has relatively low resilience, having evolved in an environment with low natural disturbance and having a slow recovery following impact. Although the intrinsic vulnerability of bryozoan turf/thicket makes it potentially at risk to impact from any gear, it did not score at high risk from crab trapping. This was mainly because there is a lower impact from a lighter, static gear with a smaller footprint.

Objective 3. Detail the distribution of exploited shelf-edge species in relation to habitat features

The information collected on habitat distribution enabled comparison between habitat types and the distribution of commercial species. The distribution of species was mainly inferred from catch rates derived from commercial logbook data, although some information was also obtained through the video data collected for this study. Of particular interest was the distribution of catches relative to (1) the bryozoan habitat and (2) the shelf/shelf break sediment terrace, for morwong, flathead, ocean perch, ling and giant crab.

Giant crabs mainly occupy the bryozoan turf habitat. This distribution overlaps with several commercial finfish including flathead (mainly taken between 150 and 170 m) and morwong (especially 160 and 180 m) while ling catch tended to be further offshore (>350 m).

The data show clearly an increase in catches of flathead and morwong in more recent years (2001-2004 time period), which corresponds to the trawl fishery exploring shallower fishing grounds in that time. Note that change in the blue grenadier catch also occurred through this period, with the majority of that catch taken by midwater trawl where there are fewer interactions with the seabed.

Microhabitat utilisation was also observed for several commercial finfish and giant crab.

Objective 4. Evaluate ecosystem links within habitats based on trophic, temperature and current-flow data.

Potential and known prey items of giant crabs were compared across habitat types. The collective distributions of prey (and inferred prey) groups of the giant crab did not show a strong association with the structured and vulnerable bryozoan habitat occurring in the interaction area. Thus, there was no evidence that degradation of bryozoan habitat is directly detrimental to giant crabs based on loss of habitat for their prey. Conversely, occasional observations carrion on the seabed suggests the discarded component of trawl catches may provide an additional food source.

Patterns in CPUE of undersize and male crabs from western Tasmania were consistent with movement to deeper water in winter and shallower water in summer. This pattern may be driven by the seasonal patterns in water temperature with crabs moving to deeper water in response to warmer water in winter (i.e. the reverse of surface waters).

Undersize crabs appeared to occupy the same depth range as legal sized catch although a distinctive spatial pattern was observed with a concentration of undersize crabs along the NW region of Tasmania. We explored whether this hot-spot of undersize abundance was a function of habitat / environmental traits of the region or of larval supply. Observations on habitat in this NW region did not identify any traits that would explain the greater abundance of juvenile crabs in this region. In contrast, simulation of larval advection suggests that this region may be a larval sink, thus explaining the abundance of undersize in this region. The observation highlights the potential importance of the NW for any discussions of spatial management.

Objective 5. Evaluate the use of video to obtain stock assessment information such as abundance, sex ratio, condition and size of target species, primarily the giant crab.

A variety of target species were observed in videos, including pink ling, morwong, gemfish and giant crab. Fish species typically fled from the towed camera platform, and thus the value of fish observations was limited. In contrast, giant crabs typically showed little sign of avoidance. We observed 75 giant crabs that could be positively identified in the 77 hours of video collected throughout the surveys. This clearly indicated that abundance and density estimation by video to contribute to regular assessments would not be feasible due to cost. However, video data have complementary and valuable for point estimates of some assessment input data.

Two potential and valuable applications of video data for the crab fishery are: (i) quantification of gear selectivity, as a portion of the crabs observed could be measured by stereoscopy; (ii) validation of model based estimates of crab abundance of a smaller subset of the fishery using swept area methods.

KEYWORDS: shelf break habitat, ecological risk assessment, video sampling, trap impacts, trawl impacts, benthic habitat, *Pseudocarcinus gigas*.

3 Acknowledgements

This project was completed with the assistance of several other groups and individuals. Sampling was conducted with the help of crews aboard the FV Dell Ritchie, and FRV Challenger. Jeff Cordell and staff in the CSIRO workshop also provided assistance in gear construction. Help with databases and data analysis was provided by many people but special mention is made of the efforts of Ken Ridgway and Peter Walsh. Graphic support was provided by Lea Crosswell. Yvonne Bone and Noel James, Patricia Mather, Monika Schlacher-Hoenlinger and Tim O'Hara assisted with the identification and interpretation of bryozoan communities, ascidians, sponges and ophiuroids, respectively.

In addition to the report's authors, several other staff made important contributions to the project. At CSIRO Marine and Atmospheric Research, Karen Gowlett-Holmes helped identify some fauna seen in images, Mark Bravington provided useful feedback on the survey design and Matt Sherlock provided help with configuring and calibrating the camera system. Pamela Brodie assisted with the management of the data, while Roland Pitcher provided input to the science review workshop at the commencement of the project. Rudy Kloser, Tim Ryan and Gordon Keith all provided input to the acquisition of mulitbeam sonar data and the provision of swath maps.

Lastly, this project relied on the input of the SE trawl and Tasmanian crab industries. We thanks all these individuals and organisations for their assistance and expertise.

4 Background

Habitat at the shelf break - a depth zone in ~180-400 m where the continental shelf drops away to form the continental slope - is an area of high productivity off southern Australia and is targeted by different fisheries using different gear types. For example, in the SEF traps are used for ling and giant crab fishing, weighted drop lines for blue eye, and various trawl gear configurations are used to target a range of finfish species. Each of these gear types interacts with the benthic habitat in different ways and there is potential for the activities of one industry to influence another through changes to target species abundance, habitat structure, and ecosystems. Sustainability of any one of these fisheries is reliant on the habitat and ecosystem, which must be considered in the context of all industries operating in the area.

The issue of fishery interactions became important in 2001-2002 when overlap in effort occurred between giant crab trappers and finfish trawlers, both of which operated in the same region at similar depths, and both of which had undergone large expansion of effort over the previous decade. Research on the habitats utilised by these industries was required for understanding interactions and broader ecosystem effects.

The research conducted through this project addressed these issues through video sampling of habitat in the region. In addition to video data, information on benthic habitats was collected through SWATH mapping, sediment grabs and sled samples.

The project was initiated at the request of industry and fisheries managers in Tasmania. The project was developed through numerous meetings and communications with various groups since early 2002 (including AFMA, DPIWE, Fishwell, the Crustacean Fishery Advisory Committee (CFAC), the Tasmanian Rock Lobster Fishermen's Association, SETFIA, and SETMAC/ SENTMAC). Throughout these discussions we attempted to involve different sectors to ensure that the project remained objective and did not promote good practice in one industry at the expense of another. This involvement of different sectors also occurred explicitly at the commencement of the project through a workshop on project methodology. A summary of the workshop is provided in Appendix 1 – Summary of Workshop. Changes in project design occurred as a result of the workshop with the methods reported in detail in Chapter 6.

A pilot scale survey was conducted in late 2003 on board a fishing vessel normally used for scallop and salmon fishing, with support from the giant crab fishing industry. That voyage conducted video tows to beyond 400 m depth and demonstrated that target species including giant crabs could be "sampled" by video tows. In addition, impacts of fishing gear were evident and habitat types and species assemblages readily classified. Methods developed for that voyage formed the basis of the review at the workshop and consequently the more extensive research described here. In addition, sampling was expanded to provide data on environment including sediment, current, temperature and bathymetry.

During the course of the project there were some developments in management of fisheries in the region. These included the introduction of Commonwealth MPAs in the SE of Australia and also a voluntary agreement between the trawl and crab fishers in 2004 to limit trawl effort in some regions. These changes are illustrated in Figure 4.1. The fisher's agreement was based on knowledge of crab fishers on where crabs are captured and thus was primarily directed to reducing gear interaction issues, rather than protection of habitat, which had not been investigated at that stage.

The fisher's agreement was:

a) trawling effort was to have the same level of access along the entire coast deeper than 270 m (150 fm) or shallower than 150m (80 fm); south of 42º 45', north of 40º, and in the Ling Hole, Pieman and Strahan canyons;

b) apart from the areas listed above, trawlers agreed to keep their effort out of the 180-270 m (100-150 fm) depth band 40º to 42º 45', and 150-180 m (80-100 fm) depth band 41º45' to 42º 45';

c) trawl and crab fishers to increase radio communication to avoid gear interaction.

Despite the agreement outlines above, there remained conflict between the sectors about several issues. These included ongoing trawling in the 150 to 180 m (80-100 fm) depth band from 41° to 41° 45', the level of retained crab bycatch, the extent of damage from trawl gear to crabs, and the vulnerability of habitats to fishing effort. The results from FRDC2004/066 provide information to evaluate the last of these concerns.

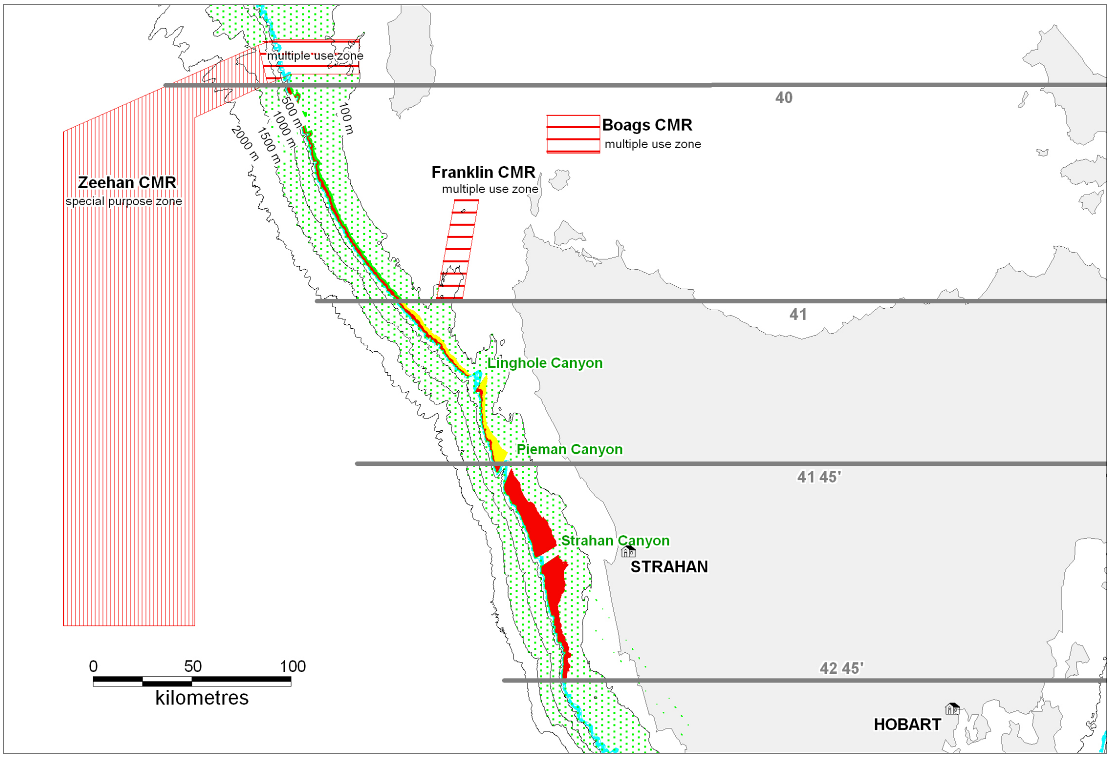

Figure 4.1 Management changes off western Tasmania have occurred since commencement of the project. Commonwealth MPAs were declared and these impact on both crab trapping and trawling effort in complete exclusion regions. A voluntary agreement that was struck between fishers in 2004 defined areas where trawling was to be excluded (marked in red). Green areas indicate those where the two sectors agreed trawling would continue. Other regions remained in dispute, with the yellow band one of these regions. The blue band marks the 200-350 m depth band associated with bryozoan turf habitat emphasised throughout this report.

5 Need

Both fishery managers and industry identified the need for this project through the Tasmanian Research Advisory Process. The project addressed high priority strategic research areas identified by both state and national fisheries organisations. It was research that targeted a high priority need across Australian fisheries: understanding the effects of fishing activities on fish and their ecosystems. The need for research was compounded in shelf-break habitats due to: (a) scarcity of basic information about shelf break habitats, (b) slow growth of many species in this region implying less resilience to impacts, (c) interaction effects between different sectors that compounded impacts.

The research need of addressing interaction between different sectors was specifically addressed in relation to the trawl and crab trapping sectors. Interaction between different fishing sectors is not unusual and is likely to be repeated in the future – work conducted here will assist in providing a template for resolution.

Understanding shelf-break habitat for sustainable management of fisheries with spatial overlap was identified as the number 1 research priority for Tasmanian crustacean research by both DPIWE and representatives of the Tasmanian crustacean fishing industry at the Tasmanian Crustacean Research Advisory Group.

The project focus was also consistent with strategies developed by the Commonwealth agencies involved in management of industries based around the shelf-break: the Commonwealth Government and the Department of Agriculture, Fisheries and Forestry Australia (AFFA). It is targeted to the FRDC program of Natural Resource Sustainability through the strategies of “Interactions between fish and their ecosystems” and “Effects of fishing activities on fish and their ecosystems”.

6 *Methods*

6.1 Sampling Design

6.1.1 Survey Design

Four surveys were conducted between 2003 and 2005 using three vessels: FV *Dell Ritchie* a commercial fishing boat (survey 1 - DR200301; 2-8 November 2003); RV *Southern Surveyor* (survey 2 - SS200404, 10-29 April 2004); and RV *Challenger* (survey 3 - CH200401, 8 November-2 December 2004; and survey 4 - CH200501, 5-15 April 2005). The primary sampling tool was a towed camera platform that enabled video and still image data to be collected on seabed habitats; during survey 2, multibeam sonar was used to map some sites, and a benthic sled was used to collect physical samples.

Survey sites were chosen in a factorial design with two primary factors: the abundance of giant crabs (high or low) based on analysis of recent catch data as recorded in the logbooks used by the State commercial giant crab trap fishery, and the overall level of trawl effort at (high or low) as indicated by individual tows plotted from logbook records of the Commonwealth trawl fishery (Table 6.1.1.1). Mid-water trawl effort was not excluded from the trawl data used for this preliminary assessment and there is some difficulty in differentiating it because it is not explicit in logbook records. However, mid-water data were removed from the data used in analysis of results. In total, 15 of the 16 planned sites were sampled successfully (Table 6.1.1.1); one (Davey) was abandoned due to adverse weather conditions on the final voyage.

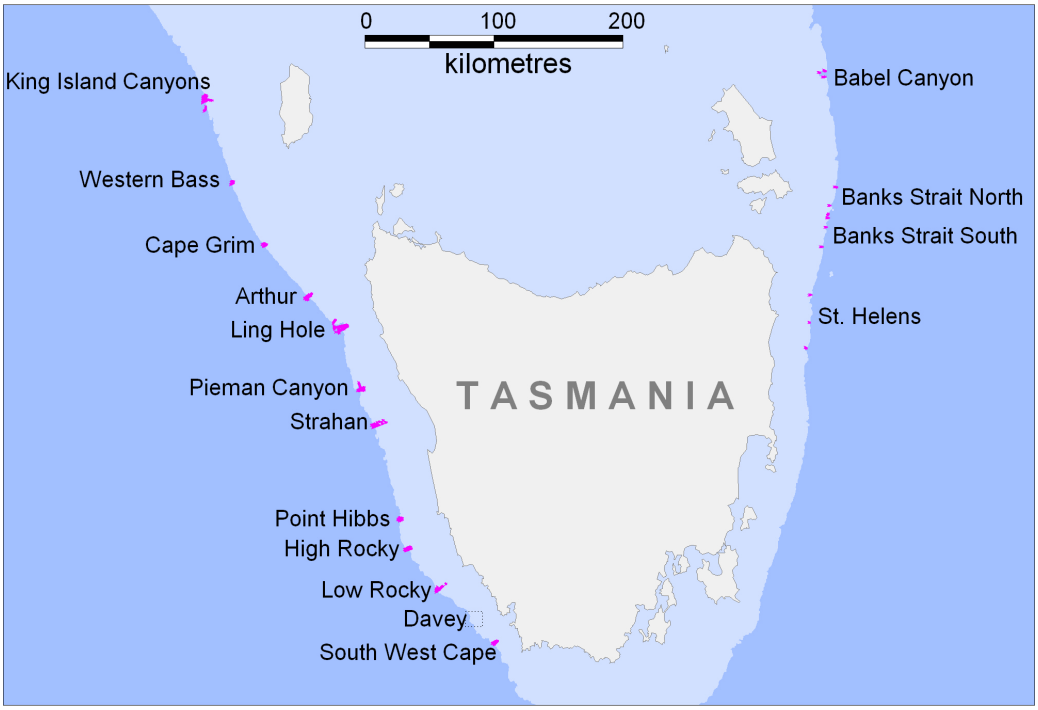

Figure 6.1.1.1 Sites sampled by towed video (pink areas indicate video transects).

Photographic data were collected along transects; at least 4 transects were attempted at each site, two across the depth range of interest (~150 m to ~600 m depths) and two along depth contours in ~170 m and 350 m depths (Table 6.1.1.1). The total depth range covered was 49.4 m (Pieman) to 578.7 m (Ling Hole). This sample design was intended to enable: (i) analysis of trends in habitats with depth; and (ii) analysis of variation at the same depth within sites (i.e. a design analogous to a classic replicated factorial design with measurement of variation between and within samples).

In total, 72 video transects were completed. These ranged from 13 minutes to over 3 hours in duration, with an average duration of 1 hour 4 minutes; collectively these yielded 78 hours of video from which data were taken (see breakdown by site in Section 7.1.1). Duration of down-slope transects was a function of slope and start depth with a start depth target of less than 150m and an end depth target of at least 400 m. This depth range was selected on industry advice that this was the most important depth range for both the crab fishery and the zone of crab-fishery / trawl-fishery interaction.

Scoring at 1-second intervals (frames) resulted in 277,500 data records; of these about 10,000 (~4%) were not scored because the camera was too far off the bottom – due either to vessel pitch in rough weather, pulling the camera upwards, or when bottom contact was lost over steep drop-offs; another 3,300 records (~1%) were removed during data processing. Consequently, the analysis was based on a subset of the data representing around 95% or 264,200 of the original frames.

Table 6.1.1.1 Overview of Sites, including the classification of each site in regard to crab catch and trawl effort, the depth range sampled and number of transects taken across and along depths.

Site	Crab catches	Trawl effort	Depth range covered (m)	N transects down-slope (across depths)	N transects across-shelf (along depth)
King Island	high	low	50 – 571	8	2
West Bass	high	low	101 – 447	3	2
Cape Grim	high	high	87 – 428	2	2
Arthur	high	high	111 – 406	2	2
Ling Hole	high	high	89 – 579	3	4
Pieman	high	high	49 – 437	6	2
Strahan	high	high	136 – 402	2	2
Pt Hibbs	high	low	132 – 446	3	2
High Rocky	low	low	135 – 460	3	2
Low Rocky	low	high	142 – 487	2	2
Davey	low	high		0	0
SW Cape	low	low	515 - 405	2	2
Babel Canyon	high	low	126 – 409	3	0
Banks Strait N	high	low	126 – 418	2	0
Banks Strait S	high	low	121 – 435	4	0
St Helens	high	low	133 - 452	3	0

6.1.2 Camera system for giant crabs surveys

The camera system used for the giant crab project surveys was originally developed as a portable system for the FRDC SEF Mapping Project (FRDC 2000/153). Additions and changes were made to improve the camera system throughout this project.

System description

The system comprised the camera platform, a custom-built electric-hydraulic winch, a cable containing a multi-mode fibre-optic and electrical conducting wires, and the 'bridge control' set-up (Figure 6.1.2.1).

(a) (b) (c) (d)

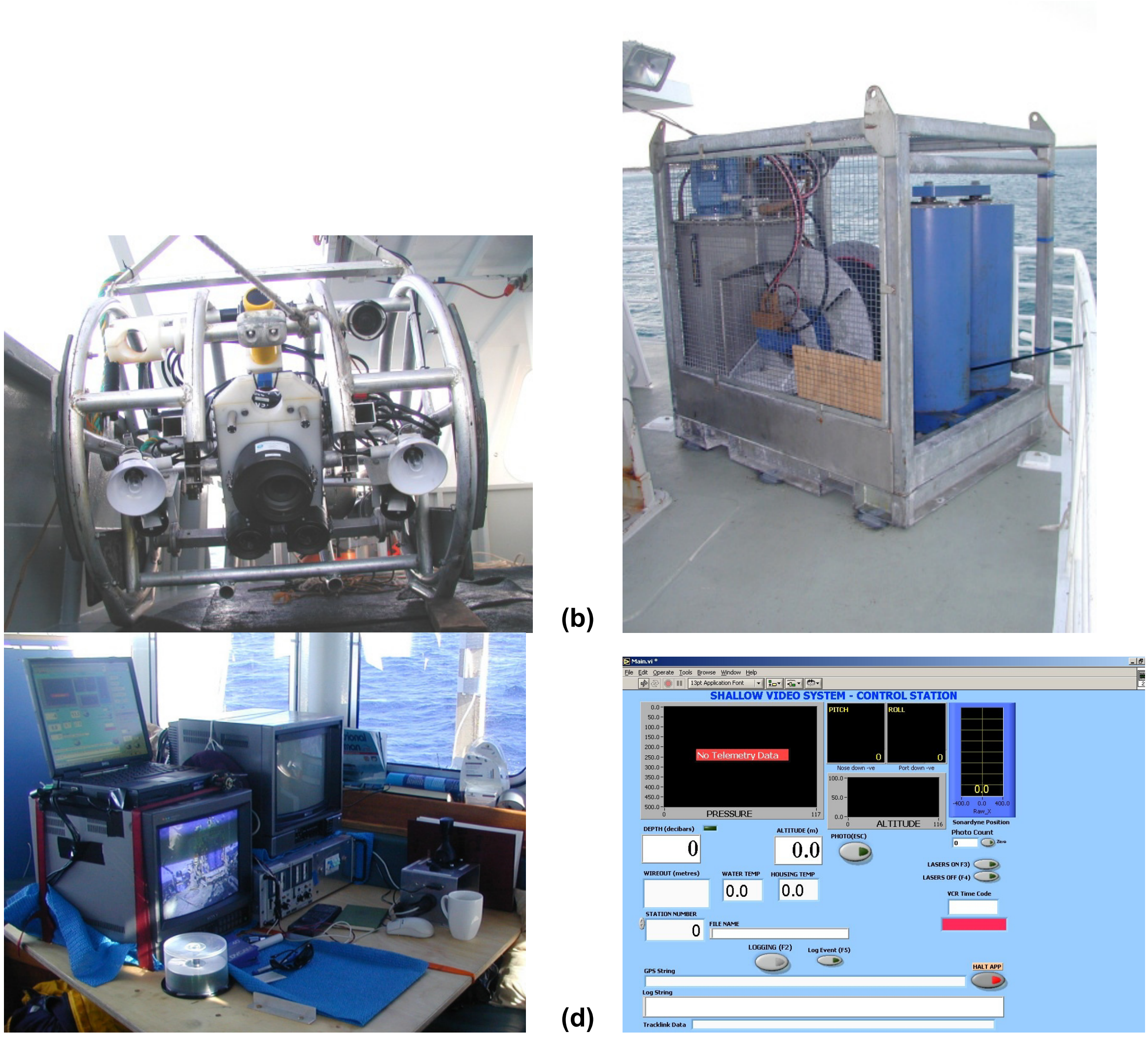

Figure 6.1.2.1 Components of the camera system: (a) camera platform (b) custom-built electric-hydraulic winch and (c &d) the bridge control set-up with monitors having real-time video feed, joystick remote control of the winch to control depth off sea-floor and a computer with (d) LabView console showing real-time position and telemetry read-outs

The winch used vessel supplied 3-phase electric 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 wire-out readout. The winch is bolted to a base plate that is welded to the deck of the vessel. A 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 contained two Hitachi HV-D30P PAL 1/3" 3 CCD colour video cameras, a low-light black and white look-ahead camera, two Deep Sea Power and Light 250 Watt incandescent flood-lights, a Canon 30D 8-megapixel digital stills camera, two Canon Speedlight 580EX strobes, and an electronics package for control of components and to manage data transmission. A custom made computer interface enabled remote switching, data logging and control of the system from the remote station. The platform also incorporated a Datasonics altimeter providing platform height-above-bottom data and 2 x 8 milli Watt laser diode lasers for scale reference.

A Ultra Short Base Line (USBL) tracking beacon was mounted on the frame to enable geo-location of the camera platform. We used a Tracklink system on surveys 3 and 4 and a Sonardyne system on survey 1 and 2. A vessel mounted motion reference unit and differential GPS unit provided position data and vessel heading, pitch and roll data. These data were logged along with camera system data and archived for post-processing to calculate gear geolocation.

Stereo cameras were incorporated into the system to enable scaling and measurements from the video imagery. Calibration of the system was completed before and after each survey.

Camera system operation

The camera system was deployed from the rear of the research vessel using an A frame gantry supporting a large diameter block (Figure 6.1.2.2). The electric-hydraulic 3 phase power winch held the ~1000 meters of fibre-optic cable. The vessel steamed as slowly as possible along the sampling transect line, towing the camera system just off the seafloor. The platform’s position relative to the seafloor was regulated by hauling or paying out wire using the remote winch control. This was done in response to observations from the real-time video imagery allowing us to respond accordingly to depth changes, vessel speed and wire to depth ratios.

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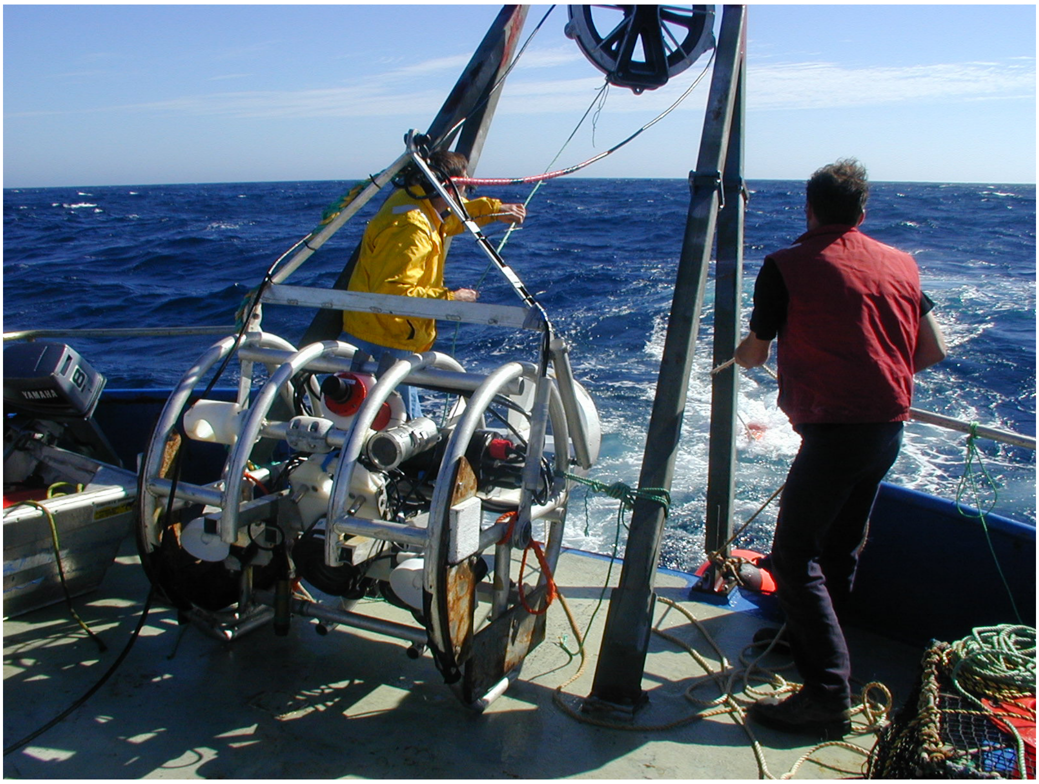


Figure 6.1.2.2 Deployment of the camera platform from RV Challenger.

The video signal from each camera was recorded on-deck to DVCam format digital tapes. The time-code of the recorded tape was output from the VCR to the camera system logging computer and combined with camera system and GPS data. Additionally, GPS data was encoded onto the audio channel of the digital tape. This information could be later decoded and read as a text string to retrieve position and time (UTC) relative to any scene on the videotape.

6.1.3 Multibeam sonar ("swath") mapping data

Swath mapping data were collected with a Simrad EM300 multi-beam sonar (MBS) and used to make maps of seabed bathymetry and roughness (from backscatter; Williams et al. 2007), and were collected from RV Southern Surveyor during Survey 2. Bottom hardness is an index derived from acoustic backscatter (Kloser et al. 2004) measured in decibels (dB); three categories of bottom type ('soft', 'hard' and an indeterminate 'mixed' type) are based on a simple classification with transition zones at -33 and -31 dB. These transition zones were determined from examination of acoustic data from locations validated with video data (Kloser et al., 2007).

6.1.4 Geolocation of video data

Geopositioning of video data was required to link that data with other spatial information such as swath maps, sled tows and fisheries data. Although accurate position were available from each voyage on the position of the vessel, determining the position of video data was a complex process because the video unit was separated from the vessel by over one km of cable on occasion. The process of calculating camera layback described below enabled geolocation of each one-second frame grab of the video within an estimated radius of ~20 m

Video data were collected on four voyages, performed from three different vessels using two different tracking systems, and different GPS units. This situation was unavoidable due to vessel and equipment availability but created a need to adopt different methods to calculate video position between voyages. Good camera tracking data was obtained from two voyages (voyages two and four). Camera positions relative to the vessel position from these voyages were used as 'training data' to provide a relationship between camera platform depth, recorded for all voyages as water pressure at the camera platform, and wire-out recorded at the winch drum.

Voyage 1

FV Del Richey Nov 2003

Camera position data, Garmin 36 – WGS84

Vessel position data, Garmin 36 – WGS84

Geo-positional data quality appeared consistently poor from this voyage as plots of tracks were unfeasibly erratic. Consequently, camera position was estimated from data on vessel position, vessel movement tracks, wire out measured at the winch drum, and camera platform depth. Layback calculations are provided in detail below.

Voyage 2

FRV Southern Surveyor 2004

Camera position data: Garmin 36 – WGS84

Vessel position data: Ashtech DGPS – WGS84

Sonardyne acoustic tracking system on the sled performed well, and accurate X and Y offsets were obtained from the system. Differential GPS positions from Southern Surveyor's bridge instruments was used as the best available vessel position. Vessel positions were converted to eastings and northings using ArcView software, to enable X and Y offsets to be easily applied.

Camera position data were filtered manually in ArcView to remove outliers, and data for the resultant missing seconds were filled in assuming constant velocity. A 60 second moving average was then applied to camera position data.

Voyage 3

FRV Challenger Nov 2004

Camera position data, Garmin 36 – WGS84

Vessel position data, Garmin 16A – AUS Datum

Geo-positional data quality appeared consistently poor from this voyage as plots of tracks were unfeasibly erratic. Consequently, camera position was estimated from data on vessel position, vessel movement tracks, wire out measured at the winch drum, and camera platform depth. Layback calculations are provided in detail below.

Voyage 4

FRV Challenger April 2005

Camera position data Garmin 16A – AUS Datum

Vessel position data Garmin 36 – WGS84

The Tracklink acoustic system performed well, and corrected camera positions were obtained directly from the Tracklink history files. Data quality deteriorated beyond 400m depth, however tracks in deeper water were reconstructed by manually filtering data in ArcView, and assuming constant velocity between remaining points.

Camera position data were recorded in AUS datum rather than WGS 84 as per other voyages, and were standardised using ArcView tools.

Layback calculations

Distance: From data obtained during voyages 2 and 4, the relationship between wire-out and water depth was best described by:

$$L_i = \frac{\sqrt{W_i^2 - P_i^2}}{0.965}$$

Where L_i is the layback for data point *i*, W_i is the wire-out, and P_i is the pressure measured by the camera instruments.

Bearing: Several methods of approximating the bearing of the camera platform from the vessel were evaluated by testing their performance on tows from voyages 2 and 4 where reliable camera position data were available. Ultimately the most reliable proved to be using the inverse of the average bearing for the entire tow. This is not surprising, as the intent was for all survey tows to be in a straight line.

Average bearing was calculated by:

1) Manually filtering vessel position data for outliers in ArcView
2) Averaging 5 consecutive points every 1 minute
3) Calculating the bearings between 1 minute positions
4) Averaging these bearings

Projection: Projection of camera position data from vessel position proceeded as follows:

1) Vessel position files were cleaned by manual filtering and applying a 120 second moving average

2) Calculated vessel laybacks were smoothed with a 120 second moving average

3) Positions of the camera were projected by applying Vincenty's equation (Vincenty 1975) to vessel position, layback and layback bearing data.

4) Final positions were further smoothed with a 5 minute moving average. As this average cannot be applied to the first and last 150 seconds in the dataset, constant speed and direction were assumed during these periods.

6.2 Image Analysis

Two types of image data were collected: (1) continuous stereo video (along transects from the shelf over the shelf edge onto the slope, nominally from ~120 m to ~500 m depth); and (2) high resolution still images (collected opportunistically on these transects, when the live feed of the video showed interesting features, animals or changes in the community). Only the video data were collected for rigorous statistical analysis, because still images are targeted by the camera operator (i.e. they are non-random). The images of the still camera were collected to create an inventory of the fauna that can be recognised from non-destructive sampling, for illustrating examples of habitat types, and for "sampling" exploited species to provide data of potential value to fisheries management.

6.2.1 Video scoring

The video was scored in a two-tiered approach. Firstly, four attributes – substratum (S), geomorphology (G), fauna (F) and abundance of the fauna (A) – were scored for each video frame at 1 second intervals, resulting in an SGFA score that was used for identifying broad-scale habitat types. This scoring system has been used in previous studies in the South East Fishery region, thus results from this project were directly comparable with data sets from other regions. Secondly, a fine-scale habitat score was added to the above scores to add a finer level of discrimination to the most common occurring habitat types: low/encrusting fauna and bare or bioturbated sediments.

Broad-scale scoring

The scoring categories SGFA were first prescribed by Kloser et al. (2002); we adapted their scoring scheme here as shown in Table 6.2.1.1. More detailed descriptions, and example images illustrating the faunal scores, are shown in Table 6.2.1.2. A detailed description of the scoring process and rules is given in Appendix 4 (Section 13.4.1). In addition to these scores, anthropogenic disturbance (e.g. gear drag-marks, lost or discarded gear and rubbish), and species of special interest such as giant crab, lobsters, and commercial fishes were noted (Table 6.2.1.3).

Table 6.2.1.1 Description of the system used for scoring underwater videos taken – adopted from Kloser et al. (2002).

	1. Substratum (S)		**2. Geomorphology (G)**
0 & 1	Mud & fine sediments combined	0	Unrippled
2	Coarse sediments	1 & 2	Rippled current & wave ripples combined
3	Gravel/pebble	3	Highly irregular
4	Cobble/boulder	4	Debris flow/rubble banks
5	Igneous/metamorphic rock	5	Subcrop
6	Sedimentary rock	6	Outcrop 1a (low <1m; no holes/cracks)
		7	Outcrop 1b (low <1m; with holes/cracks)
		8	Outcrop 2a (high >1m; no holes/cracks)
		9	Outcrop 2b (high >1m; with holes/cracks)
	3. Fauna (F) – illustrated and expanded in Table 6.2.1.2		**4. Abundance (A)**
0	None - no apparent epifauna or infauna	1	Low/sparse (<10%)
1	Sponges (large/erect)	2	Medium/intermediate (<50%)
2	Sponges (small/low)	3	High/dense (>50%)
3	Mixed fauna (erect)		
4	Crinoids		
5	Octocorals (gold corals/seawhips)		
6	Mixed fauna (low/ encrusting)		
7	Sedentary/solitary (e.g. seapens, ascidians		
8	Mobile fauna (e.g. echinoids/holothurians/asteroids)		
9	Bioturbation		

Table 6.2.1.2 Faunal categories scored for the video data analysis (*sensu* Kloser et al*.* 2002), with typical examples.

Cat	**Name**	Image
0	**None** *Description:* No apparent epifauna or infauna	
1	**Sponges (large/erect)** *Description:* Community dominated by large erect or massive sponges.	
2	**Sponges (small/low)** *Description:* Community dominated by low and/or encrusting sponges	
3	**Mixed fauna (erect)** *Description:* An obvious mixed attached invertebrate community including large bryozoans, sponges, seawhips and ascidians	
4	**Crinoids** *Description:* Community dominated by stalked and other dominant crinoids (featherstars). These organisms are generally associated with high velocity current environments.	

Table 6.2.1.2 Faunal categories scored for the video data analysis (sensu Kloser et al. 2002), with typical examples.

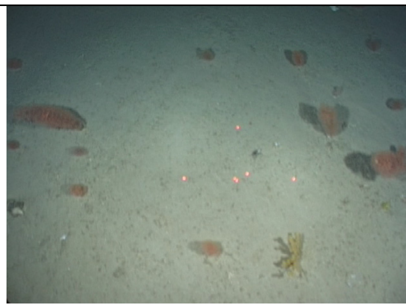
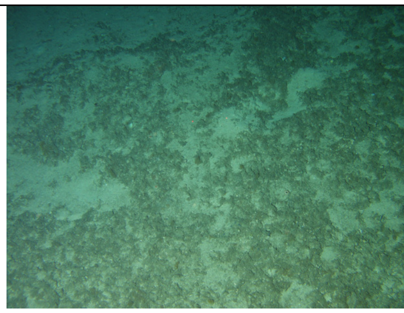
Cat	Name	Image
5	**Octocorals** *Description:* A faunal group associated with "hard" substratum and generally in deeper water than that sampled in this study. Includes gold corals.	
6	**Mixed fauna (low/ encrusting)** *Description:* Small, low mixed faunas including various types of bryozoans, but also sponges, ascidians and other phyla.	
7	**Sedentary/solitary** *Description:* Immobile fauna, rarely or never occurring in patches such as seapens, and solitary ascidians	
8	**Mobile fauna** *Description:* Mobile invertebrate fauna found on "hard" and "soft" substratum types. Examples include ophiuroids, echinoids, holothurians and asteroids. NOTE: this category was only recorded as short point records of ~3 consecutive frames, where mobile fauna was predominant over longer sections of video (e.g. ophiuroid aggregations) the attached fauna was used for scoring and an additional species score was attached to the mobile records.	
9	**Biotubating fauna** *Description:* Infaunal bioturbators that are discerned by the burrows and tracks over and in sediments.	

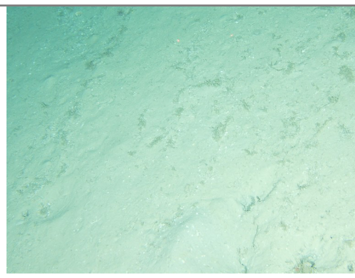
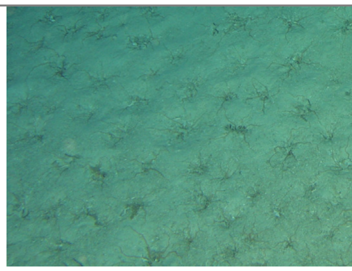
Table 6.2.1.3 Additional categories for scoring videos

	Anthropogenic		Specific fauna, targeted
1 & 2	Fishing gear/ sampling gear marks	1 & 2	Bryozoa thicket
3	Rubbish	3	Giant crab
4	Discarded catch	4	Lobster
5	Ropes	5	Other crustacea
6	Trawl gear	6	Ophiuroid aggregations
7	Fish Traps	7	Schooling fish
8	Crustacean Pots	8	Seal
9	Long line	9	Shark
10	Mesh net	10	Commercial fishes
		11	Scattering layer

Fine-scale scoring

During scoring it was apparent that some descriptive fine-scale habitat features were not captured in the SGFA scores. In particular, distinctions within the ‘low/encrusting fauna’ category were not captured in the SGFA scheme. In addition, the SGFA scheme did not cater for a distinction between bare soft sediments with no epifauna (implying no life fauna) and areas where the sediments were consolidated by a matrix of detritus and mostly dead encrusting fauna. Comments were added in the video-data scoring phase to distinguish these regions and were formalised into a fine-scale habitat score in the data processing phase. The scores, their descriptions and a typical example image are given in Table 6.2.1.4.

Table 6.2.1.4 Fine-scale habitat categories added to the SGFA scores based on observations and records collected through the scoring phase.

Cat	Name	Image
0	**No distinction** *Description:* No comment were added *F-scores affected:* all F-scores; consistently used for: 1 – Sponges (large/erect); 3 - Mixed fauna (erect)	No example
1	**Fine detritus** *Description:* fine but clearly visible layer of detrital scum on sediments, particularly obvious where the sediments are disturbed *F-scores affected:* 0 – no fauna; 9 – Bioturbation; 7- Sedentary/solitary fauna	
2 & 3	**Coarse detritus** *Description:* patched of large detritus, or a matrix of coarse detritus and/or dead, broken up fauna such as hard bryozoans or ophiuroids forming a crust on sediments *F-scores affected:* 0 – no fauna; 9 – Bioturbation; 7- Sedentary/solitary fauna; 6 – low/encrusting fauna (low abundance)	
4	**'Mattress-like'** *Description:* regular pattern of shallow burrows of ophiuroids, forming dimples, giving the sediment a mattress-like appearance. In high resolution photographs ophiuroid arms can often be distinguished in the burrows *F-scores affected:* 9 – Bioturbation; 7- Sedentary/solitary fauna; some 6 – low/encrusting fauna (low abundance)	
5	**Turf** *Description:* very low bryozoan community with many branching, hard bryozoans and sponges *F-scores affected:* 6 – low/encrusting fauna	
6	**Thicket** *Description:* moderately erect bryozoan community with many articulate zooidal and articulate branching soft bryozoans, some sponges and other fauna *F-scores affected:* 6 – low/encrusting fauna	

Thematic mapping

Thematic mapping was extensively used to illustrate the distribution and patch structure of the habitat types within sites. The calculated layback position of the camera described in Section 6.1.4 enabled geolocation of each one-second frame grab of the video within an estimated radius of ~20 m. This permitted accurate spatial overlay of the video scores on seabed maps.

The one second positional data was appropriate to demonstrate patch-sizes and patchiness in habitat distributions at individual sites; however, where a fishery wide view was necessary to show broad-scale pattern we used a stylised illustration (Figure 6.2.1.1a). In the stylised map, 50 m depth bins were shown as near-equally spaced strata, and the area mapped at each site widened to a corridor so that the thematic mapping could be seen at the scale of the whole study area. The stylisation of the depth-bins was necessary because the 150-550 m depth-band sampled in our study is very narrow — between 3 and 10 km wide in the north (Figure 6.2.1.1.b and c), and up to 15 km wide in the southwest (Figure 6.2.1.1.d).

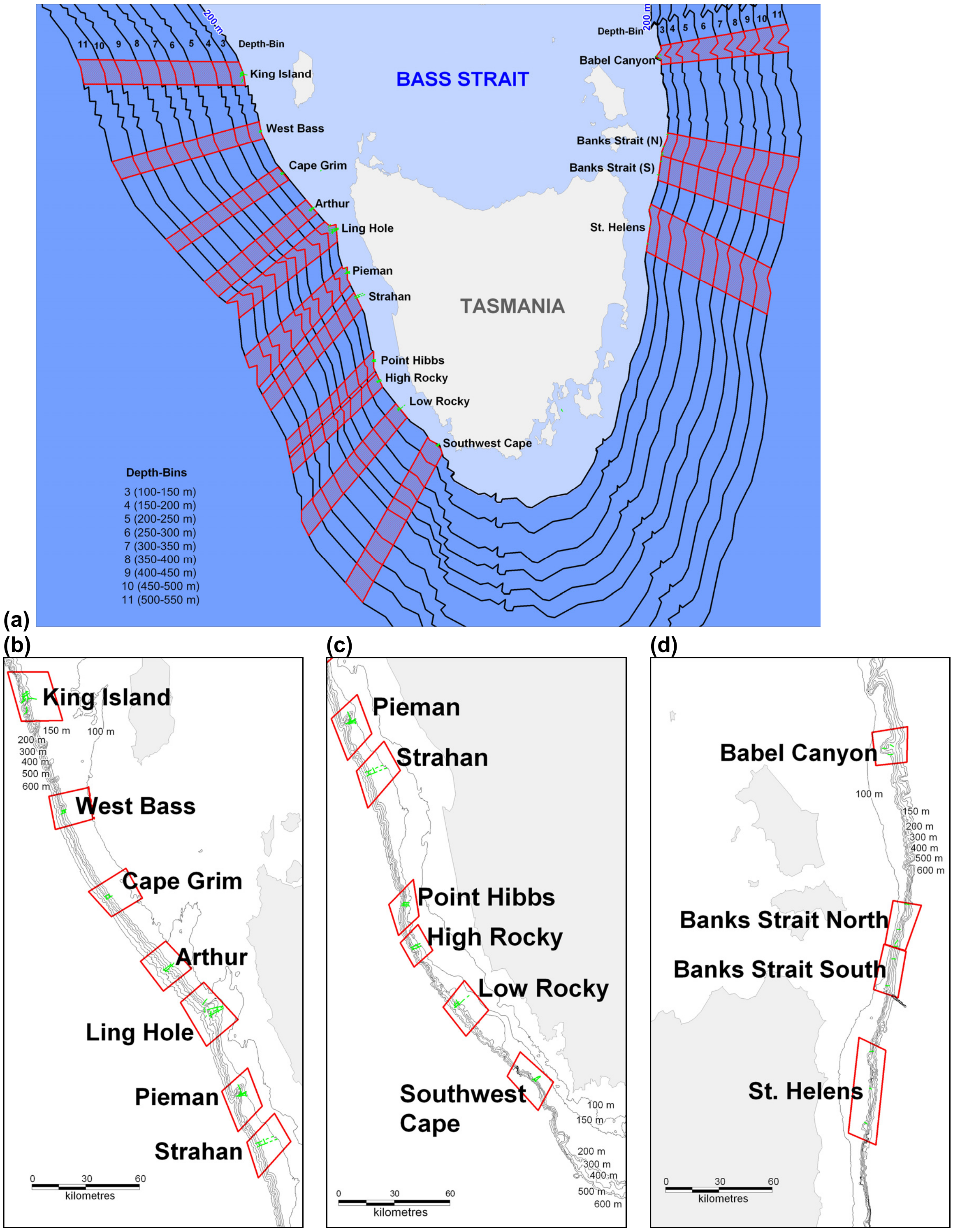


Figure 6.2.1.1 (a) Stylised map of 50 m depth bins from 150 m to 550 m, divided into near-equally spaced strata using a replicated 200 m isobath with the area mapped at each study site widened to a corridor; (b to d) the actual 100-600 m isobaths, the width of the stylised corridors (red boxes) and the video transects (green lines).

6.2.2 Measurements from stereo video

Photogrammetric methods for making measurements from stereo imagery used well established procedures. Accurate three dimensional measurements (x, y, z) were acquired by using appropriately configured and calibrated cameras (Shortis and Harvey, 1998) and the Vision Measurement System (VMS) software (Robson and Shortis 2006).

Prior to each survey, in-water calibrations of the stereo cameras were undertaken to determine the configuration of the two cameras and provide a calibration file and photo orientation file to be later used during the measurement process (see Appendix 5).

In preparation for measurements, synchronic video footage of interest needed to be located on the tapes, captured, and converted to a format compatible with the VMS software. The video scoring database included fields for the location, survey and operation number as well as the tape time-code for every data entry. Thus, a database query to extract for example all sightings of giant crabs enabled us to easily locate the equivalent video footage on both tapes. The segments of interest were captured to hard-drive on a computer using Adobe Premiere Pro and a Matrox capture card. Each clip was then compressed using DivX 6.4 codec to reduce the file size and make the .AVI clips compatible with VMS.

6.2.3 Still images

Still images were visually examined for fauna that was recognisable, and identifiable to a functional taxonomic group. An image gallery was constructed of recognisable fauna (sessile and mobile invertebrates and fishes) by cutting out each type from its parent image. Expert identifications of invertebrates to the lowest possible level – often functional group at phylum level (e.g. sponges), but to species for some of the mobile invertebrates was completed by Karen Gowlett-Holmes. Fishes were identified as far as possible by various experts at CMAR. These identifications were then compared to published lists of prey items of giant crabs.

6.3 Statistical Analysis of video data

6.3.1 Data treatment

Statistical analysis required summarising of the 277,500 records from the one second interval video data. To do this we divided each site into 50 m depth-bins (Table 6.3.1.1) and we combined the five main categories scored from the videos – S, G, F, A, and fine-scale – into 60 variables of three variable types: (1) substratum and geomorphology (SG – 30 variables), fauna and abundance (FA – 24 variables) and fine-scale (6 variables) (Table 6.3.1.2). The one-second interval video data was summarised into a matrix of percentage occurrence of each of these 60 variables by transect and depth-bin (sample). Using the percentage occurrence standardised the data for the unequal numbers of frames observed in each sample (depth-bin or site). Depth-bins 1, 2 and 11, and other samples where < 100 frames with observations were recorded were excluded from the analyses

Table 6.3.1.1 Distribution of video-frames over 11 depth-bins by site

Depth-Category	1	2	3	4	5	6	7	8	9	10	11	
Depth bin (m)	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	Total N
King Is	1	485	3361	7345	5134	7935	6284	3434	4643	3927	2052	44601
West Bass			1914	2785	1841	1104	2213	700	663			11220
Cape Grim		19	1092	2654	1066	742	1721	1809	478			9581
Arthur			2610	4059	1997	2197	2492	5205	298			18858
Ling Hole		14	4890	6680	4703	2893	3416	4986	7311	4292	3961	43146
Pieman	2	121	4494	7705	3543	4228	4611	2099	2462	2075	46	31386
Strahan			2095	8996	1051	2608	1243	764	17			16774
Pt Hibbs			2750	3583	719	1133	2246	2857	793			14081
High Rocky			3168	3726	1118	1035	2725	2364	1532	108		15776
Low Rocky			47	11314	571	588	2785	6241	1297	935		23778
SW Cape				6138	703	978	2241	632	15			10707
Babel Canyon			1239	863	1190	3214	1318	1571	250			9645
Banks Strait N			537	437	496	840	3064	1801	141			7316
Banks Strait S			1344	1159	1709	1972	4127	2586	228			13125
St Helens			967	747	1979	1937	1018	492	352	14		7506
Total # frames	3	639	30508	68191	27820	33404	41504	37541	20480	11351	6059	277500

Table 6.3.1.2 Observed combinations of substratum & geomorphology, fauna & abundance and fine-scale scores used as variables for statistical analyses of the video data

SG	SG	FA	FA	Fine-scale	Fine-scale
0/10	fine, flat	01	no fauna, low	0	No distinction
20	coarse, flat	91	Bioturbation, low	1	Fine detritus
11/2	fine, ripples	92	Bioturbation, med	2&3	Coarse detritus
21/2	coarse, ripples	93	Bioturbation, high	4	Mattress-like
0/13	fine, irregular	71	Sedentary/solitary, low	5	Turf
23	coarse, irregular	72	Sedentary/solitary, med	6	Thicket
24	coarse, debris flow	41	Crinoids, low		
15	fine, subcrop	42	Crinoids, low		
25	coarse, subcrop	51	Octocorals, low		
26	coarse, outcrop 1a	61	Mixed (low/encrusting), low		
27	coarse, outcrop 1b	62	Mixed (low/encrusting), med		
29	coarse, outcrop 2b	63	Mixed (low/encrusting), high		
30	gravel, flat	21	Sponge (small/low), low		
33	gravel, irregular	22	Sponge (small/low), med		
35	gravel, subcrop	23	Sponge (small/low), high		
36	gravel, outcrop 1a	31	Mixed (erect), low		
37	gravel, outcrop 1b	32	Mixed (erect), med		
44	cobble/boulder, debris flow	33	Mixed (erect), high		
45	cobble/boulder, subcrop	11	Sponge (large/erect), low		
46	cobble/boulder, outcrop 1a	12	Sponge (large/erect), med		
47	cobble/boulder, outcrop 1b	13	Sponge (large/erect), high		
49	cobble/boulder, outcrop 2b	81	Mobile, low		
60	rock, flat	82	Mobile, med		
62	rock, rippled	83	Mobile, high		
63	rock, irregular				
65	rock, subcrop				
66	rock, outcrop 1a				
67	rock, outcrop 1b				
68	rock, outcrop 2a				
69	rock, outcrop 2b				

6.3.2 Statistical methods used

We used a variety of analyses from the statistics software package Primer v5 (Clarke and Gorley 2001); they are named and a short description of their usage is given in Table 6.3.2.1). The Bray-Curtis similarity measure (Bray and

Curtis 1957) was used for all video data, Euclidean distance measure (Clarke and Gorley 2001) for environmental data.

Table 6.3.2.1 Statistical methods in Primer v5 employed for the analyses of data, including a short description paraphrased from Clarke and Gorley (2001).

Statistical method	Reference
ANOSIM	ANOSIM procedure operates on a similarity matrix, carrying out a rough analogue to the standard univariate 1- and 2-way ANOVA tests. *R*-statistic: value between 0 (no difference) to 1 (statistic: value between 0 (no difference) to 1 (all similarities within groups are less than any similarities between groups) similarities within groups are less than *any* similarities between groups).
Group-average Cluster analysis	Cluster analysis based on a similarity matrix is used to identify groupings of samples based on their similarity; a similarity dendrogram can be used to visualise the separation of groups
Non-metric Multidimensional scaling (MDS)	Analysis based on a similarity matrix, fitting the information into 2- or more dimensional space.
SIMPER	Calculates the 'species' (variable) contribution to the within group similarity and between groups dissimilarity.
RELATE	Calculates a rank correlation coefficient (ρ) between two similarity matrices; used to test if the among-sample relationships for two sets of variables for the same samples are the same (ρ=1) or how much they differ (ρ approximately zero if there is no relationship whatsoever)
BIOENV	Calculates a measure of agreement between the data matrix and corresponding matrices derived from all combinations of environmental variables. Basically a RELATE analysis for each combination of environmental variables

6.4 Ecological risk assessment analysis

We assessed the potential risk for impacts on seabed habitats from bottom trawling and crab trapping using an existing framework, the "Ecological Risk Assessment for the Effects of Fishing" (ERAEF) - developed jointly by CSIRO Marine and Atmospheric Research, and the Australian Fisheries Management Authority (Hobday et al 2006). The full ERAEF framework is a hierarchical system to assess the ecological risks from fishing against five ecological components – target species; by-product and by-catch species; threatened, endangered and protected (TEP) species; habitats; and (ecological) communities (Hobday et al 2006; Wayte et al 2006). The ERAEF hierarchical framework moves from a comprehensive but largely qualitative analysis of risk at Level 1, through a more focused and semi-quantitative approach at Level 2, to a highly focused and fully quantitative "model-based" approach at Level 3

(Hobday et al 2006; Wayte et al 2006). Here, we used only the Level 2 component.

ERAEF Level 2 (ERAEF method version 9.2) is a 'Productivity - Selectivity Analysis' (PSA) that scores the characteristics of subfishery (gear) types against habitat types using a set of productivity (resilience) and susceptibility (resistance) attributes. Habitat productivity attributes take account of the speed of regeneration of fauna, and likelihood of natural disturbance, while susceptibility attributes consider the distributions and overlaps of habitat and the subfishery and the relative disturbance caused by its gear type, and the physical nature of the habitat type (including removability, hardness, area, slope) (Table 6.3.2.1). Each habitat type encountered by the subfishery is ranked from 1 (low vulnerability) to 3 (high vulnerability) for each attribute via a set of lookup tables and decision rules, and an overall score of 'potential risk' is calculated. Interactions scoring at high potential risk identify the priorities for further examination when an absolute measure or risk may be determined by a full risk assessment at Level 3.

Table 6.3.2.1 Susceptibility and productivity attributes for habitats used in the PSA (from Wayte et al., 2006)

Aspect	Attribute	Concept	Rationale
Susceptibility			
Availability	General depth range (Biome)	Spatial overlap of subfishery with habitat defined at biomic scale	Habitat occurs within the management area
Encounterability	Depth zone and feature type	Habitat encountered at the depth and location at which fishing activity occurs	Fishing takes place where habitat occurs
	Ruggedness (fractal dimension of substratum and seabed slope)	Relief, rugosity, hardness and seabed slope influence accessibility to different sub-fisheries	Rugged substratum is less accessible to mobile gears. Steeply sloping seabed is less accessible to mobile gears
	Level of disturbance	Gear footprint and intensity of encounters	Degree of impact is determined by the frequency and intensity of encounters (inc. size, weight and mobility of individual gears)
Selectivity	Removability/ mortality of fauna/ flora	Removal/ mortality of structure forming epifauna/ flora (inc. bioturbating infauna)	Erect, large, rugose, inflexible, delicate epifauna and flora, and large or delicate and shallow burrowing infauna (at depths impacted by mobile gears) are preferentially removed or damaged.
	Extent of area	How much of each habitat is present	Effective degree of impact greater in rarer habitats: rarer habitats may maintain rarer species.
	Removability of substratum	Certain size classes can be removed	Intermediate sized clasts (~6 cm to 3 m) that form attachment sites for sessile fauna can be permanently removed
	Substratum hardness	Composition of substrata	Harder substratum is intrinsically more resistant
	Seabed slope	Mobility of substrata once dislodged; generally higher levels of structural fauna	Gravity or latent energy transfer assists movement of habitat structures, e.g. turbidity flows, larger clasts. Greater density of filter feeding animals found where currents move up and down slopes.
Productivity			
Productivity	Regeneration of attached fauna	Accumulation/ recovery of fauna	Fauna have different intrinsic growth and reproductive rates which are also variable in different conditions of temperature, nutrients, productivity.
	Natural disturbance	Level of natural disturbance affects intrinsic ability to recover	Frequently disturbed habitats adapted to recover from disturbance

7 *Results/Discussion*

7.1 Define and map key habitats on the shelf edge (~150-400 m) at locations around Tasmania where fisheries using different gear types interact

7.1.1 <u>Initial data summary and exploratory analysis</u>

Initially, the data are presented as 15 site by site summaries for the 72 successful photographic transects that spanned the main area of the crab fishery from King Island in the north to SW Cape in the south (with some comparative sites on the east coast). In total we coded 277,500 video records for five categories, describing the substratum (S), geomorphology (G), fauna (F), its abundance (A), and fine-scale fauna (fine-scale).

We described each site using summaries of percentage occurrence of the scored categories, and the distribution of the combined S and G scores (SG – 30 variables), the combined F and A scores (FA – 24 variables), and the fine-scale scores (6 variables) over 50 m depth bins.

An initial statistical analysis comparing sites and depth zones based on these, the raw data, was also included.

Data summary and description by site

King Island (high crab / low trawl)

Eight cross-depth and two along depth transects were completed Table 6.1.1.1. A summary of data for this site is given in Table 7.1.1.1 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.2. There were high proportions of irregular and flat coarse sediments, with smaller proportions of rippled and flat fine sediments, and outcropping rock. Fauna were predominantly low and encrusting, mixed erect fauna and bioturbating fauna; sedentary and mobile fauna were present in relatively low proportions between 150 and 450 m depths, substrata were a mix of irregular coarse and flat coarse sediments, with an increase in the proportion of the latter beyond 300 m depth. Irregular coarse sediments made up all substrata between 200 and 300 m depth. In depths < 150 m, there was a substantial proportion of rocky outcrop (25%) together with rippled fine sediments (35%). Beyond 450 m depth, substrata were predominantly flat fine sediments with some rocky outcrops and boulders (Figure 7.1.1.1 a).

Between 150-300 m depth, the fauna was dominated by low and encrusting forms, with bryozoan thicket and turf (Figure 7.1.1.1 b & c) collectively making up the largest proportions between 200 and 300 m depth, with mixed erect fauna (Figure 7.1.1.1 b) making up smaller proportions. Below 300 m, bryozoan thicket and turf was progressively replaced by other encrustors (to 450 m) and then by bioturbating fauna (Figure 7.1.1.1 b & c). In the shallowest depth range sampled (100 to 150 m), mixed erect fauna (Figure 7.1.1.1 b) was the dominant type in > 40% of video records (Figure 7.1.1.1 b).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.2) (a) low/encrusting (soft bryozoans) on rippled fine sediments; (b) mixed erect fauna (sponges and bryozoans) on outcropping (undercut) rock; (c) fine detritus on rippled coarse sediment; (d) low/encrusting (soft bryozoans) on coarse sediments; (e) low/encrusting turf (bryozoans and sponges) on irregular coarse sediments; (f) low/encrusting turf (bryozoans) on irregular coarse sediments with giant crab; (g) low/encrusting fauna on low rocky outcrop; (h) low/encrusting fauna on high rocky outcrop.

Table 7.1.1.1 King Island: Details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200501	5	161.9	279.7	2944	23	2921
L	CH200501	7	252.2	417.2	4467	79	4388
X	CH200401	31	252.5	500.6	6161	146	6015
X	CH200501	6	150.9	527.8	5168	99	5069
X	CH200501	8	181.3	377.2	2214	12	2202
X	SS200404	32	196.9	456.9	3211	10	3201
X	SS200404	33	50	529.4	4393	1384	3009
X	SS200404	39	151.6	419.1	4601	111	4490
X	SS200404	40	221.3	570.9	5490	214	5276
X	SS200404	41	107.8	310.6	5952	32	5920

Table 7.1.1.2 King Island: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of major faunal types based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	7.5	Unrippled	*34.0*
Coarse sediments	**87.4**	Rippled	2.9
Gravel/pebble	0.0	Highly irregular	**56.7**
Cobble/boulder	0.6	Debris flow/rubble banks	0.0
Sedimentary rock	4.4	Subcrop	2.2
		Outcrop (low a)	1.2
		Outcrop (low b)	2.3
		Outcrop (high a)	0.0
		Outcrop (high b)	0.7
Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	3.8	No distinction	**50.5**
Bioturbation	*18.3*	Fine detritus	0.3
Solitary/sedentary fauna	1.6	Coarse detritus	11.4
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	0.5
Octocorals	0.0	Bryozoan turf	*17.7*
Mixed fauna (low/ encrusting)	**63.5**	Bryozoan thicket	*19.6*
Sponge (small/low)	0.2		
Sponge (large/erect)	10.8		
Mixed fauna (erect)	0.3		
Mobile fauna	1.5		

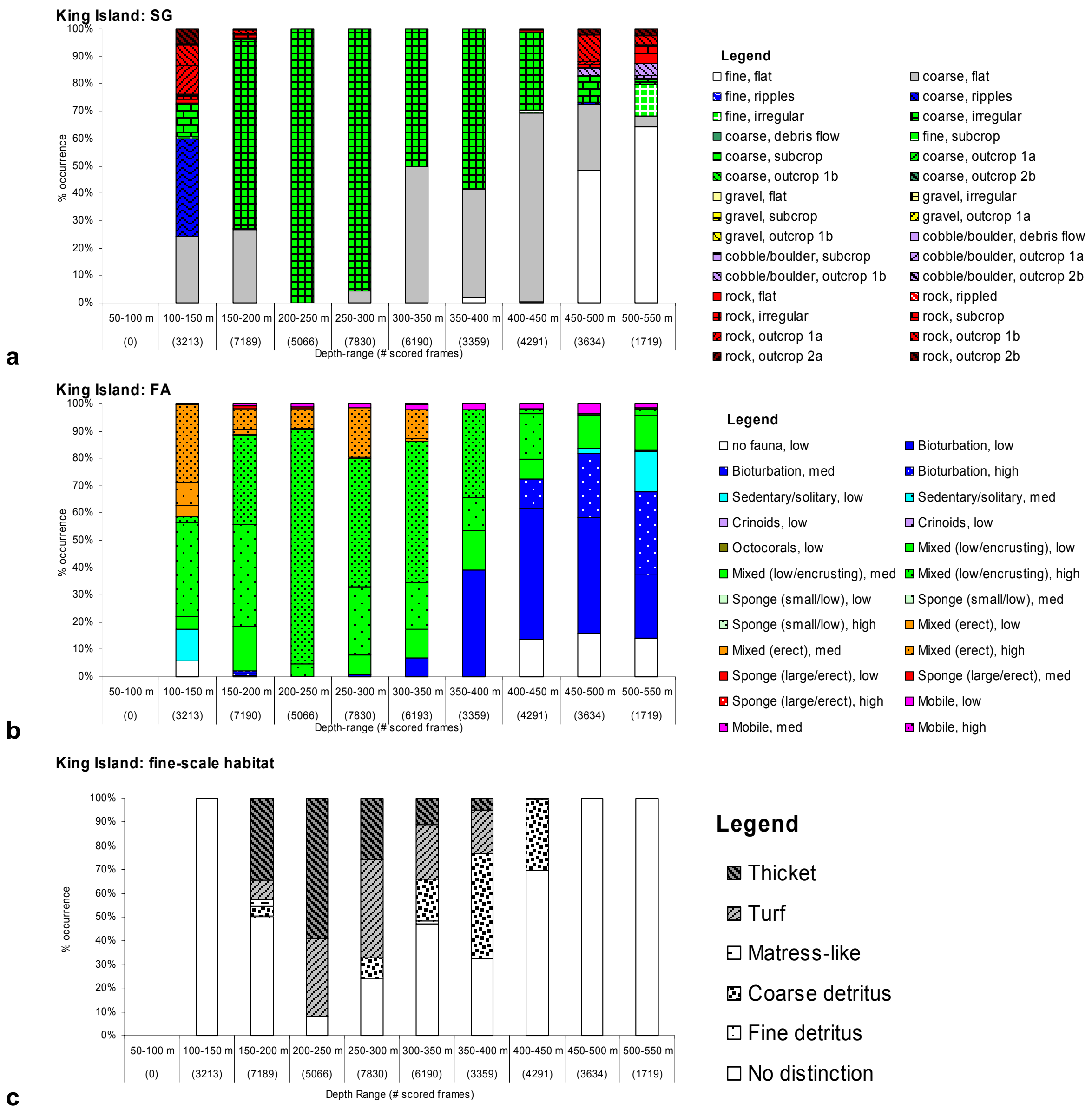
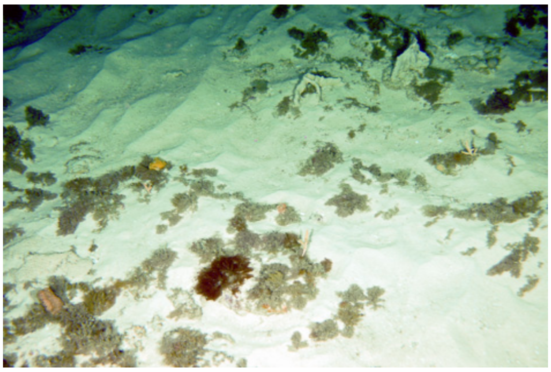


Figure 7.1.1.1 King Island: percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.



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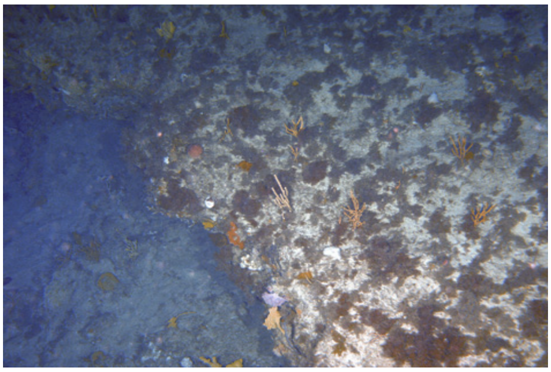

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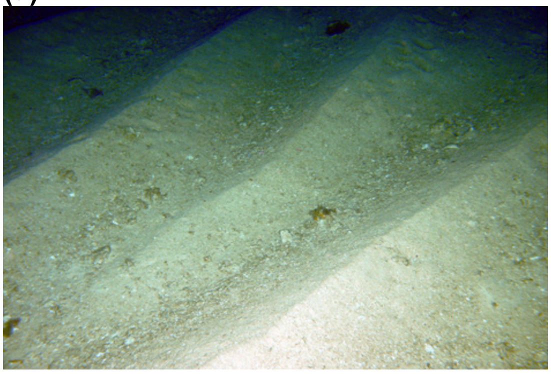

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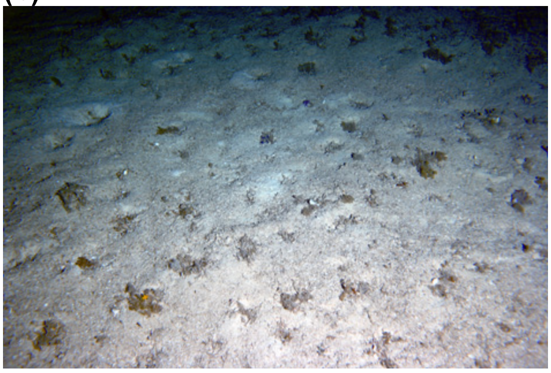

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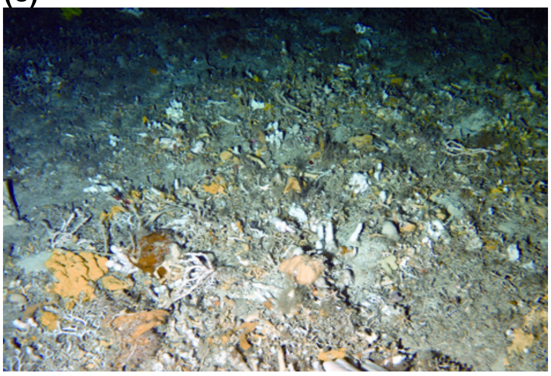

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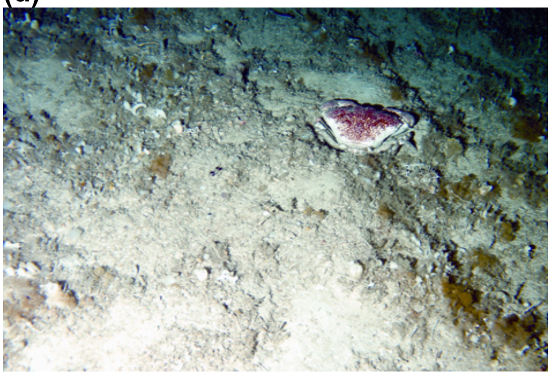

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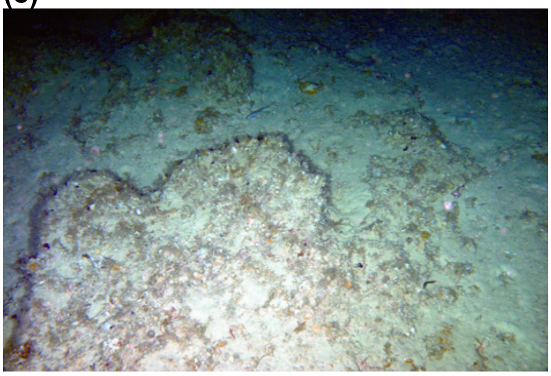

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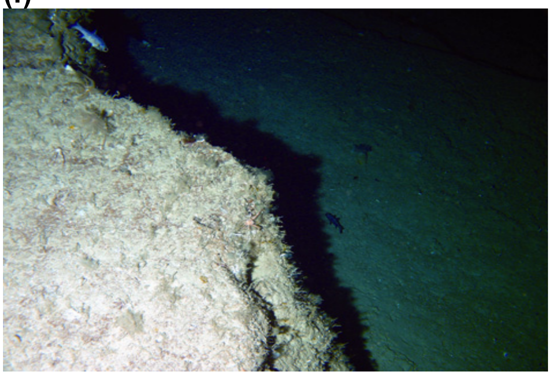


(h)

Figure 7.1.1.2 Seabed images from the 'King Island' site. Depth in meters and transect number (T) is given for each (a) 117 m, T 41(b) 191 m, T 41 (c) 122 m, T 41 (d) 168 m, T 5 (e) 192 m, T 39 (f) 291 m, T 39 (g) 448 m, T 32 (h) 503 m, T 33. See text for descriptions

West Bass (high crab / low trawl)

Three cross-depth and two along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.3 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.4. There was a high proportion of irregular coarse sediments, with smaller proportions of flat coarse sediment, rippled sediment and rocky outcrops. Fauna were predominantly low/encrusting with a relatively high proportion of bioturbating fauna.

In depths between 150 and 400 m, substrata were virtually all irregular coarse sediments, with flat coarse sediment in > 400 m depth and an even mix of rock outcrop, rippled and flat coarse sediments and irregular coarse sediments in depths < 150 m. No data were collected below 450 m (Figure 7.1.1.3a).

Between 150-400 m depth, the fauna was dominated by low and encrusting forms, with bryozoan thicket making up the largest proportions between 150 and 250 m depth, and turf between 250 and 300 m, and a mix of turf and coarse detritus between 300 and 350 m depth. Below 350 m, bioturbating fauna appeared, becoming virtually 100% of fauna below 400 m depth. A mix of faunal types occurred in the shallowest depth range sampled (100 to 150 m): bioturbating fauna dominated (~60%) with smaller proportions of low/encrusting and mixed erect fauna (Figure 7.1.1.3b). A high proportion of shallow bioturbating fauna was ‘mattress-like’ in appearance indicating the likely presence of ophiuroids.

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.4) (a and b) mixed erect fauna (sponges and bryozoans) on outcropping rock; (c) habitat transition between mixed erect fauna on rocky outcrop with bioturbated fine sediment; (d) bioturbated rippled sediments; (e and f) soft bryozoans on irregular fine sediments (‘mattress-like’ in appearance indicating the likely presence of burrowing ophiuroids); (g) bryozoan turf on irregular coarse sediments; and (h) fine detritus on bioturbated fine sediment.

Table 7.1.1.3 West Bass: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200501	11	122.5	141.9	624	10	614
L	CH200501	10	228.1	351.9	2478	0	2478
L	CH200501	12	161.2	191.9	1452	8	1444
X	CH200501	9	101.3	399.4	3365	31	3334
X	CH200501	13	136.6	447.2	3301	27	3274

Table 7.1.1.4 West Bass: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	0.0	Unrippled	10.5
Coarse sediments	**95.0**	Rippled	5.2
Gravel/pebble	0.0	Highly irregular	**79.3**
Cobble/boulder	0.2	Debris flow/rubble banks	0.0
Sedimentary rock	4.8	Subcrop	1.3
		Outcrop (low a)	0.5
		Outcrop (low b)	3.0
		Outcrop (high a)	0.2
		Outcrop (high b)	0.0
Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	0.4	No distinction	**24.7**
Bioturbation	*23.8*	Fine detritus	6.1
Solitary/sedentary fauna	0.0	Coarse detritus	13.4
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	9.8
Octocorals	0.0	Bryozoan turf	**21.0**
Mixed fauna (low/ encrusting)	**71.6**	Bryozoan thicket	**24.9**
Sponge (small/low)	0.2		
Sponge (large/erect)	3.3		
Mixed fauna (erect)	0.1		
Mobile fauna	0.6		

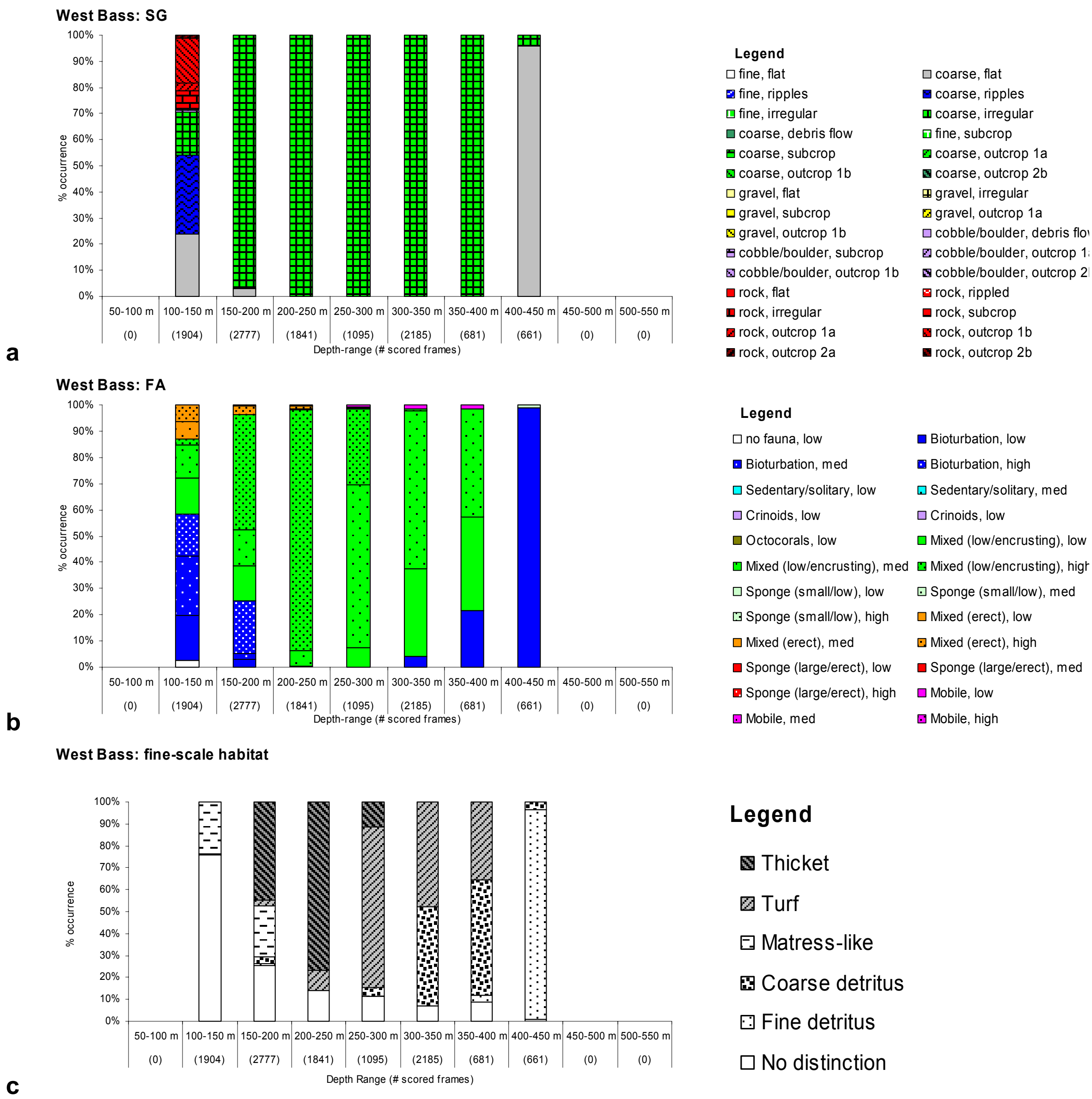


Figure 7.1.1.3 West Bass: percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

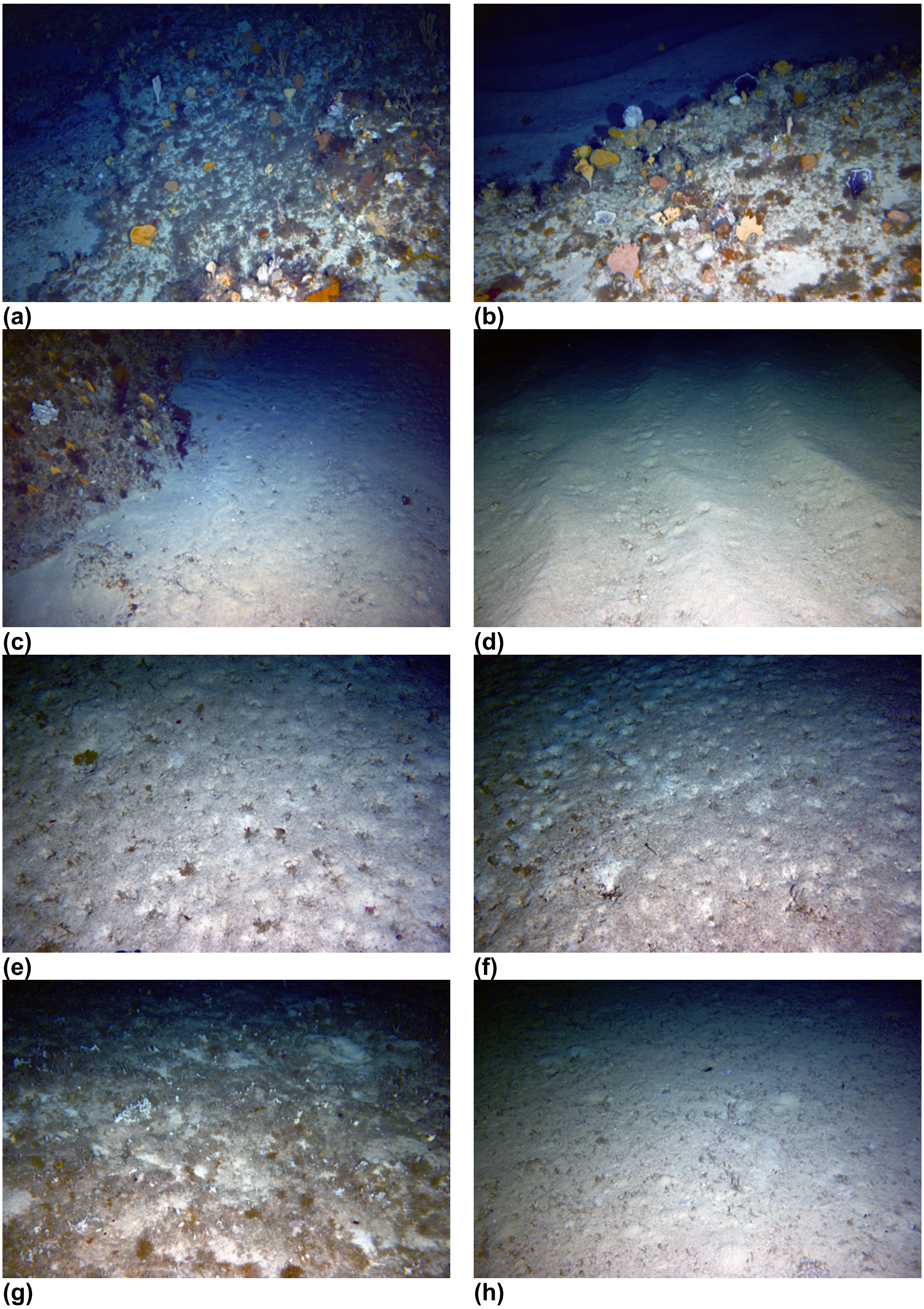


Figure 7.1.1.4. Seabed images from the 'West Bass' site. Depth in meters and transect number (T) is given for each (a) 111 m, T 19 (b) 119 m, T 9 (c) 130 m, T 11 (d) 132 m, T 11 (e) 163 m, T 9 (f) 178 m, T 13 (g) 260 m, T 9 (h) 416 m, T 13. See text for descriptions

Cape Grim (high crab / high trawl)

Two cross-depth and two along depth transects were completed Table 6.1.1.1. A summary of data for this site is given in Table 7.1.1.5 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.6. There was a high proportion of irregular coarse sediments, a substantial proportion of flat coarse sediment, and small proportion of rocky outcrops. Cobble/boulder in the 50-100 m depth range is represented by only 13 video records. Fauna were predominantly low/encrusting with a relatively high proportion of bioturbating fauna but also included mixed erect fauna and large sponges.

Between 200 and 350 m depths, substrata were virtually all irregular coarse sediments. Below 300 m depth, the proportion of flat coarse sediment rapidly increases, becoming 100% in >400 m depth. In the shallow range sampled, a mix of flat and irregular coarse sediments occurred in 150-200 m, and a mix of rock outcrop, rippled, irregular and flat coarse sediments in depths < 150 m (Figure 7.1.1.5a).

Between 200 and 400 m depth, the fauna was dominated by low and encrusting forms, with bryozoan thicket making up the largest proportions between 200 and 250 m depth, and turf between 250 and 300 m, and a mix of turf and increased coarse detritus between 300 and 400 m depth (Figure 7.1.1.5b & c). Bioturbating fauna appeared at 300 m, and made up~50% below 400 m depth. However, few data were taken below 400 m depth. A mix of faunal types occurred in 100 to 200 m depths: bioturbating fauna dominated (~50-60%) of which a large fraction appeared 'mattress-like' indicating the likely presence of ophiuroids; low/encrusting fauna, mixed erect fauna and large sponges were also present (Figure 7.1.1.5b).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.6) (a) transition between fine, rippled sediments and mixed erect fauna (soft bryozoans and sponges) on coarse sediment, possibly as a veneer on rock subcrop; (b) mixed erect fauna (sponges and bryozoans) on high relief outcropping rock; (c) detritus on irregular coarse sediment; (d and e) bioturbating fauna (predominantly ophiuroids) on irregular coarse sediments; (f) low/encrusting turf (bryozoans and ascidians) on irregular coarse sediments;

(g) low/encrusting fauna (ascidians and bryozoans) on irregular/flat coarse sediment; (h) bioturbators and coarse detritus on irregular coarse sediment.

Table 7.1.1.5 Cape Grim: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200501	1	145.9	160.9	1191	13	1178
L	CH200501	3	325	423.4	2131	487	1644
X	CH200501	2	86.9	374.1	3285	37	3248
X	CH200501	4	141.6	428.1	2974	1	2973

Table 7.1.1.6 Cape Grim: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of major faunal types based on video scores at 1-second intervals.

Substratum (S)	**% occ.**	**Geomorphology (G)**	**% occ.**
Fine sediments	0.6	Unrippled	*36.6*
Coarse sediments	**95.2**	Rippled	1.8
Gravel/pebble	0.0	Highly irregular	**57.3**
Cobble/boulder	0.4	Debris flow/rubble banks	0.0
Sedimentary rock	3.8	Subcrop	0.8
		Outcrop (low a)	1.7
		Outcrop (low b)	0.5
		Outcrop (high a)	0.0
		Outcrop (high b)	1.3

Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	*19.9*	No distinction	*16.4*
Bioturbation	**30.7**	Fine detritus	3.3
Solitary/sedentary fauna	0.6	Coarse detritus	**43.7**
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	*18.4*
Octocorals	0.0	Bryozoan turf	12.8
Mixed fauna (low/ encrusting)	**44.3**	Bryozoan thicket	5.4
Sponge (small/low)	0.6		
Sponge (large/erect)	2.5		
Mixed fauna (erect)	0.1		
Mobile fauna	1.3		

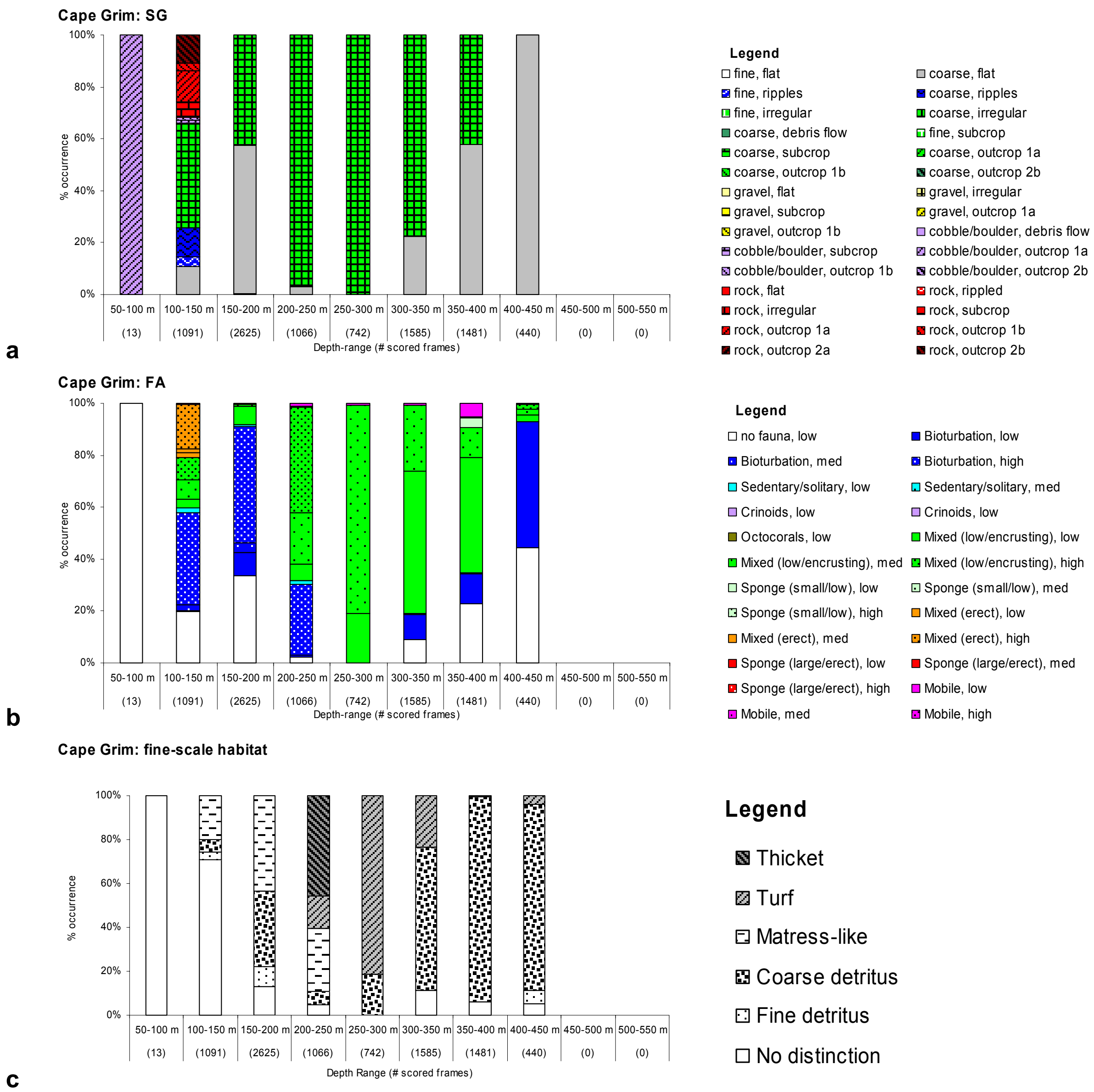
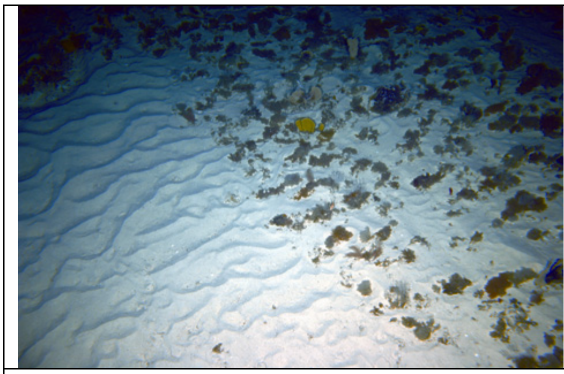


Figure 7.1.1.5 Cape Grim: percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.



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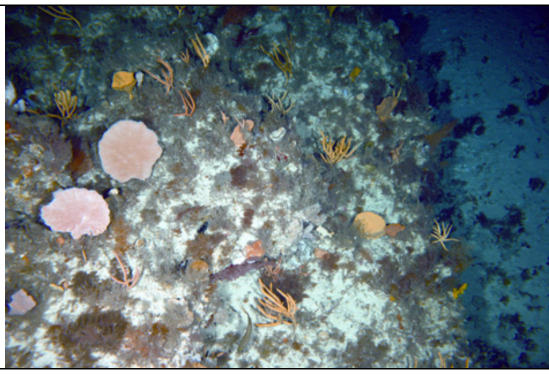

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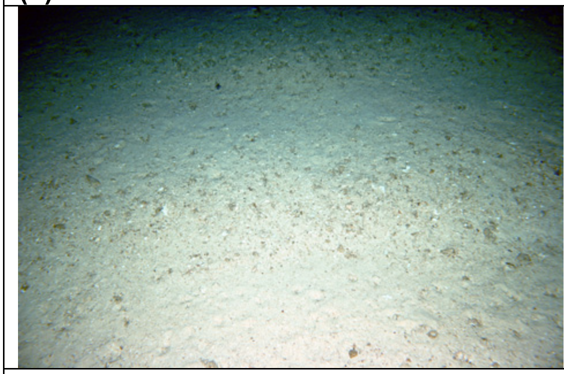

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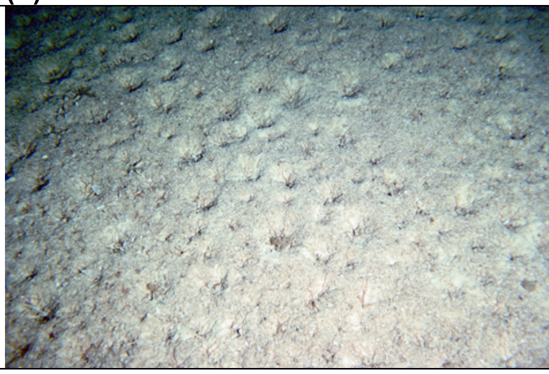

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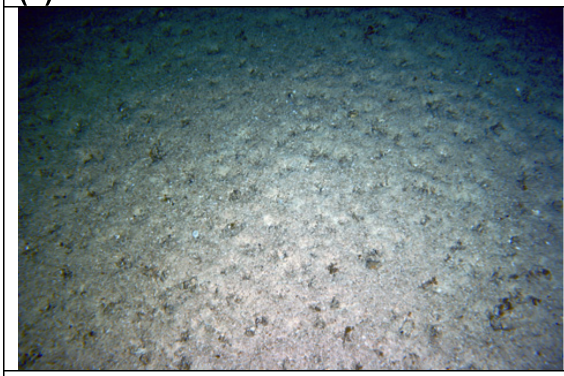

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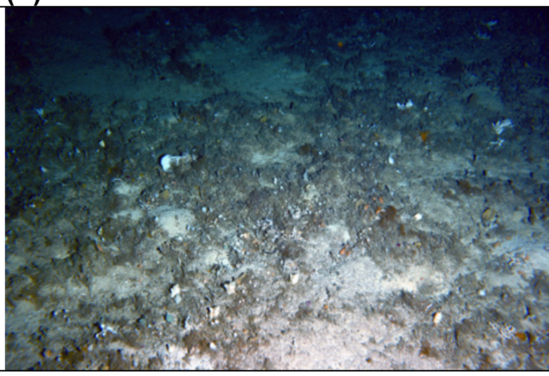

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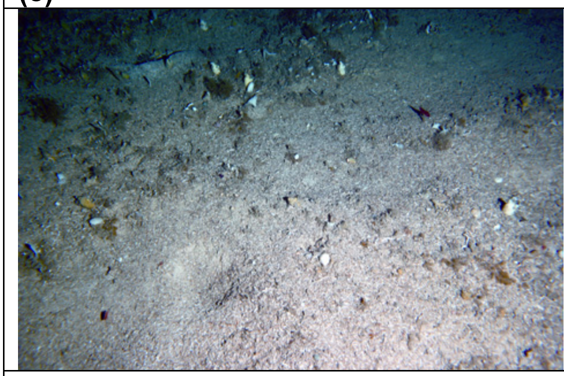

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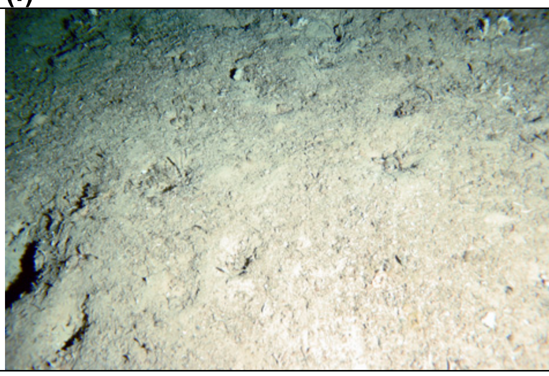

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Figure 7.1.1.6 Seabed images from the ‘Cape Grim’ site. Depth in meters and transect number (T) is given for each (a) 121 m, T 2(b) 123 m, T 2 (c) 129 m, T 2 (d) 149 m, T 4 (e) 186 m, T 1 (f) 269 m, T 2 (g) 270 m, T 4 (h) 401 m, T 3. See text for descriptions

Arthur (high crab / high trawl)

Two cross-depth and two along depth transects were completed Table 6.1.1.1. A summary of data for this site is given in Table 7.1.1.7 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.8. There was a high proportion of irregular coarse sediments; flat coarse sediments made up a small proportion and outcropping rock and rippled coarse sediments were present. Fauna were predominantly low/encrusting and bioturbating; mixed erect fauna made up a small proportion.

Irregular coarse sediments made up the great majority (> 70%) of substrata in all depths between 150 and 450 m depths, with flat coarse sediments making up the remainder. A greater diversity was observed in depths <150 m where there were near-equal proportions of outcropping rock and rippled, flat and irregular coarse sediments (Figure 7.1.1.7a).

Between 200 and 300 m depth, the fauna was dominated by low and encrusting bryozoan turf and coarse detritus (Figure 7.1.1.7b & c). From 300 to 400 m depth, there was a diminishing proportion of low/encrusting fauna and a marked increase of bioturbating fauna. These were associated with coarse detritus; turf and thicket were no longer observed. Below 400 m depth, only bioturbators and fine detritus were observed – but there were few data records. Between 150 and 200 m depth, there was a near equal mix of low/encrusting and bioturbating faunas, each with a substantial fraction of 'mattress-like' patterning indicating the likely presence of ophiuroids. A mix of faunal types occurred in 100 to 150 m depths: bioturbating fauna dominated (~70%) of which a large fraction appeared 'mattress-like' indicating the likely presence of ophiuroids; low/encrusting fauna, mixed erect fauna and a few large sponges were also present (Figure 7.1.1.7b).

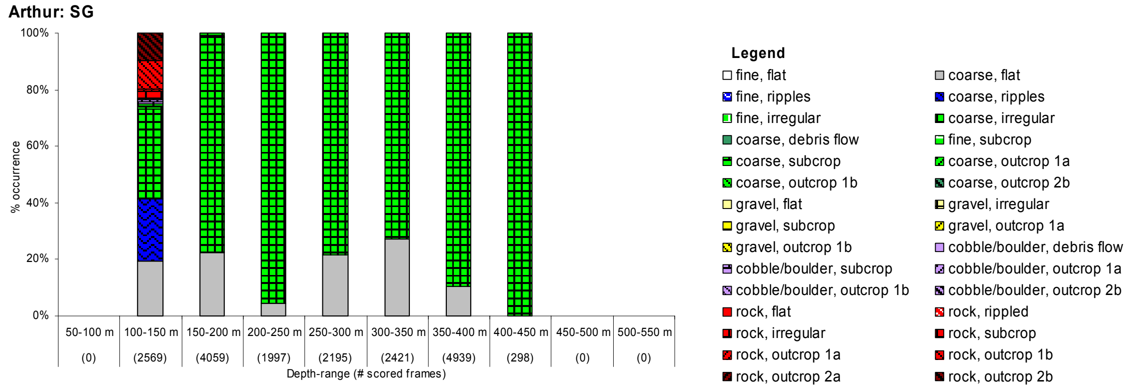
A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.8) (a) mixed erect fauna (soft bryozoans and sponges) on undercut rock outcrop; (b) high abundance of mixed erect fauna (soft bryozoans and sponges) on rock outcrop; (c) bioturbating fauna (forming 'mattress-like' pattern) on strongly rippled coarse sediment; (d) low/encrusting fauna and coarse detritus on irregular coarse sediments; (e) low/encrusting fauna forming dense turf on irregular coarse sediment; (f) coarse detritus on irregular coarse sediment; (g) mix of low/encrusting fauna and coarse detritus on irregular coarse sediments with large excavation from unknown burrower; (h) coarse detritus on flat coarse sediment showing parallel tracks from bottom trawl.

Table 7.1.1.7 Arthur: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200501	16	128.8	158.8	2243	37	2206
L	CH200501	15	331.9	406.3	4134	292	3842
X	CH200501	14	110.6	403.4	6957	21	6936
X	CH200501	17	144.4	405.6	5524	30	5494

Table 7.1.1.8 Arthur: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of major faunal types based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	0.0	Unrippled	17.1
Coarse sediments	**96.5**	Rippled	3.0
Gravel/pebble	0.0	Highly irregular	**76.0**
Cobble/boulder	0.3	Debris flow/rubble banks	0.0
Sedimentary rock	3.2	Subcrop	0.9
		Outcrop (low a)	0.2
		Outcrop (low b)	1.4
		Outcrop (high a)	0.0
		Outcrop (high b)	1.4
Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	1.8	No distinction	*21.5*
Bioturbation	**46.2**	Fine detritus	7.6
Solitary/sedentary fauna	0.3	Coarse detritus	**44.1**
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	10.2
Octocorals	0.0	Bryozoan turf	*15.8*
Mixed fauna (low/ encrusting)	**49.1**	Bryozoan thicket	0.7
Sponge (small/low)	0.1		
Sponge (large/erect)	2.0		
Mixed fauna (erect)	0.0		
Mobile fauna	0.5		



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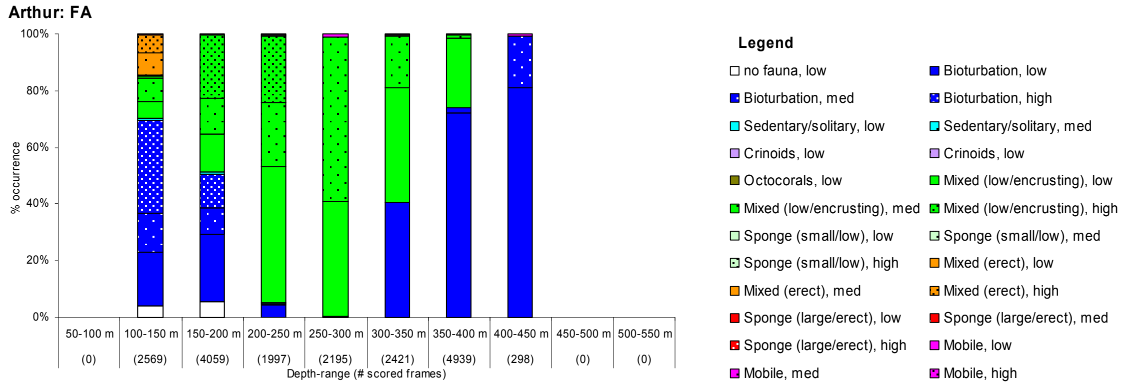
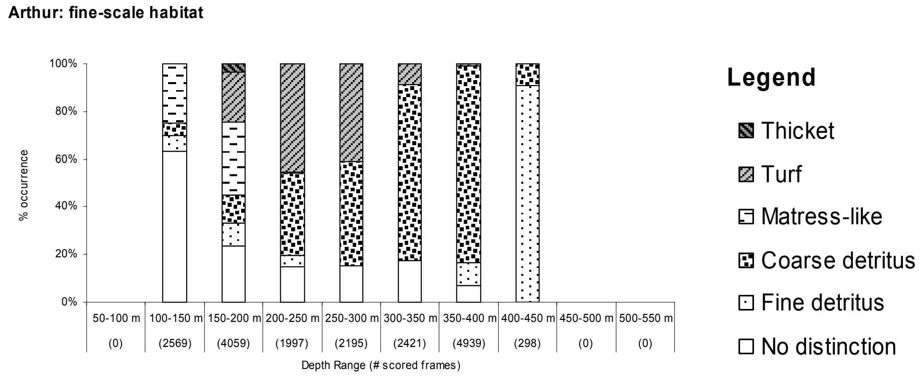


b



c

Figure 7.1.1.7 Arthur: percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

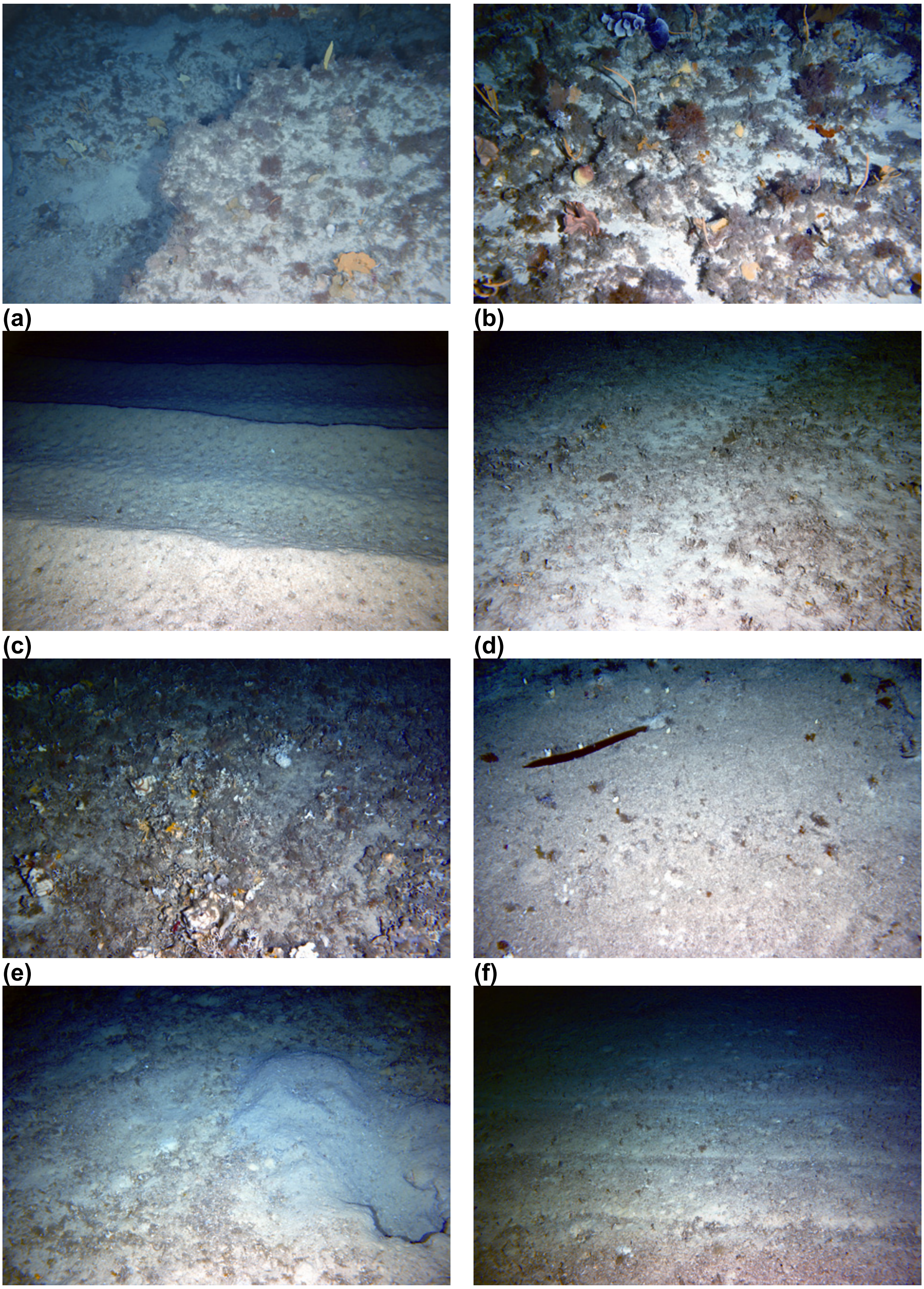


Figure 7.1.1.8 Seabed images from the 'Arthur' site. Depth in meters and transect number (T) is given for each (a) 112 m, T 14, (b) 116 m, T 14 (c) 156 m, T 14 (d) 180 m, T 17 (e) 181 m, T 14 (f) 225 m, T 17 (g) 357 m, T 17 (h) 384 m, T 14. See text for descriptions

Ling Hole (high crab / high trawl)

Three cross-depth and four along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.9 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.10. There were high proportions of flat and irregular coarse and fine sediments; rippled coarse sediments and outcropping rock made up small proportions. Fauna were predominantly low/encrusting and bioturbating, and solitary/ sedentary fauna were present; no fauna were detected in a relatively large proportion of video observations.

Irregular coarse sediments made up the majority (> 70%) of substrata in 200 to 300 m, and were rapidly replaced by coarse and fine flat sediments as depth increased to 550 m. Some rippled fine sediments (~15%) were observed in the 500-550 m stratum. The shallow stratum (100-150 m depth) was predominantly rippled coarse sediments with some rocky outcrop and boulders (Figure 7.1.1.9a).

Low and encrusting fauna and coarse detritus in low to medium abundance made up a large proportion (> 40-50%) of all strata > 150 m depth except 400-450 m. From 250 m depth, there was an increasing proportion of bioturbating fauna, also in low abundance. Small proportions of solitary/sedentary (mainly > 450 m), mixed erect and sponges (< 250 m) and mobiles (50-550 m) also occurred (Figure 7.1.1.9b & c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.10) (a) mixed erect fauna (soft bryozoans and sponges) on large boulder and rock outcrop; (b) high abundance of mixed erect fauna (soft bryozoans and sponges) on undercut rock outcrop; (c) bioturbating fauna (forming 'mattress-like' pattern) on irregular coarse sediment; (d) low/encrusting fauna (bryozoans) on irregular coarse sediments; (e) low/encrusting fauna with coarse detritus on irregular coarse sediment; (f) low/encrusting fauna (sponges and bryozoans) on irregular coarse sediments with giant crab; (g) coarse detritus on flat coarse sediments; (h) low abundance of coarse detritus, some bioturbating fauna on flat coarse sediment showing faint parallel tracks from bottom trawl.

Table 7.1.1.9 Ling Hole: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200501	19	159.7	241.6	2603	0	2603
L	SS200404	75	300.5	577.9	6702	19	6683
L	CH200401	30	409.4	578.7	4371	151	4220
X	CH200501	18	139.7	451.6	11202	176	11026
X	CH200501	20	89.4	471.3	7078	473	6605
X	CH200501	21	140	463.1	6436	319	6117
X	SS200404	49	105.3	250.3	4754	812	3942

Table 7.1.1.10 Ling Hole: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of major faunal types based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	*33.2*	Unrippled	**60.6**
Coarse sediments	**63.7**	Rippled	10.2
Gravel/pebble	0.0	Highly irregular	*26.3*
Cobble/boulder	0.8	Debris flow/rubble banks	0.1
Sedimentary rock	2.3	Subcrop	0.1
		Outcrop (low a)	0.4
		Outcrop (low b)	0.6
		Outcrop (high a)	0.3
		Outcrop (high b)	1.6

Fauna (F)	% occ.	Fine scale habitat	% occ.
No fauna	11.1	No distinction	**74.1**
Bioturbation	**32.7**	Fine detritus	5.2
Solitary/sedentary fauna	2.6	Coarse detritus	16.6
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	1.4
Octocorals	0.0	Bryozoan turf	1.8
Mixed fauna (low/ encrusting)	**49.4**	Bryozoan thicket	0.9
Sponge (small/low)	0.1		
Sponge (large/erect)	3.2		
Mixed fauna (erect)	0.0		
Mobile fauna	1.0		

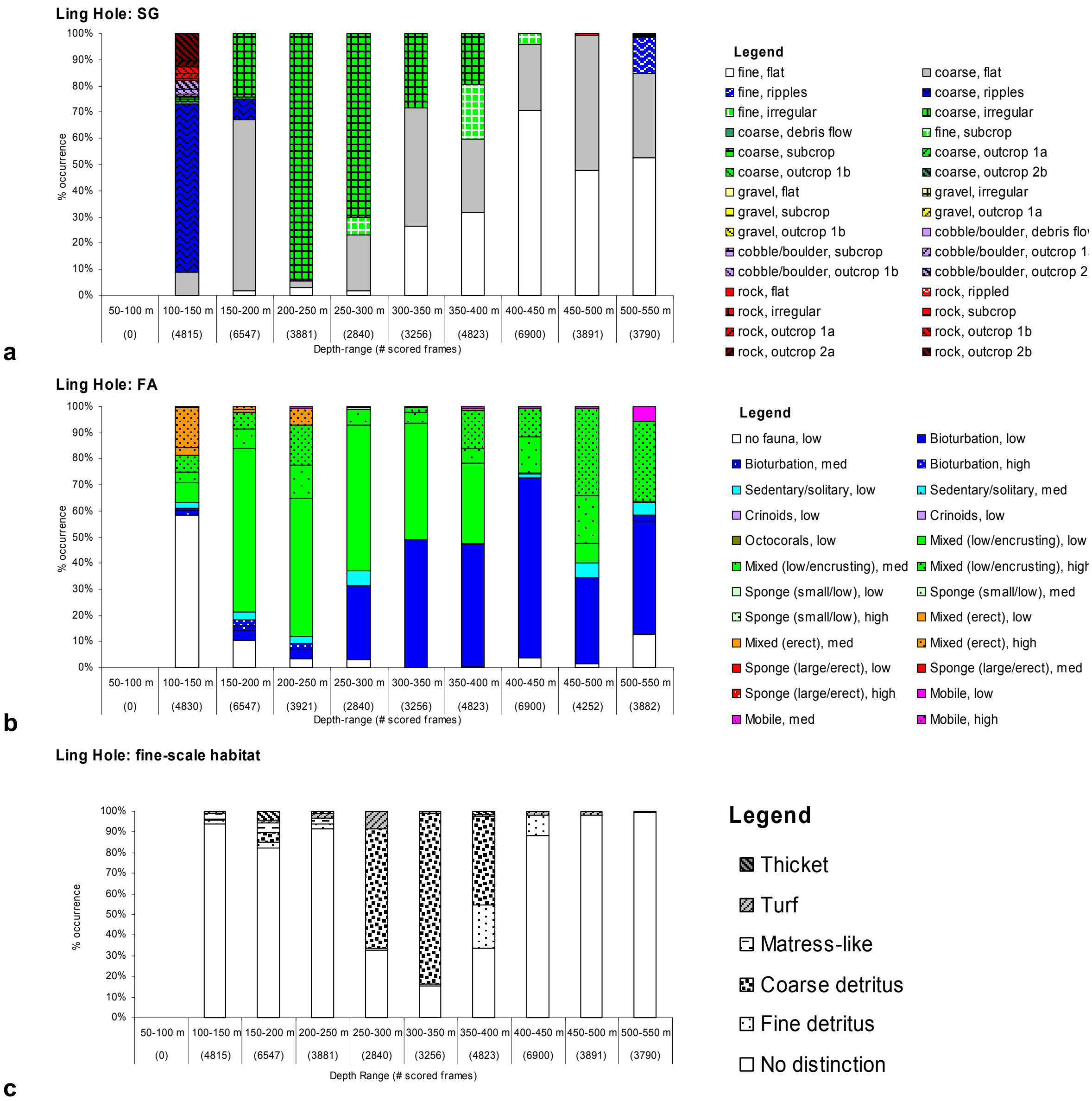


Figure 7.1.1.9 Ling Hole: histograms showing percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') at the Ling Hole site in 50 m depth intervals based on video scores at 1-second intervals.

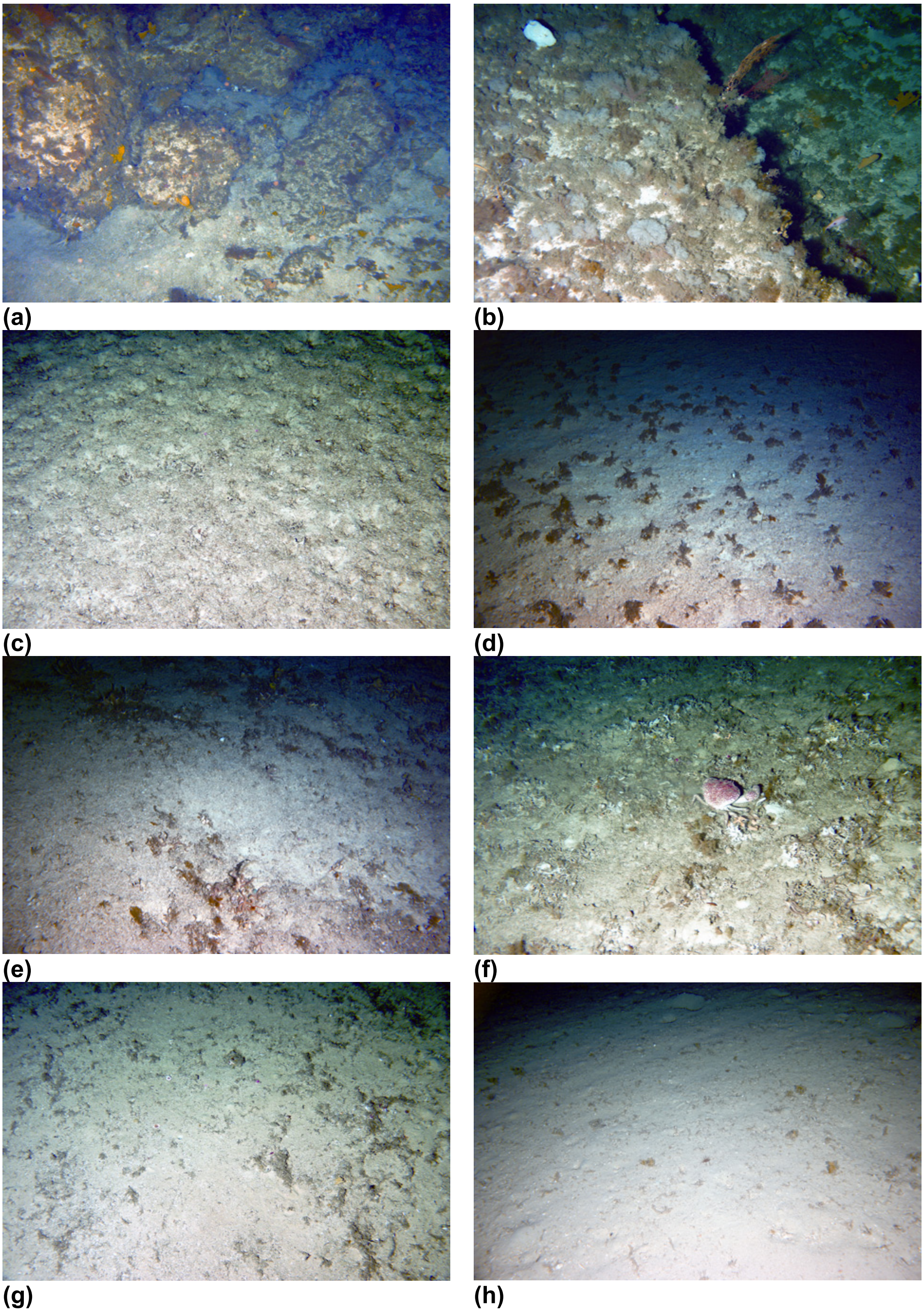


Figure 7.1.1.10 Seabed images from the 'Ling Hole' site. Depth in meters and transect number (T) is given for each (a) 115 m, T 49 (b) 120 m, T 49 (c) 151 m, T 49 (d) 188 m, T 19 (e) 229 m, T 18 (f) 240 m, T 49 (g) 371 m, T 75 (h) 422 m, T 18. See text for descriptions

Pieman (high crab / high trawl)

Six cross-depth and two along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.11 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in

Table 7.1.1.12. There were high proportions of irregular and flat coarse sediments; rippled coarse and fine sediments and flat fine sediments made up a moderate proportion of observations. Low/encrusting and bioturbating faunas predominated; there were a large number of observations where no fauna were recorded. Some mixed erect fauna were also observed.

Irregular coarse sediments dominated (> 90%) substrata in 250 to 350 m, and were replaced by coarse and fine flat sediments as depth increased to 550 m. Irregular coarse sediments made up the majority (> 50%) of substrata between 150 and 250 m depth, with irregular fine sediments below 200 m and a mix of rippled and flat coarse sediments in 150 to 200 m depth. Rippled coarse sediments (> 65%) dominated in the 100 to 150 m depth range. Some rock, boulders and subcrops were also observed in the shallowest depth range (Figure 7.1.1.11a).

Low and encrusting fauna, in moderate to high abundance, made up a large proportion (> 40-50%) of all fauna types in less than 400 m depth. These fauna formed bryozoan turf and some thicket between 250 and 400 m depths. Bioturbating fauna with decreasing abundance of coarse detritus dominated below 400 m depth. Mixed erect fauna and erect sponges were moderately abundant throughout depth ranges below 250 m depth. Low/encrusting and bioturbating fauna with 'mattress-like' patterning dominated in the 150 to 250 m depths. Ophiuroid aggregations were observed in these areas. No fauna were observed in nearly half the video records in 100 to 150 m depth, the remainder comprised low/encrusting and some mixed erect fauna (Figure 7.1.1.11b and c).

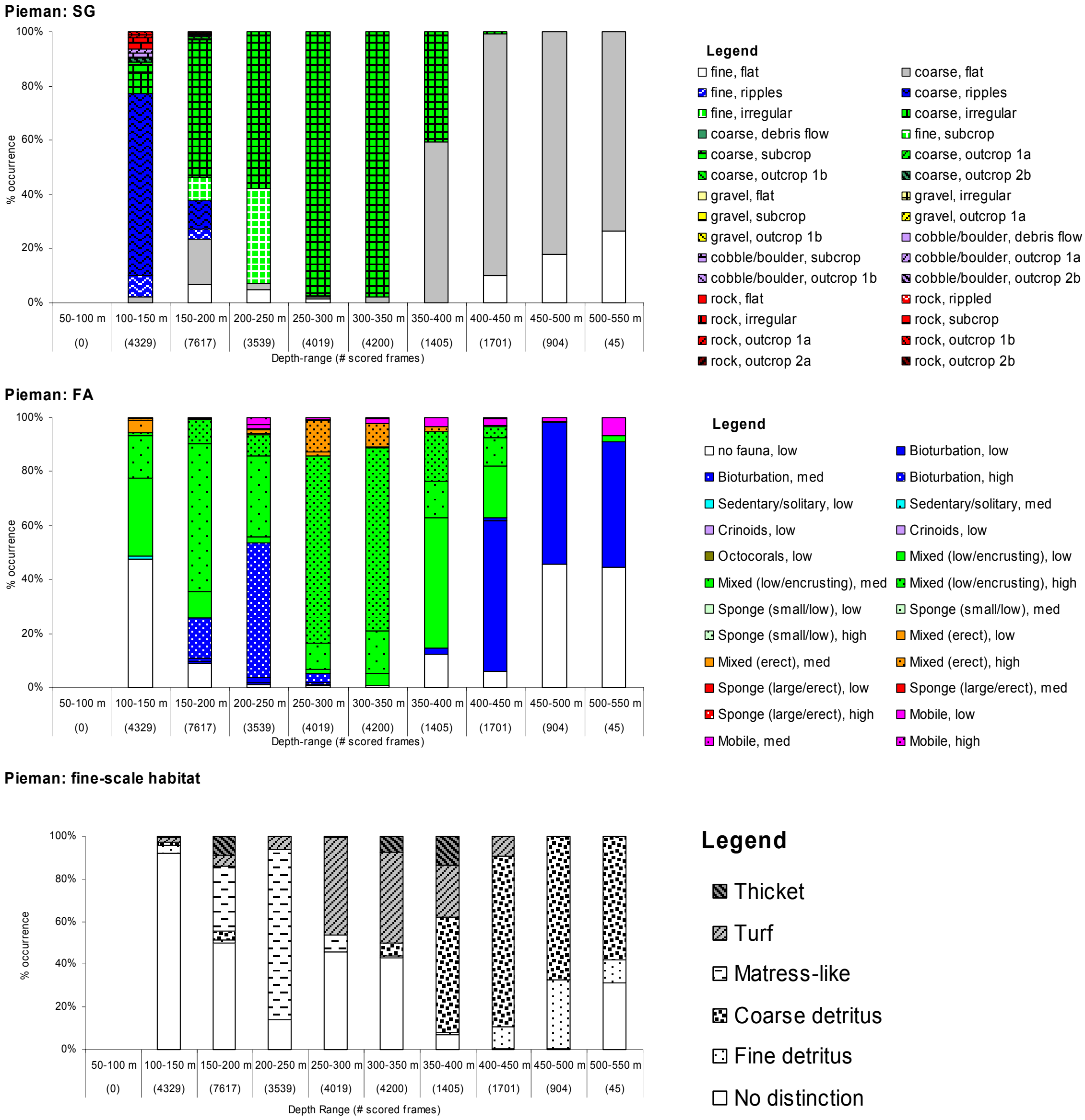
A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.12) (a) mixed erect fauna (soft bryozoans and sponges) on rock outcrop amongst coarse sediments; (b) low abundance of bioturbation in rippled coarse sediments; (c) mixed erect fauna (sponges and bryozoans) on low outcrops and boulders; (d) low/encrusting turf (bryozoans and sponges with ophiuroids) on irregular coarse sediments; (e) low/encrusting fauna (bryozoans), sparse solitary/sedentary fauna and bioturbating fauna (forming 'mattress-like' pattern) on irregular coarse sediment; (f) bioturbating fauna (forming 'mattress-like' pattern) on irregular coarse sediment; (g) dense low/encrusting turf (sponges and bryozoans) on irregular coarse sediments; (h) low abundance of coarse detritus, some bioturbating fauna on flat coarse sediment.

Table 7.1.1.11 Pieman: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200401	20	141.6	152.5	1347	5	1342
L	CH200401	19	231.9	356.9	3616	17	3599
X	CH200401	17	144.1	354.1	3778	51	3727
X	CH200401	18	136.9	298.7	3376	209	3167
X	CH200401	27	137.5	470.3	5478	6	5472
X	CH200401	28	403.1	505	1597	3	1594
X	CH200401	29	185.9	416.2	1700	4	1696
X	SS200404	63	49.4	473.1	10494	3332	7162

Table 7.1.1.12 Pieman : percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	13.0	Unrippled	*20.8*
Coarse sediments	**85.0**	Rippled	15.6
Gravel/pebble	0.0	Highly irregular	**60.4**
Cobble/boulder	0.7	Debris flow/rubble banks	0.0
Sedimentary rock	1.2	Subcrop	1.8
		Outcrop (low a)	0.4
		Outcrop (low b)	0.7
		Outcrop (high a)	0.0
		Outcrop (high b)	0.2
Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	12.9	No distinction	**43.5**
Bioturbation	*17.3*	Fine detritus	2.8
Solitary/sedentary fauna	0.2	Coarse detritus	12.3
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	19.6
Octocorals	0.0	Bryozoan turf	17.5
Mixed fauna (low/ encrusting)	**63.4**	Bryozoan thicket	4.3
Sponge (small/low)	0.1		
Sponge (large/erect)	4.6		
Mixed fauna (erect)	0.1		
Mobile fauna	1.4		



c

Figure 7.1.1.11 Pieman: percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

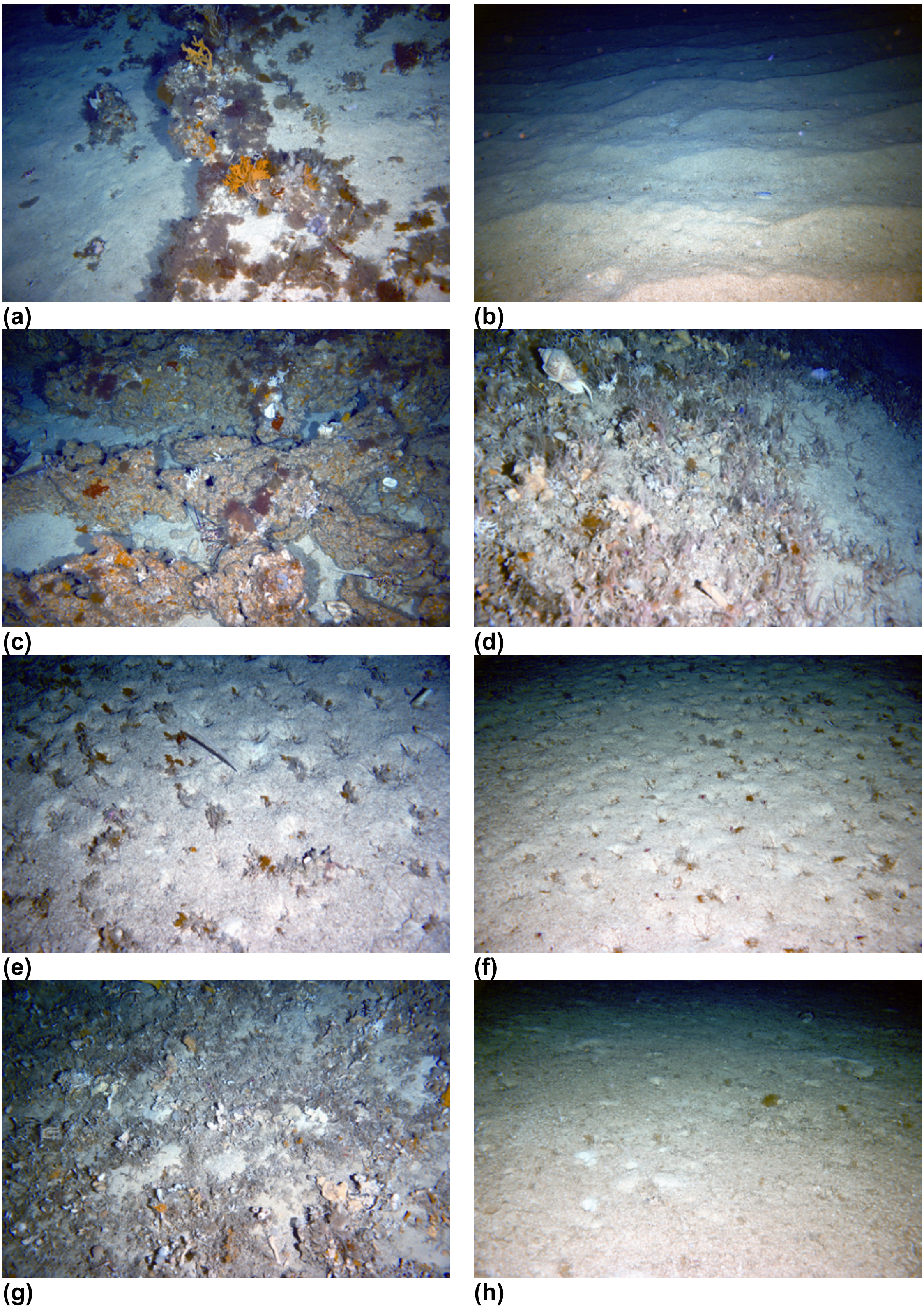


Figure 7.1.1.12 Seabed images from the 'Pieman' site. Depth in meters and transect number (T) is given for each (a) 150 m, T 18 (b) 151 m, T 17 (c) 170 m, T 18 (d) 186 m, T 18 (e) 198 m, T 17 (f) 209 m, T 29 (g) 299 m, T 19 (h) 404 m, T 29. See text for descriptions

Strahan (high crab / high trawl)

Two cross-depth and two along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.13 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.14. There were high proportions of irregular and flat coarse sediments; rippled coarse sediments and rocky outcrops were present. Low/encrusting fauna at moderate abundance were predominant; some mixed erect fauna and large sponges were also observed.

Irregular coarse sediments dominated (> 90%) substrata in 200 to 350 m making up all substrata between 250 and 350 m depth; these were replaced by flat coarse sediments as depth increased to 450 m. A mix of irregular, rippled and flat coarse sediments occurred in 150 to 200 m depth. Rippled coarse sediments (> 50%) dominated in the 100 to 150 m depth range where rock subcrop and outcrop also occurred (~25%) (Figure 7.1.1.13a).

Low and encrusting fauna, in moderate abundance, made up a large proportion (> 70%) of all fauna types in > 150 m depth – except 400-450 m where there were few records (17). These fauna formed bryozoan turf between 200 and 350 m depths and were replaced by coarse detritus below 350 m. Mixed erect fauna and large sponge collectively made up > 40% of records in the 100-150 m stratum. Between 200 and 250 m there was likely occurrence of ophiuroids based on 'mattress-like' bioturbation patterns; some large sponges occurred in 350-400 m (Figure 7.1.1.13b and c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.14) (a) transition of mixed erect fauna (soft bryozoans and sponges), probably on rock subcrop, and strongly rippled coarse sediments; (b and c) high abundance of mixed erect fauna (sponges and bryozoans) on low outcrops and boulders; (d) rippled coarse sediments with no fauna; (e) medium density of low/encrusting fauna (soft bryozoans), on irregular coarse sediment; (f) low to medium abundance of bioturbating fauna (forming 'mattress-like' pattern) on irregular coarse sediment; (g) dense low/encrusting turf (bryozoans, sponges and isolated anemones) on irregular coarse sediments; (h) low abundance of low/encrusting fauna and coarse detritus (and ghost flathead) on flat coarse sediment.

Table 7.1.1.13 Strahan: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200401	16	152.8	164.1	1936	5	1931
L	CH200401	15	232.2	286.2	2113	0	2113
X	CH200401	13	135.9	402.2	6908	88	6820
X	CH200401	14	143.8	359.4	5817	92	5725

Table 7.1.1.14 Strahan: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of major faunal types based on video scores at 1-second intervals.

Substratum (S)	**% occ.**	**Geomorphology (G)**	**% occ.**
Fine sediments	0.0	Unrippled	16.9
Coarse sediments	**96.1**	Rippled	*22.7*
Gravel/pebble	0.0	Highly irregular	**55.8**
Cobble/boulder	0.2	Debris flow/rubble banks	0.2
Sedimentary rock	3.7	Subcrop	1.6
		Outcrop (low a)	0.6
		Outcrop (low b)	2.1
		Outcrop (high a)	0.0
		Outcrop (high b)	0.2
Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	6.7	No distinction	**39.4**
Bioturbation	0.4	Fine detritus	4.2
Solitary/sedentary fauna	0.4	Coarse detritus	13.4
Crinoids	0.0	‘Mattress-like’ (likely pres of ophiuroids)	4.8
Octocorals	0.0	Bryozoan turf	**34.0**
Mixed fauna (low/ encrusting)	**86.9**	Bryozoan thicket	4.2
Sponge (small/low)	0.1		
Sponge (large/erect)	3.8		
Mixed fauna (erect)	0.1		
Mobile fauna	1.6		

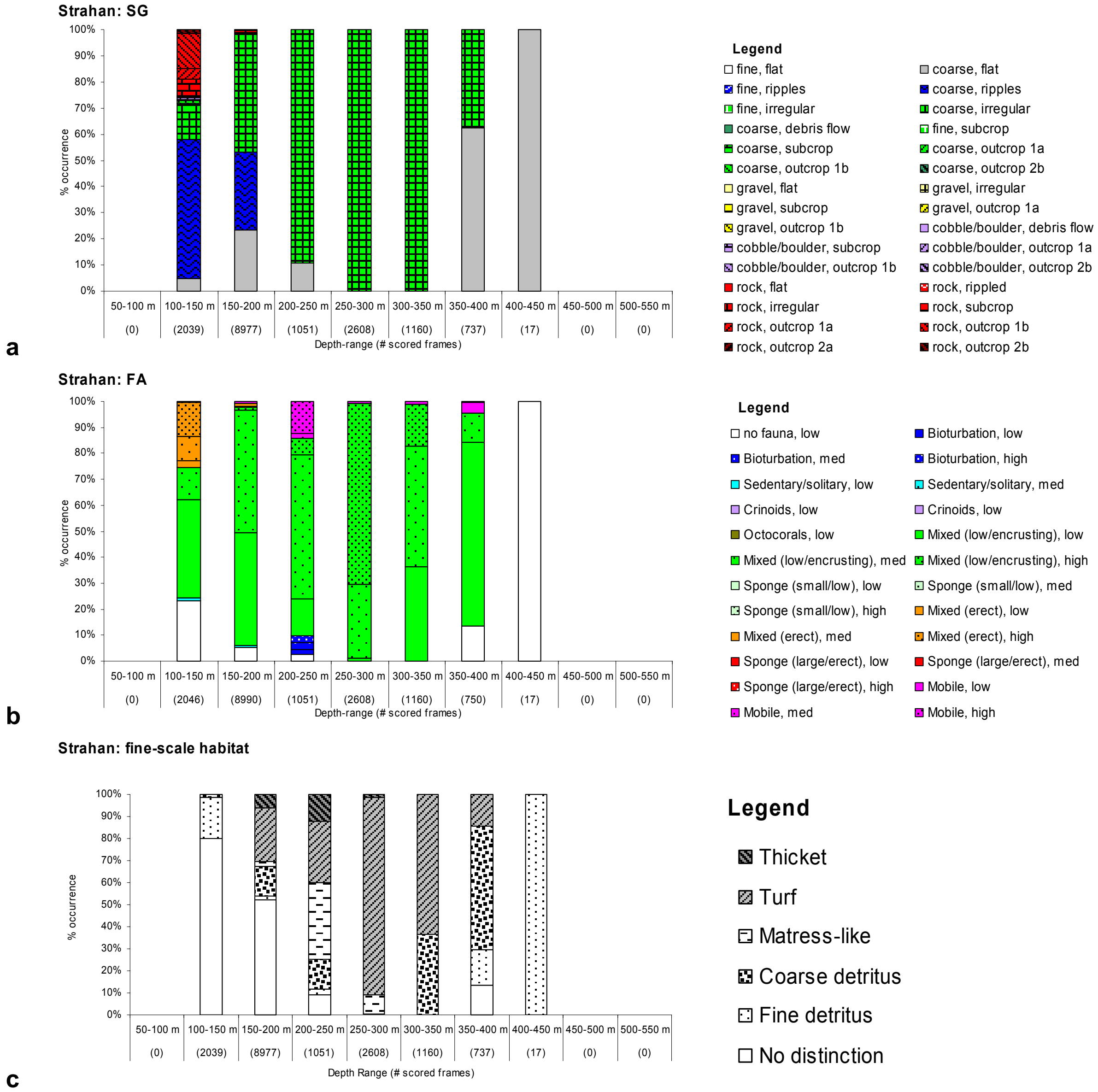


Figure 7.1.1.13 Strahan: histograms showing percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

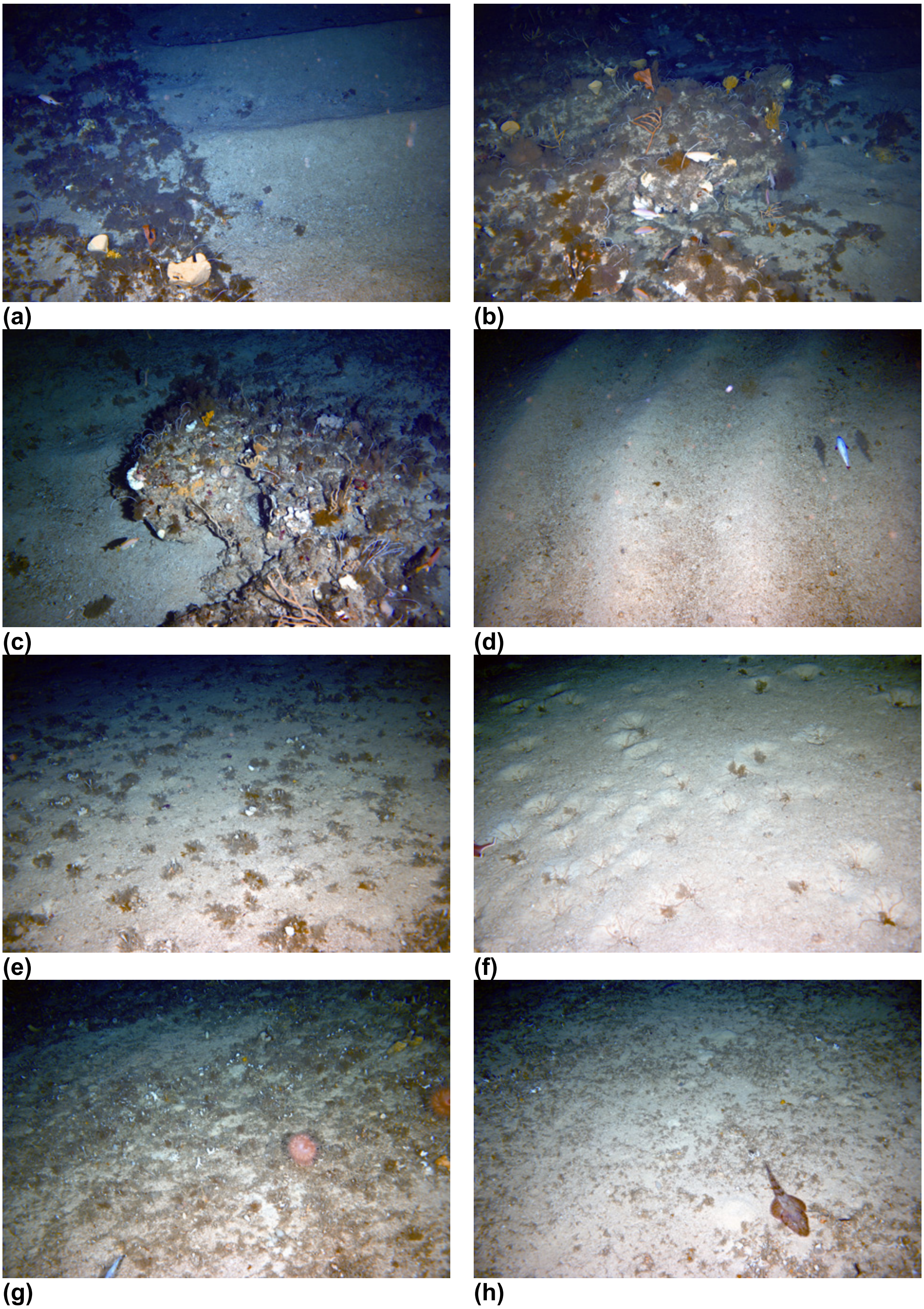


Figure 7.1.1.14 Seabed images from the ‘Strahan’ site. Depth in meters and transect number (T) is given for each (a) 144 m, T 13 (b) 145 m, T 13 (c) 153 m, T 14 (d) 159 m, T 16 (e) 193 m, T 13 (f) 212 m, T 14 (g) 277 m, T 15 (h) 332 m, T 14. See text for descriptions

Point Hibbs (high crab / low trawl)

Three cross-depth and two along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.15 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.16. There were high proportions of irregular and flat coarse sediments; rippled coarse sediments and rocky outcrops were present. Low/encrusting fauna at moderate to high abundance were predominant; some mixed/erect and bioturbating fauna were also observed.

Irregular and flat coarse sediments were the dominant substrata types for depths greater than 150 m. The frequency of the irregular substrata increased from ~15% at 150 to 200 m to 100% at 250 to 350 m depths and decreases with increasing depth to 450 m. Flat fine sediments were observed below 400 m depth. In the shallowest depth range (100-150 m) the majority of substrata were rippled coarse sediments with some flat coarse sediments and outcropping rock and boulders (Figure 7.1.1.15a).

Low and encrusting fauna, in moderate to high abundance, made up the majority (>95%) of fauna types in 150 to 400 m depth. These fauna form mostly bryozoan thicket between 200 and 350 m depths and were replaced by turf and coarse detritus below 350 m. Low abundance of bioturbating fauna were observed in 50% video records in 400-450 m depth. Mixed erect fauna and large sponges collectively made up > 25% of records in the 100-150 m stratum (Figure 7.1.1.15b and c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.16) (a) mixed erect fauna (soft bryozoans and sponges and whips) on high and undercut rock outcrop; (b) mixed erect fauna (soft bryozoans and large sponges and whips) on rock outcrop; (c and d) medium abundance of low and encrusting bryozoans on irregular coarse sediments; (e and f) high density of bryozoan thicket (soft bryozoans, sponges and ascidians), on irregular coarse sediment; (g and h) low density of bioturbating fauna and coarse detritus on flat coarse sediments.

Table 7.1.1.15 Point Hibbs: details of transects and seabed video.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200401	12	145.3	166.6	798	33	765
L	CH200401	11	297.5	380	2570	31	2539
X	CH200401	24	134.4	425.9	3721	80	3641
X	CH200401	25	139.1	445.6	3468	46	3422
X	CH200401	26	131.9	414.1	3524	50	3474

Table 7.1.1.16 Point Hibbs: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and major faunal types based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	3.9	Unrippled	**48.8**
Coarse sediments	**91.0**	Rippled	10.9
Gravel/pebble	0.3	Highly irregular	**34.8**
Cobble/boulder	2.0	Debris flow/rubble banks	0.0
Sedimentary rock	2.8	Subcrop	0.9
		Outcrop (low a)	1.5
		Outcrop (low b)	1.1
		Outcrop (high a)	0.0
		Outcrop (high b)	2.1
Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	3.3	No distinction	**41.6**
Bioturbation	2.8	Fine detritus	1.5
Solitary/sedentary fauna	0.3	Coarse detritus	16.2
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	0.0
Octocorals	0.0	Bryozoan turf	17.5
Mixed fauna (low/ encrusting)	**88.3**	Bryozoan thicket	23.3
Sponge (small/low)	0.1		
Sponge (large/erect)	4.8		
Mixed fauna (erect)	0.0		
Mobile fauna	0.4		

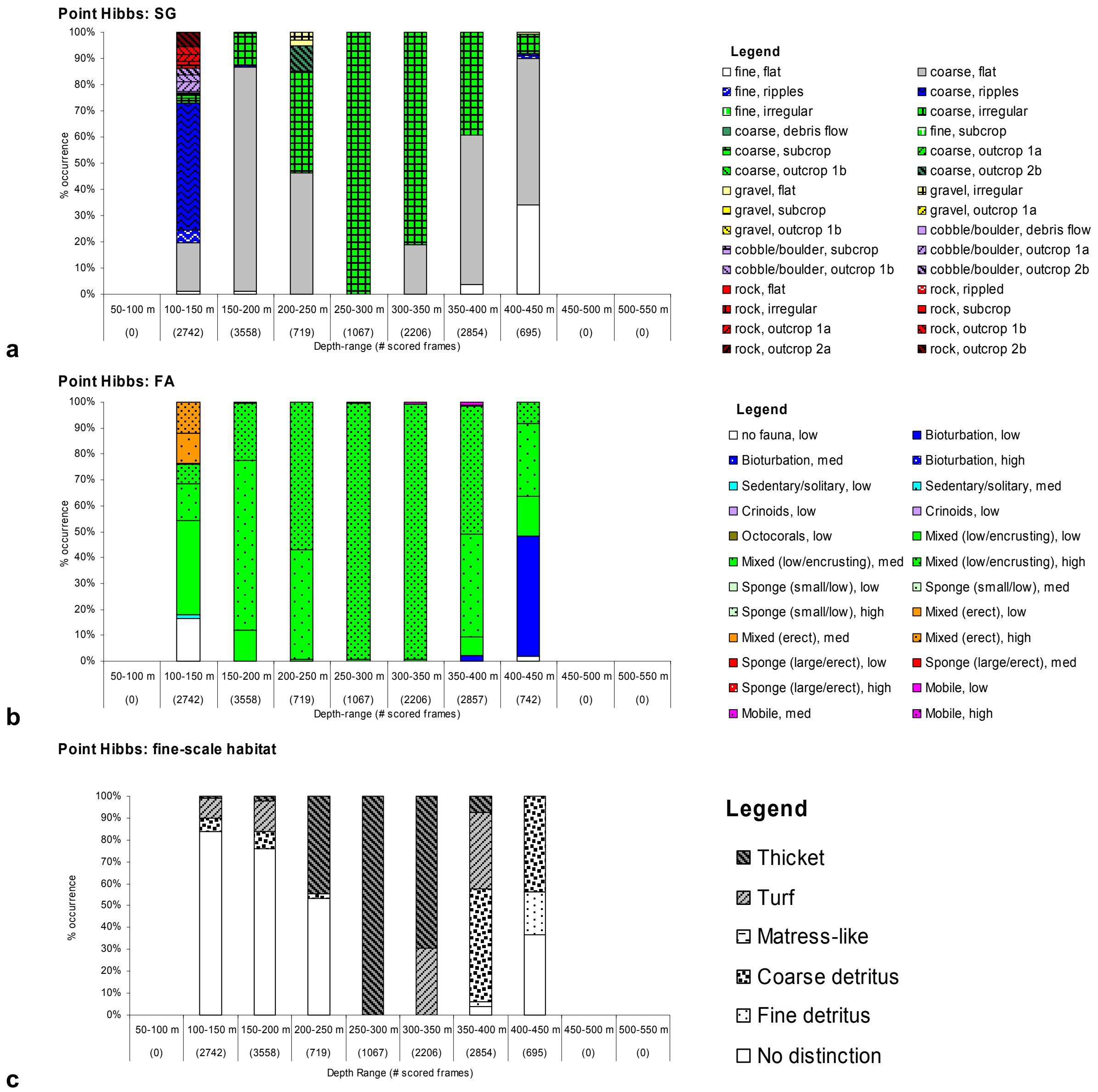
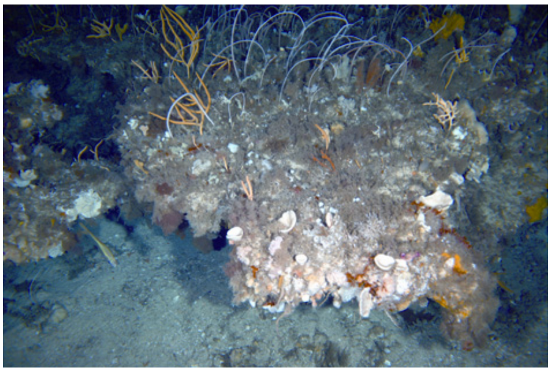


Figure 7.1.1.15 Point Hibbs: percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.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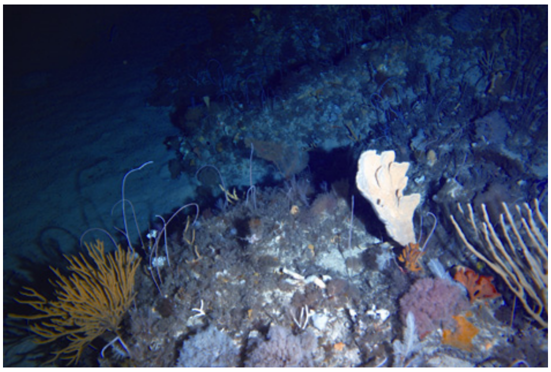
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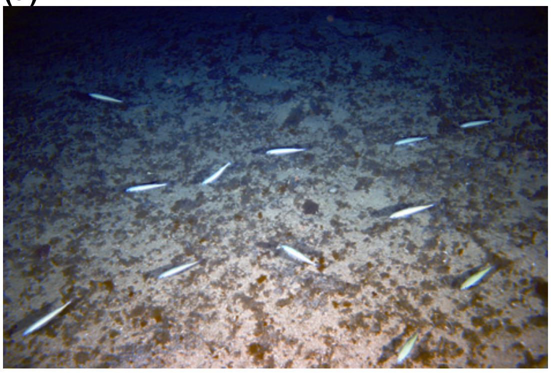
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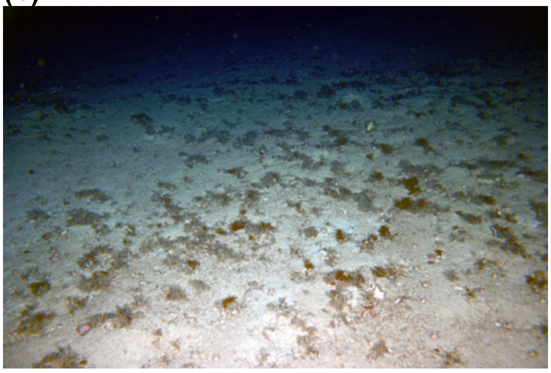
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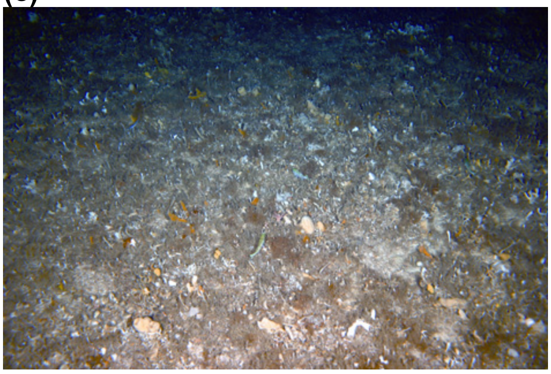
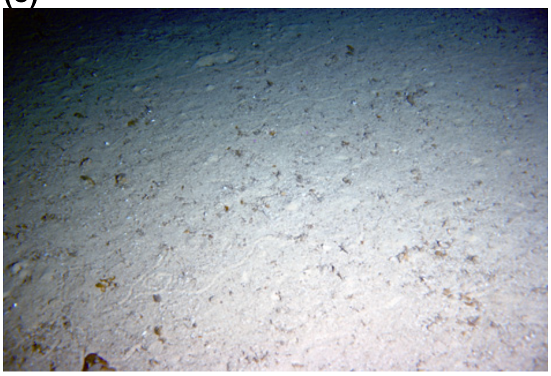

(e)


(f)


(g)

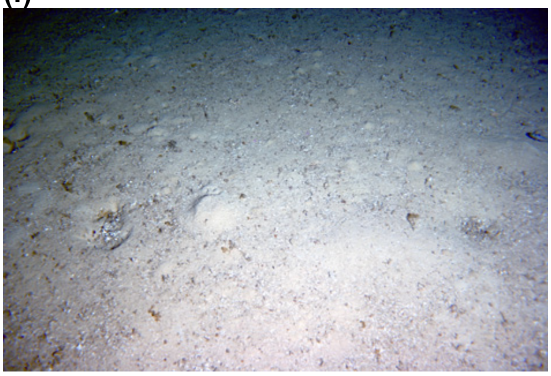

(h)

Figure 7.1.1.16 Seabed images from the 'Point Hibbs' site. Depth in meters and transect number (T) is given for each (a) 138 m, T 26 (b) 141 m, T 24 (c) 149 m, T 26 (d) 200 m, T 26 (e) 252 m, T 26 (f) 274 m, T 24 (g) 405 m, T 25 (h) 411 m, T 26. See text for descriptions

High Rocky Point (low crab / low trawl)

Three cross-depth and two along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.17 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.18. There were predominantly flat coarse sediments; with lower proportions of rippled and irregular coarse sediments. Low/encrusting fauna at moderate to high abundance were predominant; some mixed/erect fauna were also observed.

Irregular coarse sediments dominate (> 90%) substrata in 200 to 350 m making up all substrata between 250 and 350 m depth; these were replaced by flat coarse sediments as depth increased to 450 m. A mix of irregular, rippled and flat coarse sediments occurred in 150 to 200 m depth. Rippled coarse sediments (> 50%) dominated in the 100 to 150 m depth range where rock subcrop and outcrop also occurred (~25%) (Figure 7.1.1.17a).

Low and encrusting fauna, in moderate abundance, made up a large proportion (> 80%) of all fauna types in all depth ranges (100-500 m). These fauna mostly formed bryozoan turf and some thicket between 200 and 350 m depths and were replaced by coarse detritus below 350 m. Mixed erect fauna were observed in ~10% of records in the 100-150 m stratum. Small hermit crabs (Paguridae) were regularly observed in depths shallower than 200 m (Figure 7.1.1.17a b and c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.18) (a) heavily rippled coarse sediments with low abundance of detritus; (b) mixed erect fauna (soft bryozoans, sponges and whips) on irregular coarse substrate most likely with underlying subcropping rock; (c) mixed erect fauna (soft bryozoans and sponges) on high outcrop with undercut; (d) a large massive sponge in a patch of soft bryozoans on irregular coarse sediments; (e) medium density of low/encrusting thicket (soft bryozoans, ascidians and sponges) on irregular coarse sediment; (f) low to medium abundance of low/encrusting turf and coarse detritus on irregular coarse sediment; (g) coarse detritus and bioturbating fauna on flat very coarse sediments; (h) low abundance coarse detritus (and seastar) on flat coarse sediments.

Table 7.1.1.17 High Rocky: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200401	21	145.3	176.9	2201	5	2196
L	CH200401	22	357.5	415.6	2904	106	2798
X	CH200401	5	134.7	352.8	4164	4	4160
X	CH200401	6	138.4	318.8	4426	0	4426
X	CH200401	23	297.5	460.3	2081	0	2081

Table 7.1.1.18 High Rocky: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and major faunal types based on video scores at 1-second intervals.

Substratum (S)	**% occ.**	**Geomorphology (G)**	**% occ.**
Fine sediments	1.9	Unrippled	**79.2**
Coarse sediments	**96.5**	Rippled	7.9
Gravel/pebble	0.6	Highly irregular	11.3
Cobble/boulder	0.1	Debris flow/rubble banks	0.0
Sedimentary rock	0.9	Subcrop	0.7
		Outcrop (low a)	0.3
		Outcrop (low b)	0.2
		Outcrop (high a)	0.0
		Outcrop (high b)	0.3

Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	2.9	No distinction	**61.6**
Bioturbation	0.0	Fine detritus	0.0
Solitary/sedentary fauna	0.9	Coarse detritus	*22.7*
Crinoids	0.0	‘Mattress-like’ (likely pres of ophiuroids)	0.0
Octocorals	0.0	Bryozoan turf	11.6
Mixed fauna (low/ encrusting)	**93.3**	Bryozoan thicket	4.1
Sponge (small/low)	0.0		
Sponge (large/erect)	1.7		
Mixed fauna (erect)	0.1		
Mobile fauna	1.2		

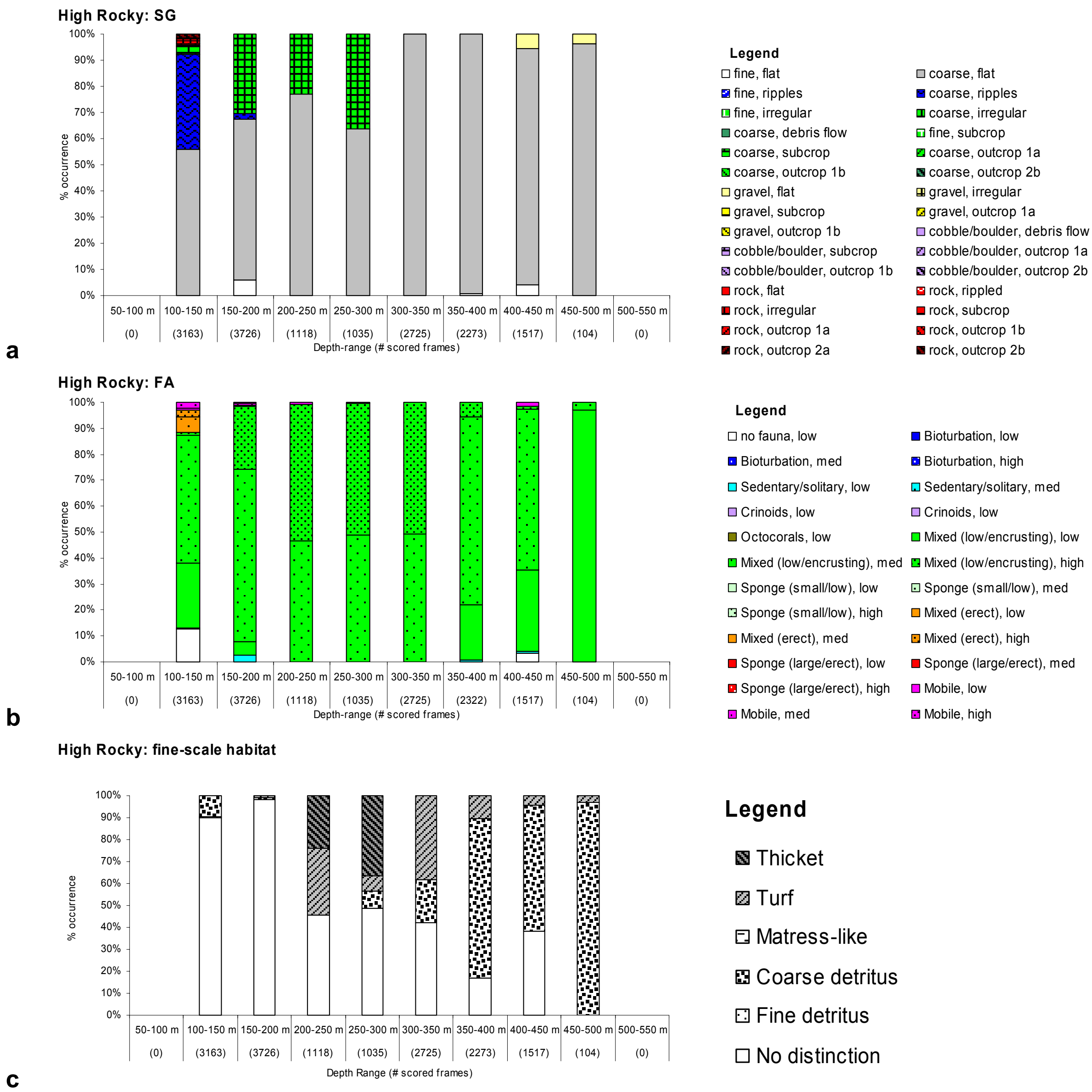
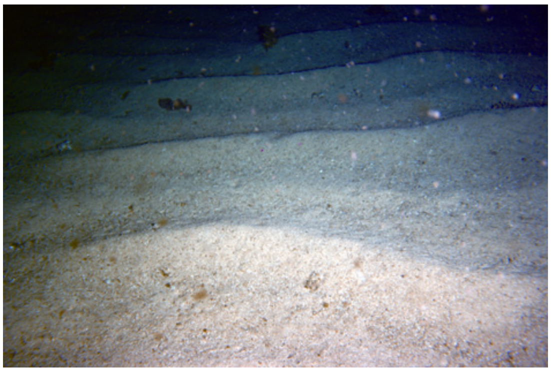


Figure 7.1.1.17 High Rocky: histograms showing percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.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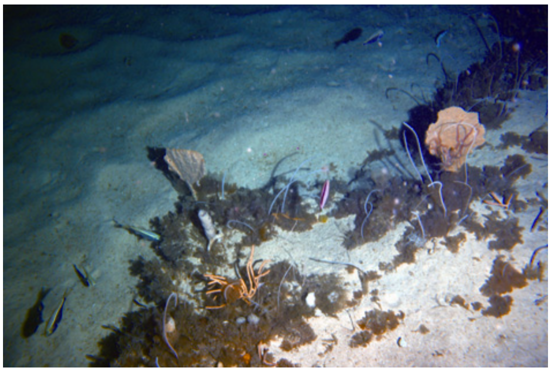
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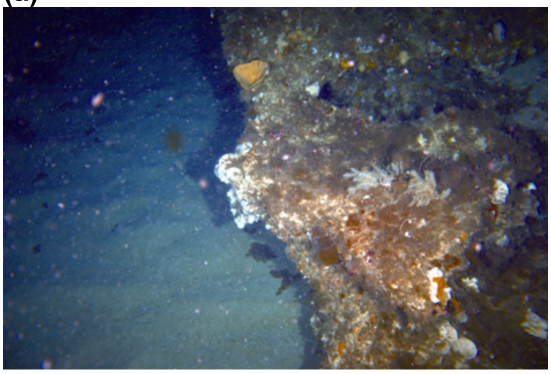
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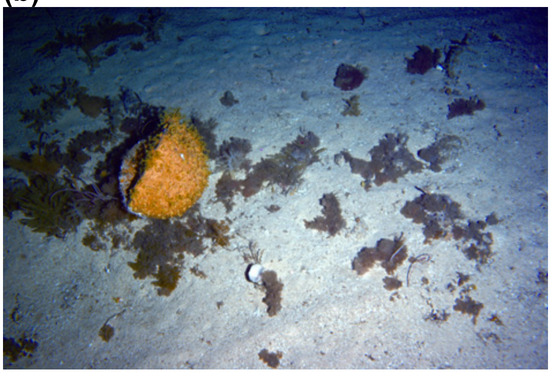
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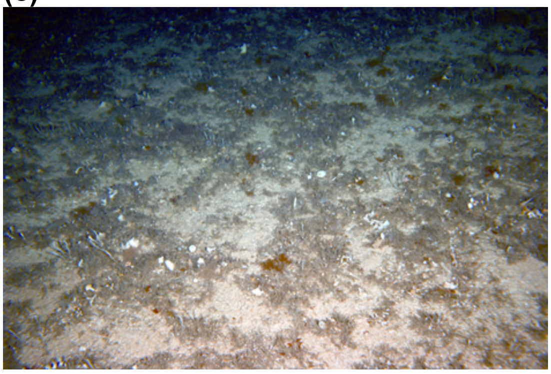
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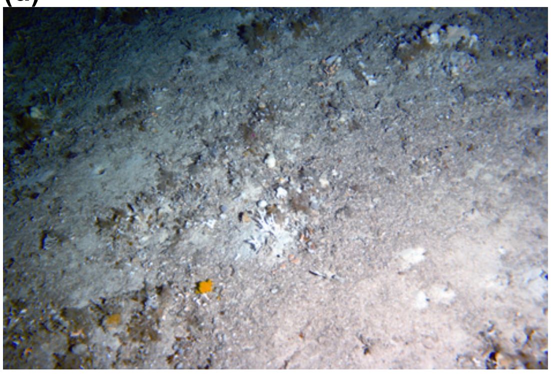
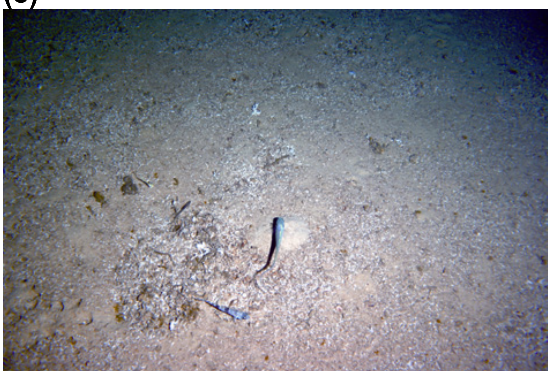

(f)


(g)


(h)

Figure 7.1.1.18 Seabed images from the 'High Rocky' site. Depth in meters and transect number (T) is given for each (a) 139 m, T 5 (b) 141 m, T 6 (c) 143 m, T 6 (d) 144 m, T 23 (e) 238 m, T 5 (f) 318 m, T 23 (g) 408 m, T 22 (h) 415 m, T 5. See text for descriptions

Low Rocky Point (low crab / high trawl)

Two cross-depth and two along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.19 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.20. There were high proportions of flat coarse sediments with some flat fine and irregular coarse sediments. Boulders and rocky outcrops were also observed. Low/encrusting fauna at moderate to high abundance were predominant; some mobile and sedentary/solitary fauna were also observed. More than 10% of video records had no fauna.

Flat coarse sediments were the dominant (> 70%) substrata types for depths greater between 200 and 450 m. Below 450 m depth flat fine sediments dominated with some boulders and outcropping rocks making up ~15% collectively. Some outcropping rocks were also observed at 400 to 450 m depth. Flat fine sediments (65%) and outcropping boulders made up the major substratum types in the shallow depth range (100-150 m) but there were only 17 records in this range. A mix of substratum types were observed in the 150 to 200 m depth range with flat fine and coarse sediments making up ~70% collectively and ~10% rippled and ~20% irregular coarse sediments (Figure 7.1.1.19a).

Low and encrusting fauna, in moderate to high abundance, made up the majority (> 80%) of fauna types in 100 to 400 m depth. These fauna formed mostly bryozoan turf and thicket between 200 and 350 m depths and were replaced by coarse detritus in 350 to 450 m. There was an increase in the proportion of no epifauna, mobile animals (small hermit crabs and ophiuroids) and some sedentary/solitary fauna between 400 and 500 m depth with a corresponding decrease of the low and encrusting fauna across the same depth range (Figure 7.1.1.19b and c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.20) (a) a patch of low/encrusting fauna (soft bryozoans, a sponge and ascidians) amongst flat coarse sediments with small hermit crabs (Paguridae); (b) a massive sponge covered in ophiuroids on a patch of low and encrusting fauna (soft bryozoans) on slightly rippled coarse sediments; (c) mobile fauna (ophiuroids and hermit crabs) on flat coarse sediments; (d) a low abundance of low/encrusting fauna and very coarse detritus on irregular coarse sediments; (e) medium abundance of sedentary/solitary fauna (anemones) and coarse detritus on irregular coarse sediments; (f) low abundance of low/encrusting fauna on outcropping rock with dory in foreground; (g) low abundance of low/encrusting fauna on outcropping rock; (h) octocorals (black corals) on flat subcropping rock.

Table 7.1.1.19 Low Rocky: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200401	4	165	181.6	3503	8	3495
L	CH200401	3	335.9	415	4660	4	4656
X	CH200401	1	142.2	486.9	10831	71	10760
X	CH200401	2	161.6	381.6	4784	30	4754

Table 7.1.1.20 Low Rocky: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	21.1	Unrippled	**79.0**
Coarse sediments	**77.7**	Rippled	5.2
Gravel/pebble	0.0	Highly irregular	14.5
Cobble/boulder	0.6	Debris flow/rubble banks	0.0
Sedimentary rock	0.6	Subcrop	0.1
		Outcrop (low a)	0.3
		Outcrop (low b)	0.7
		Outcrop (high a)	0.0
		Outcrop (high b)	0.2

Fauna (F)	% occ.	Fine scale habitat	% occ.
No fauna	12.0	No distinction	**69.9**
Bioturbation	0.3	Fine detritus	0.2
Solitary/sedentary fauna	1.2	Coarse detritus	14.8
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	0.3
Octocorals	0.0	Bryozoan turf	7.5
Mixed fauna (low/ encrusting)	**81.1**	Bryozoan thicket	7.2
Sponge (small/low)	0.2		
Sponge (large/erect)	0.2		
Mixed fauna (erect)	0.1		
Mobile fauna	5.0		

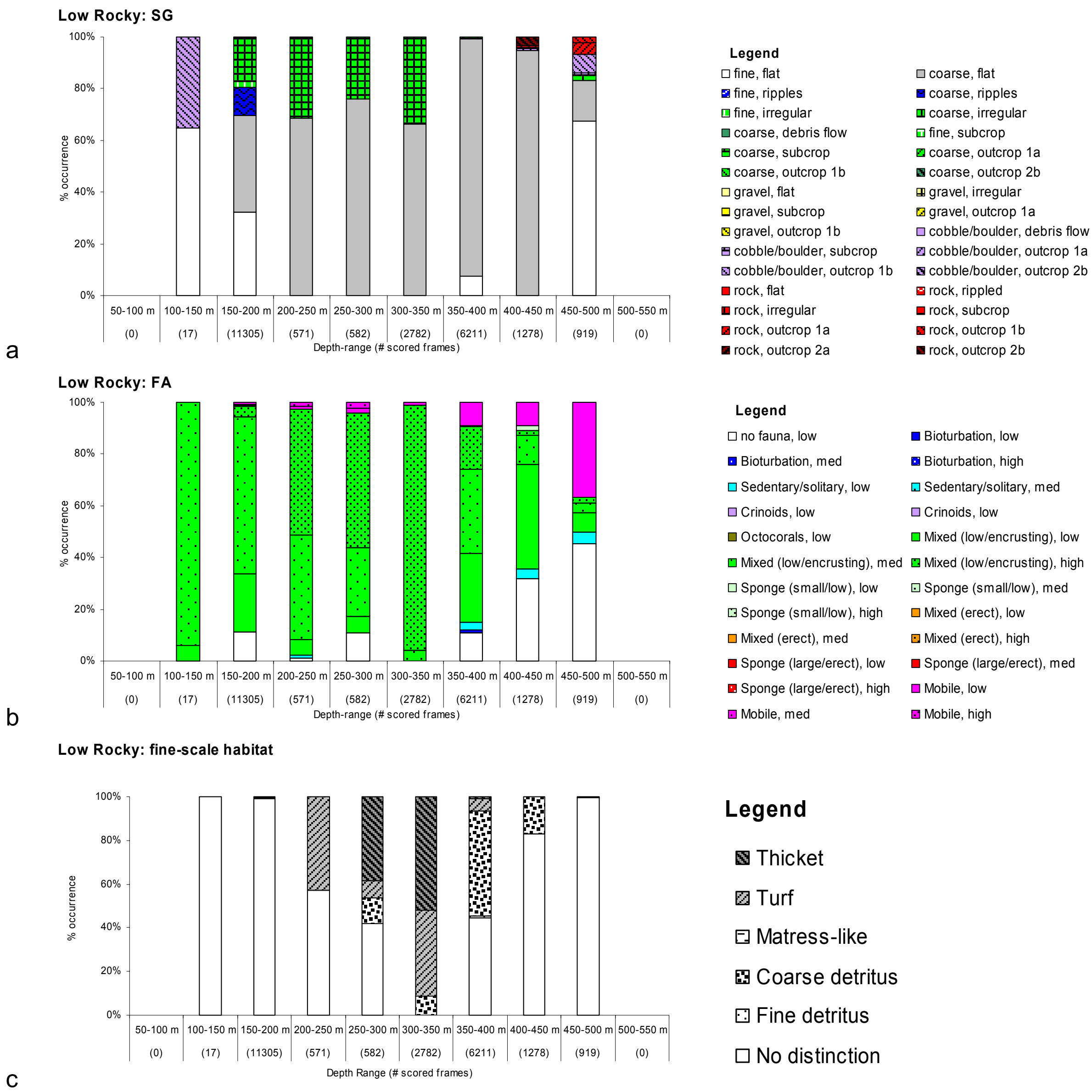


Figure 7.1.1.19 Low Rocky: percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

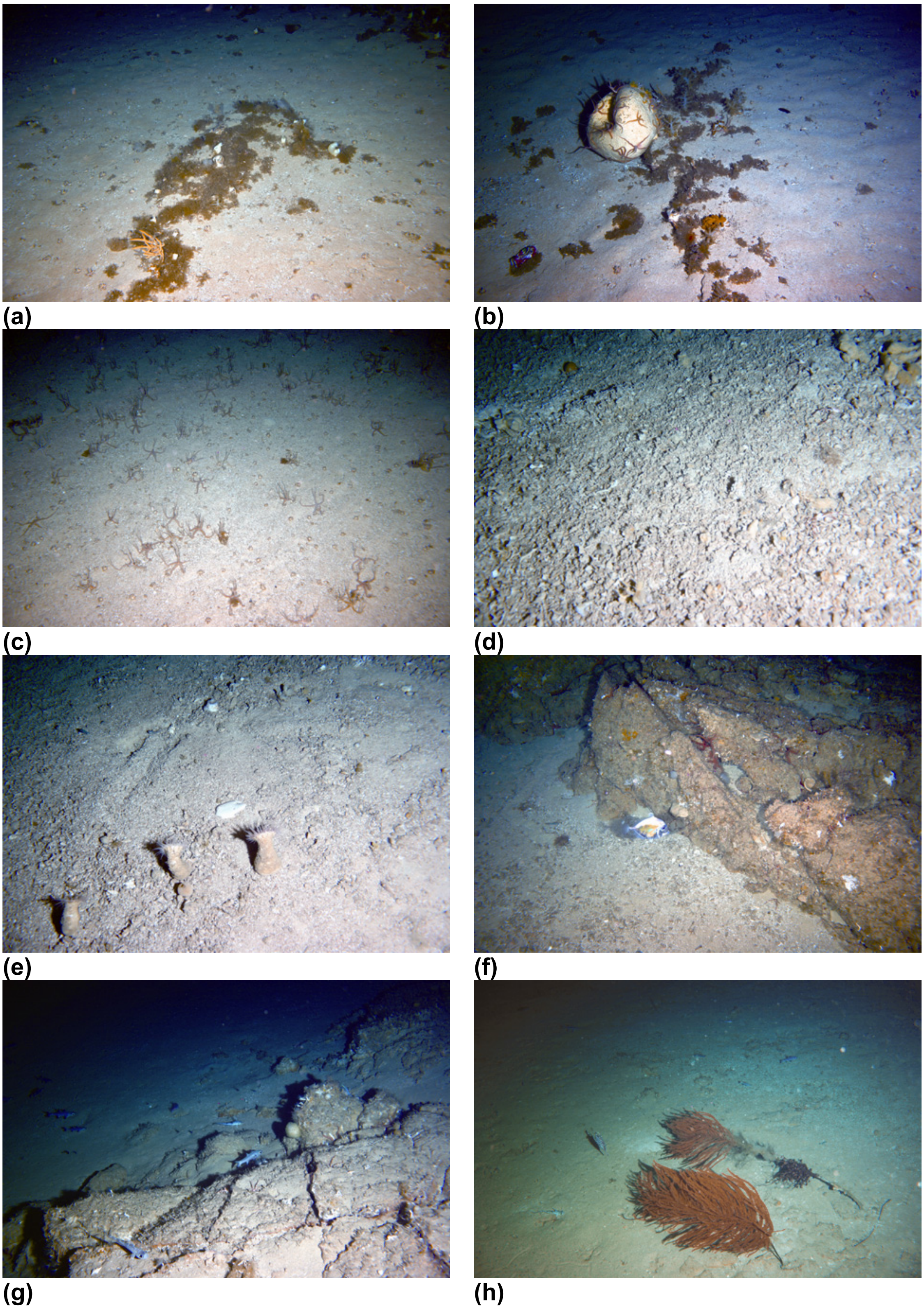


Figure 7.1.1.20 Seabed images from the 'Low Rocky' site. Depth in meters and transect number (T) is given for each (a) 153 m, T 1 (b) 155 m, T 1 (c) 180 m, T 2 (d) 312 m, T 2 (e) 413 m, T 3 (f) 439 m, T 1 (g) 458 m, T 1 (h) 465 m, T 1. See text for descriptions

Southwest Cape (low crab / low trawl)

Two cross-depth and two along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.23 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.22. There were high proportions of irregular and some flat coarse sediments. Low/encrusting fauna at moderate abundance were predominant with bioturbating fauna making up the remainder.

Irregular coarse sediments were dominant (> 65%) for depths shallower than 400 m. Increasing proportions of flat coarse sediments were observed throughout the 300 to 450 m depth ranges. The deepest depth range was represented by only 14 records (Figure 7.1.1.21a).

Low and encrusting fauna, in mostly moderate abundance, made up the majority (> 70%) of fauna types in 150 to 300 m depth. These fauna formed mostly bryozoan turf between 200 and 300 m depths. There was an equal proportion of mostly low abundance, low/encrusting and bioturbating fauna with some coarse detritus, in the 300 to 350 m depth range. Bioturbating fauna and coarse and fine detritus was dominant below 350 m depth. A small proportion of mixed erect fauna was observed in 150 to 200 m depths, some 'mattress-like' patterns were observed in the shallower part of this range. Dense ophiuroid aggregations were noted between 160-210 m depth (Figure 7.1.1.21b and c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.22) (a) a moderate density of low/encrusting thicket (bryozoans and sponges) on irregular coarse sediments; (b) a low abundance of low/encrusting fauna (bryozoans) on flat coarse sediments; (c) a moderate density of low/encrusting turf (sponges and bryozoans) with ophiuroids on coarse irregular sediments; (d) a transition zone of coarse sediments with ophiuroid aggregations adjacent to dense low/encrusting fauna on a rock outcrop; (e and f) a moderate density of low/encrusting turf (sponges and bryozoans) on irregular coarse sediments; (g) bioturbating fauna and coarse detritus on irregular coarse sediments; (h) fine detritus on flat coarse sediments.

Table 7.1.1.21 Southwest Cape: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
L	CH200501	22	154.4	166.6	791	0	791
L	CH200501	24	235.6	343.4	2288	1	2287
X	CH200501	23	151.9	402.8	3490	4	3486
X	CH200501	25	150.6	404.7	4138	56	4082

Table 7.1.1.22 Southwest Cape: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and major faunal types based on video scores at 1-second intervals.

Substratum (S)	**% occ.**	**Geomorphology (G)**	**% occ.**
Fine sediments	0.0	Unrippled	16.5
Coarse sediments	**100.0**	Rippled	0.0
Gravel/pebble	0.0	Highly irregular	**83.5**
Cobble/boulder	0.0	Debris flow/rubble banks	0.0
Sedimentary rock	0.0	Subcrop	0.0
		Outcrop (low a)	0.0
		Outcrop (low b)	0.0
		Outcrop (high a)	0.0
		Outcrop (high b)	0.0
Fauna (F)	**% occ.**	**Fine scale habitat)**	**% occ.**
No fauna	0.5	No distinction	24.9
Bioturbation	*30.0*	Fine detritus	3.3
Solitary/sedentary fauna	0.1	Coarse detritus	27.6
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	19.9
Octocorals	0.0	Bryozoan turf	22.8
Mixed fauna (low/ encrusting)	**66.6**	Bryozoan thicket	1.5
Sponge (small/low)	0.0		
Sponge (large/erect)	1.3		
Mixed fauna (erect)	0.0		
Mobile fauna	1.4		

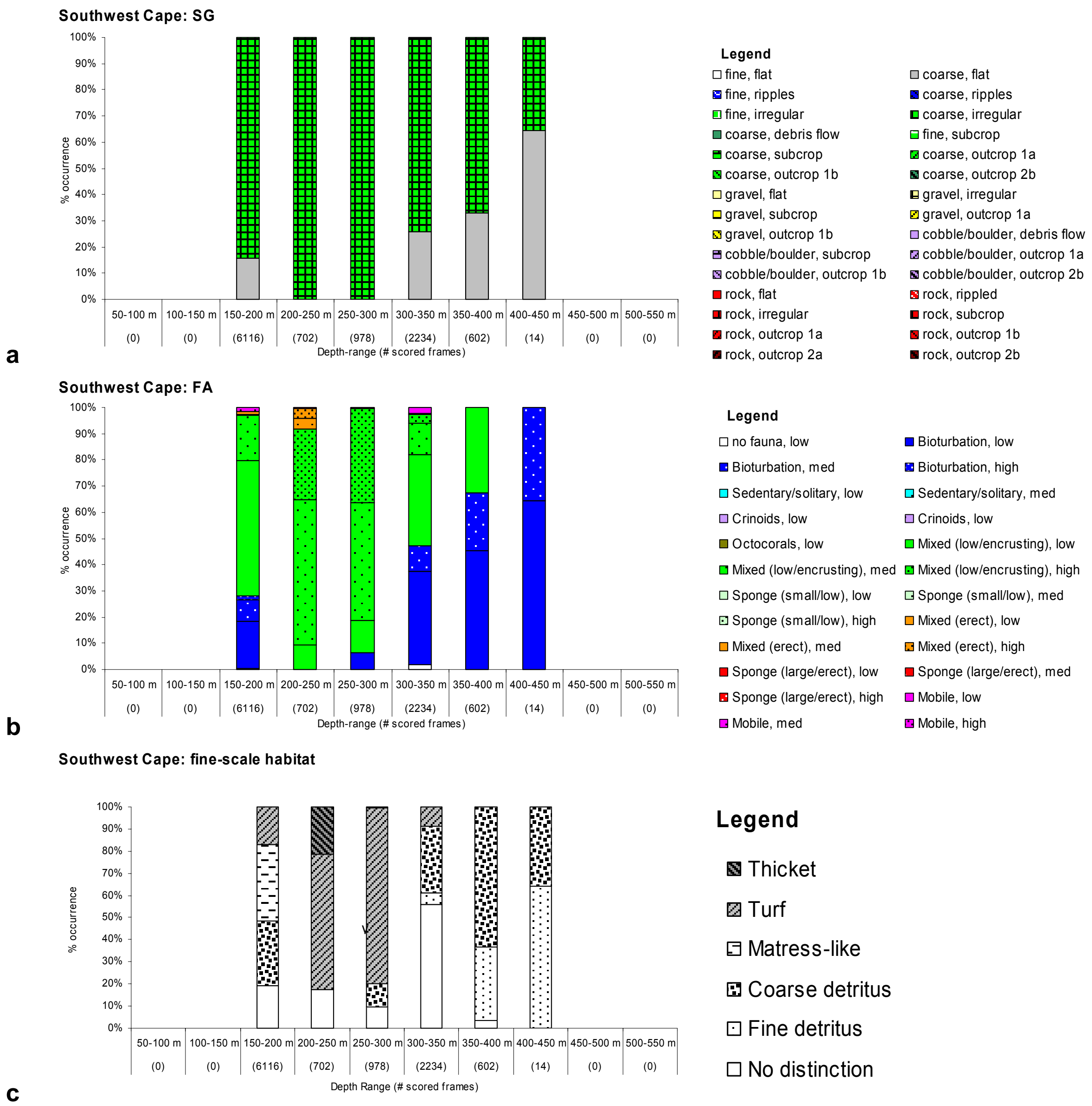


Figure 7.1.1.21 Southwest Cape: percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

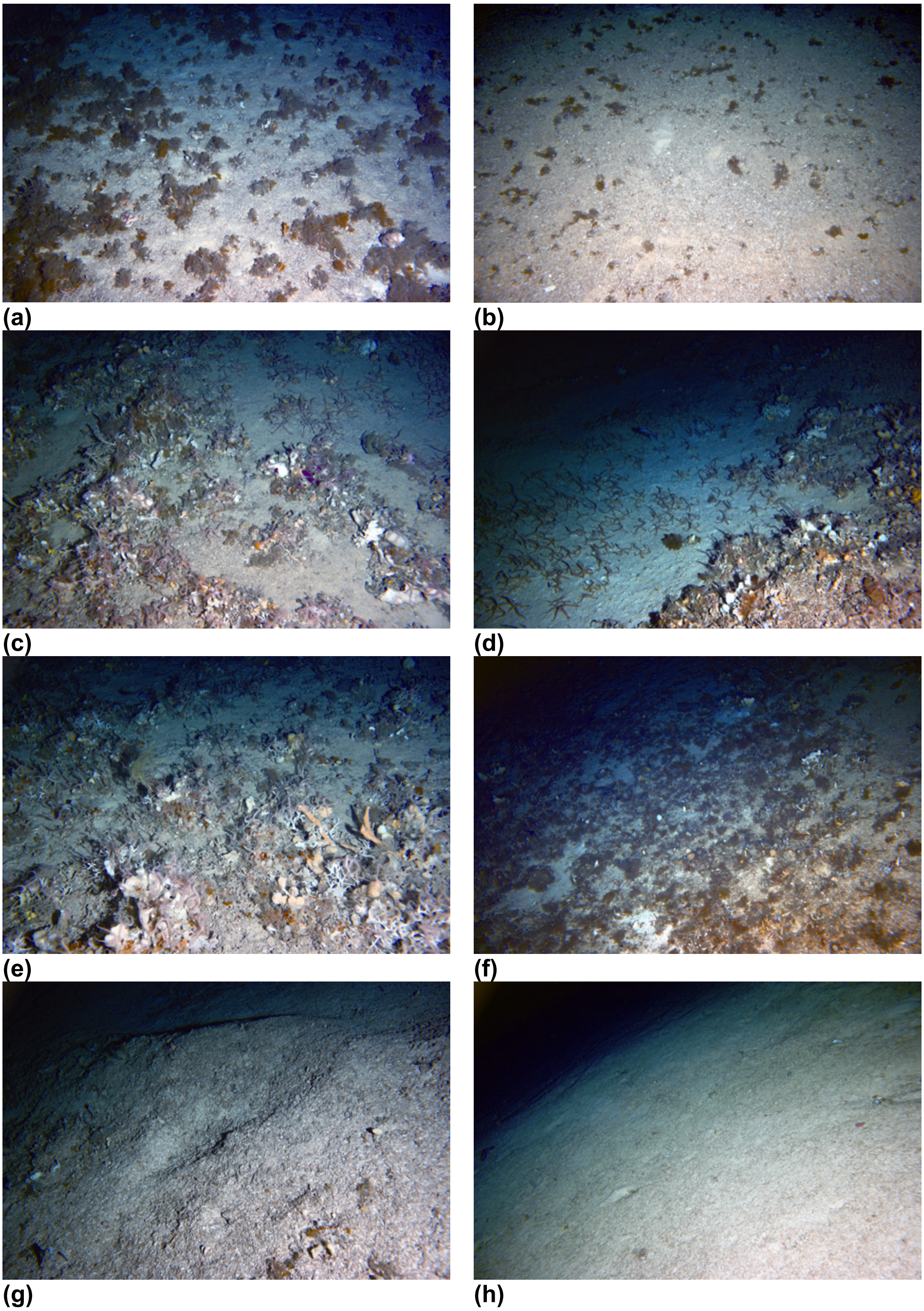


Figure 7.1.1.22 Seabed images from the 'Southwest Cape' site. Depth in meters and transect number (T) is given for each (a) 159 m, T 22 (b) 159 m, T 23 (c) 189 m, T 23 (d) 197 m, T 25 (e) 203 m, T 23 (f) 243 m, T 24 (g) 312 m, T 24 (h) 323 m, T 25. See text for descriptions

Babel Island (high crab / low trawl)

Three cross-depth but no along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given inTable 7.1.1.23 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.24. There were high proportions of flat and some irregular coarse sediments. Some rippled coarse sediments and subcropping rocks were also observed. Sedentary/solitary fauna and coarse detritus in low to moderate abundance made up ~60% of fauna types. No fauna were observed in ~20% of video records. The remainder of the fauna was made up of bioturbating, low/encrusting fauna and small sponges.

Flat coarse sediments were dominant (> 60%) for all depth ranges (100 to 450 m) with the exception of 200 to 300 m, where irregular and rippled coarse sediments made more than 50% of the substrata types. Subcropping boulders and rocks were observed in the 150 to 200 m and 350 to 400 m depth ranges respectively. Some outcropping rocks were observed in the deepest depth range (400 to 450 m) (Figure 7.1.1.23a).

Sedentary/solitary fauna (mostly small solitary ascidians) and coarse detritus made up > 50% of fauna types in all depth ranges (100 to 450 m). Low abundance of low and encrusting fauna (bryozoans), and small sponges decreased in frequency of occurrence from ~20% in the shallowest (100 to 150 m) to <5% at the deepest depth range (400 to 450 m). Bioturbating fauna and coarse detritus were observed throughout all depth ranges with an increased frequency of occurrence below 350 m depth. Throughout all depth ranges, except at 150 to 250 m, no fauna were recorded for ~10 to 30% of video records. Erect sponges (~20%) were observed in the shallowest depth range (100 to 150 m) (Figure 7.1.1.23b and c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.24) (a) a moderate density of low/encrusting fauna (sponges, ascidians and some bryozoans) on irregular coarse sediments; (b) a low abundance of large sponges on cobbles with surrounding flat coarse sediments; (c) some coarse detritus rippled coarse sediments; (d) low encrusting fauna (bryozoans, ascidians and small sponges) and coarse detritus on irregular coarse sediments; (e) low encrusting fauna (sponges and ascidians) and crinoids on a undercut rock outcrop; (f) coarse detritus with some small solitary ascidians burrowed holothurians (feeding apparatus visible) on irregular coarse sediments; (g) bioturbating fauna and coarse detritus on irregular coarse sediments; (h) bioturbating fauna and coarse detritus on a rock outcrop.

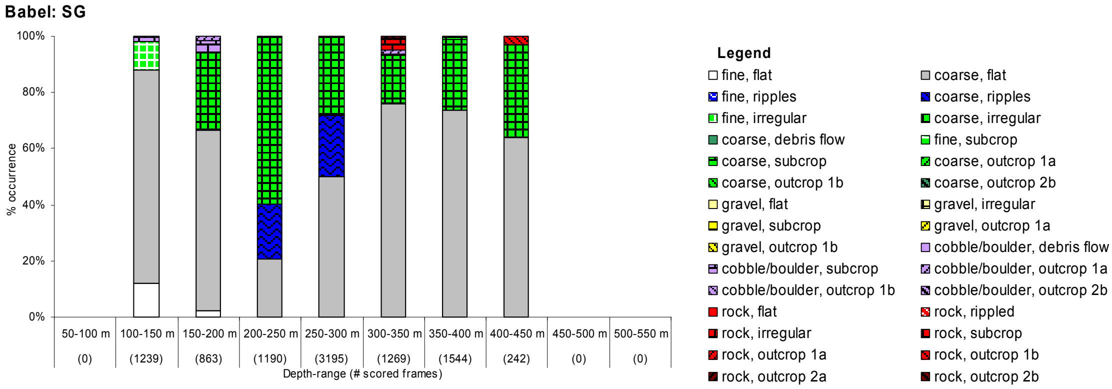
Table 7.1.1.23 Babel: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
X	DR200301	3	125.6	295	3209	14	3195
X	DR200301	4	129.7	409.1	3369	86	3283
X	DR200301	5	150.6	406.6	3067	3	3064

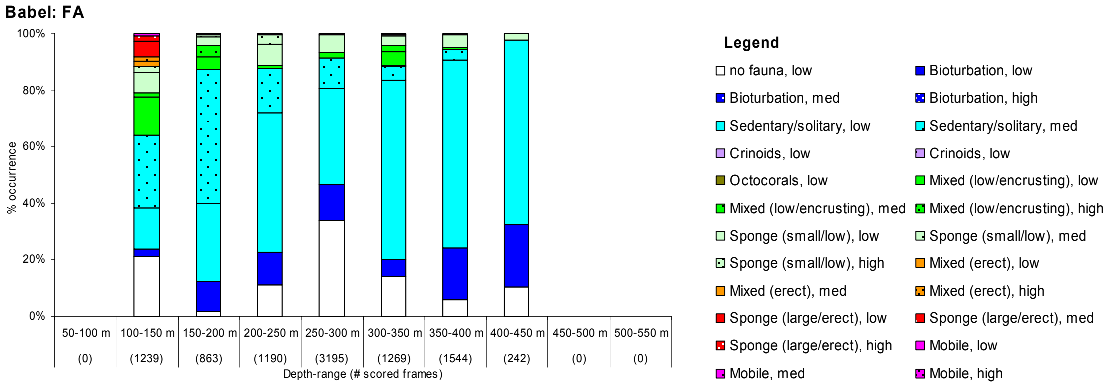
Table 7.1.1.24 Babel: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and major faunal types based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	3.1	Unrippled	**60.4**
Coarse sediments	**95.2**	Rippled	9.7
Gravel/pebble	0.0	Highly irregular	*28.0*
Cobble/boulder	1.0	Debris flow/rubble banks	0.0
Sedimentary rock	0.7	Subcrop	1.2
		Outcrop (low a)	0.3
		Outcrop (low b)	0.2
		Outcrop (high a)	0.0
		Outcrop (high b)	0.1

Fauna (F)	% occ.	Fine scale habitat	% occ.
No fauna	*18.8*	No distinction	22.4
Bioturbation	11.3	Fine detritus	1.6
Solitary/sedentary fauna	**57.1**	Coarse detritus	75.9
Crinoids	0.0	‘Mattress-like’ (likely pres of ophiuroids)	0.0
Octocorals	0.0	Bryozoan turf	0.0
Mixed fauna (low/ encrusting)	4.6	Bryozoan thicket	0.0
Sponge (small/low)	6.4		
Sponge (large/erect)	0.5		
Mixed fauna (erect)	1.0		
Mobile fauna	0.3		



a



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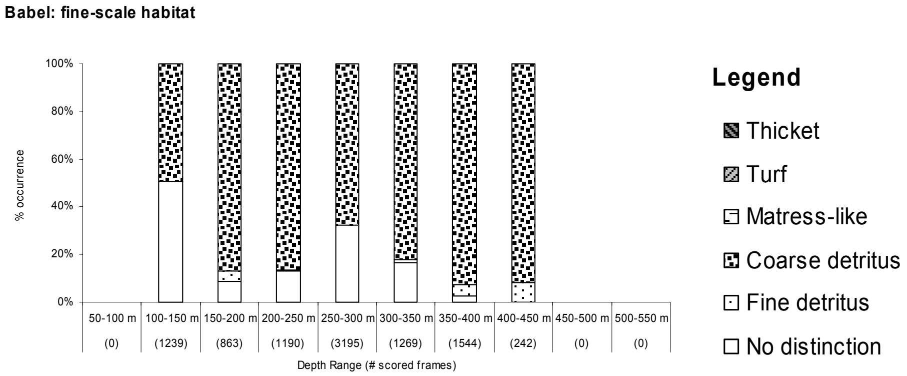


c

Figure 7.1.1.23 Babel: percentage of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

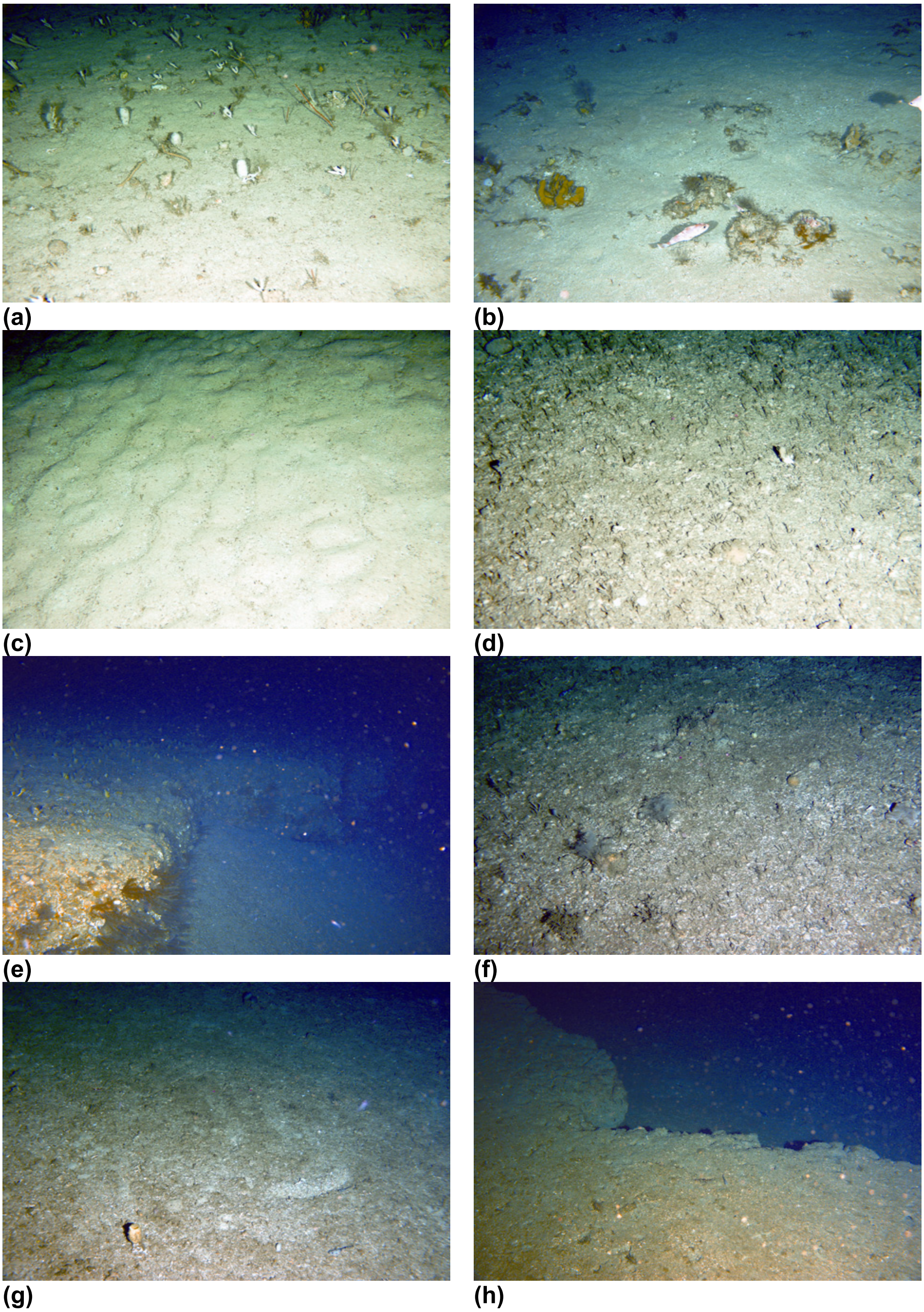


Figure 7.1.1.24 Seabed images from the 'Babel' site. Depth in meters and transect number (T) is given for each (a) 135 m, T 3 (b) 155 m, T 3 (c) 266 m, T 3 (d) 294 m, T 4 (e) 307 m, T 5 (f) 338 m, T 4(g) 373 m, T 5 (h) 402 m, T4. See text for descriptions

Banks Strait (high crab / low trawl)

The Banks Strait site includes samples from northern and southern areas combined into a single Banks Strait site. All six transects at this site were cross-depth (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.25 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.26. There were high proportions of irregular coarse sediments and some flat coarse sediments. Some sub- and outcropping rocks were also observed. Sedentary/solitary fauna (mostly small solitary ascidians) and coarse detritus, as well as low and encrusting turf and small sponges in low to moderate abundance collectively made up ~60% of fauna types. Some bioturbating fauna were also observed.

Irregular coarse sediments were dominant (> 50%) for all depth ranges between 100 and 400 m. Flat coarse sediments increased in occurrence from ~10% in 150 to 200 m depth to ~50% in 300 to 400 m depth. Sub- and outcropping rocks made up >65% of observations in the deepest depth range (400 to 450 m) (Figure 7.1.1.25a).

Sedentary/solitary fauna (mostly small solitary ascidians) and coarse detritus increased in frequency of occurrence from ~10% in 100 to 150 m, to > 60% in the 300 to 400 m depth range. Medium abundance of low and encrusting turf (bryozoans) dominated the 100 to 250 m depth ranges. Low and encrusting fauna and small sponges made up ~30% of fauna types between 250 to 400 m depth. Low/encrusting fauna (bryozoans, ascidians and sponges) occupied the rock substrate in the deepest depth range (400 to 450 m) (Figure 7.1.1.25b and c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.26 and Figure 7.1.1.27). For Banks Strait north (Figure 7.1.1.26): (a, b, c and d) a moderate to low abundance of sedentary/solitary fauna (ascidians and some sponges) and coarse detritus on irregular coarse sediments, image (d) shows an anemone; (e) low/encrusting fauna (sponges and ascidians) on rock outcrop; (f) low abundance of small sponges and some ascidians and coarse detritus on irregular coarse sediments; (g) low abundance of low encrusting fauna on subcropping rock; (h) moderate abundance of low/encrusting fauna on outcropping rock.

For Banks Strait south (Figure 7.1.1.27): (a) a high abundance of low/encrusting turf (bryozoans, ascidians and sponges) on irregular coarse sediments; (b) a high abundance of low/encrusting turf (bryozoans, ascidians and sponges) and some large erect sponges on irregular coarse sediments; (c) a high abundance of sedentary/solitary fauna (solitary ascidians and an anemone) and coarse detritus on flat coarse sediments; (d) a low abundance of sedentary/solitary fauna (solitary ascidians) and coarse detritus on flat coarse sediments; (e) a medium abundance of small sponges and coarse detritus on subcropping rock with a giant crab utilizing a low edge; (f) low abundance of solitary/sedentary ascidians and fine detritus on flat coarse sediments; (g) low encrusting fauna on a undercut outcrop; (h) bioturbating fauna and fine detritus on flat fine sediments.

Table 7.1.1.25 Banks Strait: details of transects and seabed video data.

Site	Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
North	X	DR200301	6	128.1	383.1	4163	33	4130
North	X	DR200301	13	126.3	418.1	3153	1	3152
South	X	DR200301	10	121.2	383.8	3168	1	3167
South	X	DR200301	11	131.6	377.2	3318	12	3306
South	X	DR200301	12	131.6	435.3	3164	64	3100
South	X	DR200301	14	158.1	381.6	3475	61	3414

Table 7.1.1.26 Banks Strait: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types based on video scores at 1-second intervals.

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	0.0	Unrippled	*30.3*
Coarse sediments	**96.0**	Rippled	0.0
Gravel/pebble	0.4	Highly irregular	**63.3**
Cobble/boulder	0.3	Debris flow/rubble banks	0.0
Sedimentary rock	3.3	Subcrop	3.9
		Outcrop (low a)	0.6
		Outcrop (low b)	1.2
		Outcrop (high a)	0.5
		Outcrop (high b)	0.2
Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	0.7	No distinction	20.9
Bioturbation	5.9	Fine detritus	0.0
Solitary/sedentary fauna	**48.4**	Coarse detritus	**63.5**
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	0.0
Octocorals	0.0	Bryozoan turf	15.5
Mixed fauna (low/ encrusting)	**31.8**	Bryozoan thicket	0.0
Sponge (small/low)	11.2		
Sponge (large/erect)	0.0		
Mixed fauna (erect)	0.2		
Mobile fauna	1.6		

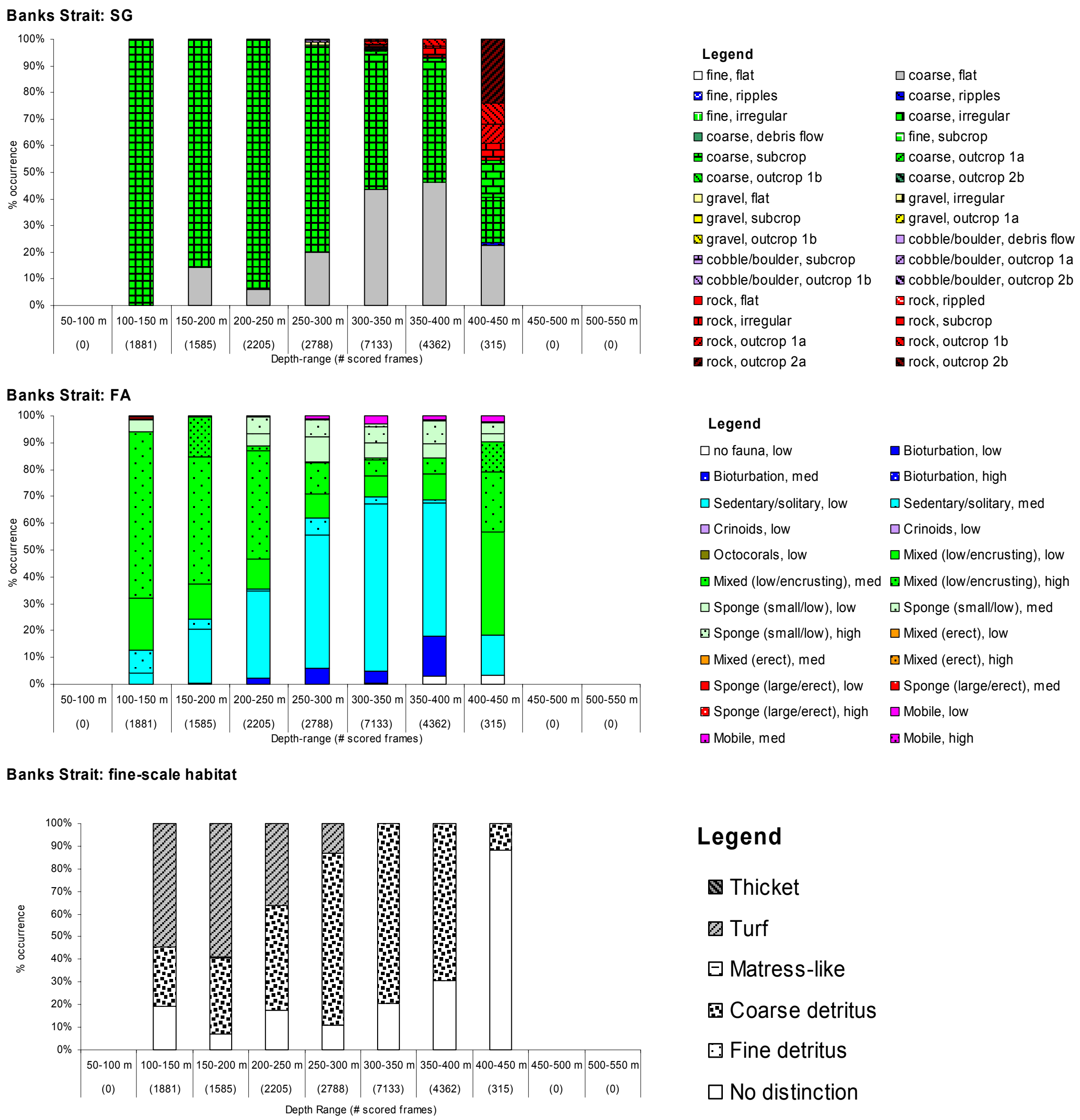


Figure 7.1.1.25 Banks Strait : percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

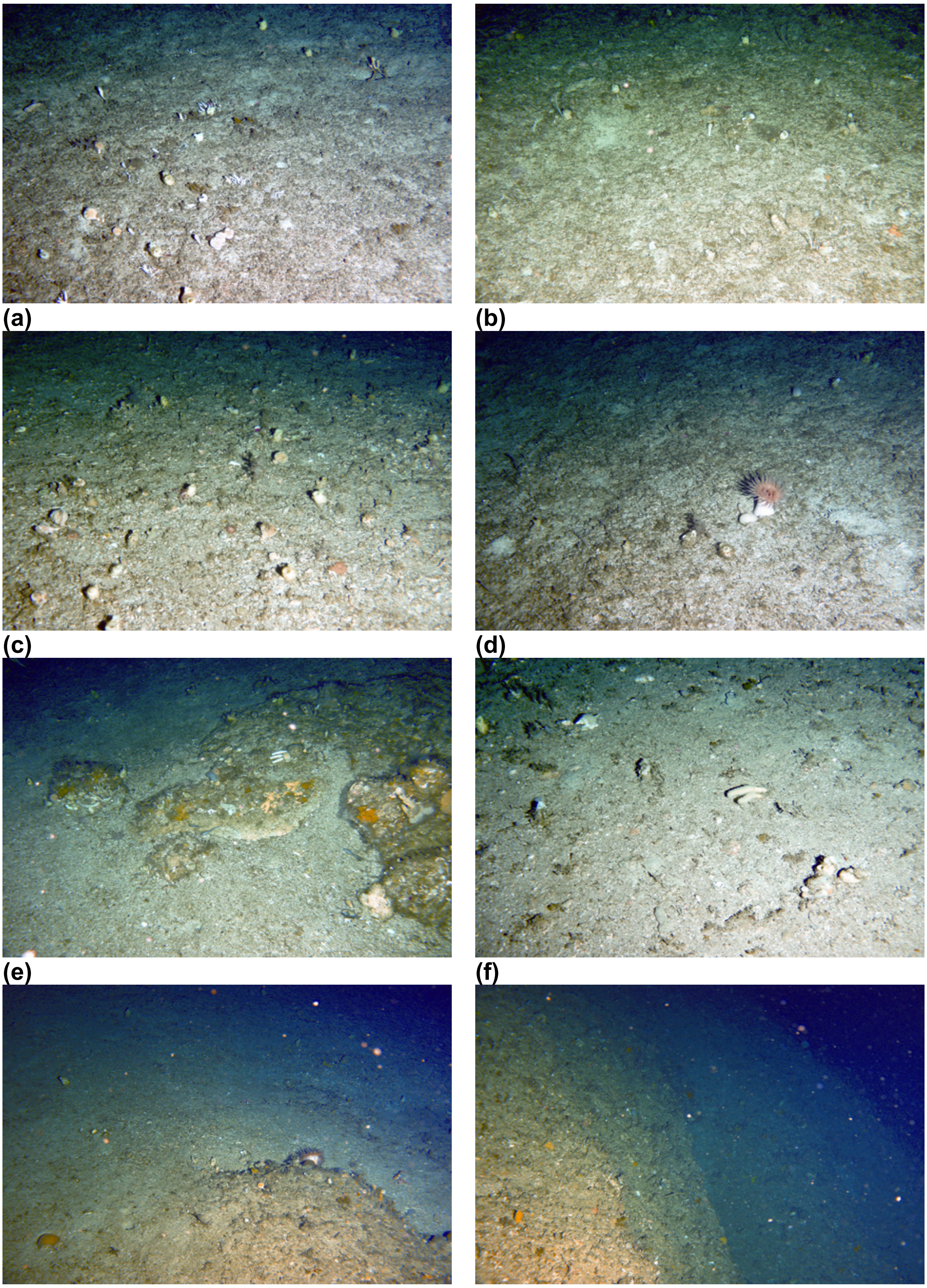


Figure 7.1.1.26 Seabed images from the 'Banks Strait north' site. Depth in meters and transect number (T) is given for each (a) 135 m, T 6 (b) 203 m, T 13 (c) 215 m, T 6 (d) 256 m, T 13 (e) 349 m, T 13 (f) 351 m, T 13 (g) 394 m, T 13 (h) 412 m, T 13. See text for descriptions

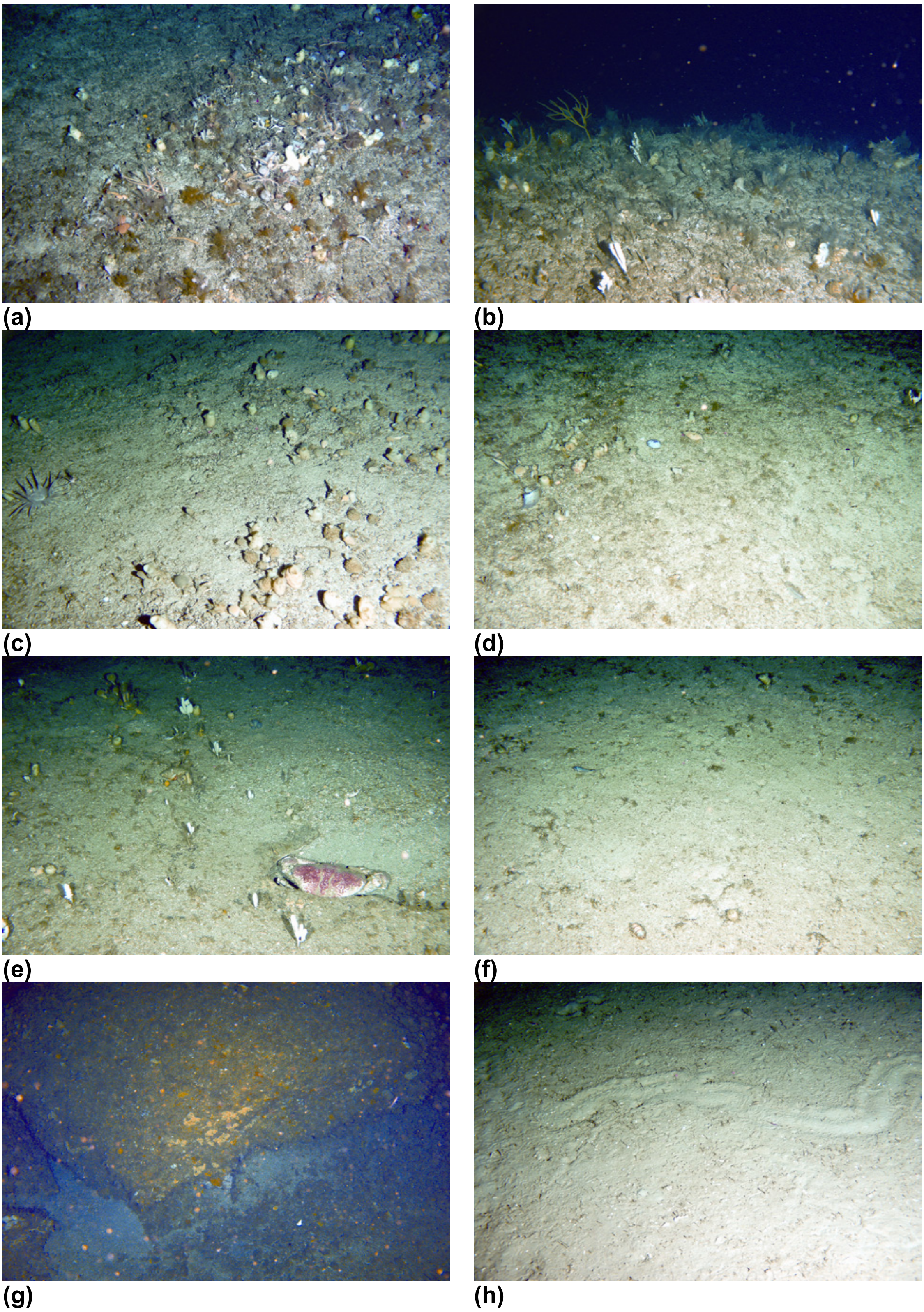


Figure 7.1.1.27 Seabed images from the 'Banks Strait south' site. Depth in meters and transect number (T) is given for each (a) 152 m, T 12 (b) 252 m, T 11 (c) 328 m, T 10 (d) 342 m, T 11 (e) 352 m, T 12 (f) 362 m, T 10 (g) 376 m, T 14 (h) 521 m, T11. See text for descriptions

St Helens (high crab / low trawl)

Three cross-depth but no along depth transects were completed (Table 6.1.1.1). A summary of data for this site is given in Table 7.1.1.27 and the percentages of substratum (S), geomorphology (G) fauna (F) and a breakdown of some faunal types are shown in Table 7.1.1.28. There were high proportions of irregular coarse sediments and some flat coarse sediments. Some sub- and outcropping rocks were also observed. Low/encrusting turf dominated (~60%) the fauna types. Small sponges, sedentary/solitary and bioturbating fauna, and coarse detritus collectively made up ~40% of video records.

Irregular coarse sediments were dominant (> 70%) for all depth ranges between 100 and 400 m. Flat coarse sediments increased in occurrence from ~30% in 350 to 400 m depth to > 60% below 400 m depth (the 450 to 500 m depth range is only has 14 records). Outcropping rocks were observed in the 400 to 450 m depth range (Figure 7.1.1.28a).

Medium abundance of low and encrusting fauna (bryozoans) dominated the 100 to 400 m depth ranges. These fauna formed mostly bryozoan turf up to 250 m depth, below this coarse detritus became prevalent. Sedentary/solitary fauna (mostly small solitary ascidians) and coarse detritus occurred consistently at 100 to 350 m depth (between 10 and 30%). Bioturbating fauna and coarse detritus, in low abundances, dominated the 400 to 500 m depth ranges (Figure 7.1.1.28b and c).

A range of characteristic habitats is shown by a selection of still images (Figure 7.1.1.29) (a) low/encrusting turf (sponges, ascidians and bryozoans) on irregular coarse sediments; (b) coarse detritus on irregular coarse sediments; (c) medium abundance of low/encrusting turf (sponges, ascidians and bryozoans) and a seastar on irregular coarse sediments; (d) low/encrusting turf (ascidians, sponges and bryozoans) on irregular coarse sediments; (e) low/encrusting fauna on coarse sediments and showing a transition to coarse detritus with a massive sponge on irregular coarse sediments; (f) sedentary/solitary fauna (ascidians and an anemone) and coarse detritus on low relief edge forming structure (possibly dead bryozoan matrix); (g) low/encrusting fauna on undercut outcropping rock with adjacent coarse detritus on flat coarse sediments; (h) coarse detritus on flat coarse sediments.

Table 7.1.1.27 St Helens: details of transects and seabed video data.

Transect Type (X across, L along depth)	Survey	Transect	Min depth (m)	Max depth (m)	# records	# Frames off bottom	# Frames Scored
X	DR200301	7	167.2	363.8	2151	35	2116
X	DR200301	8	132.5	268.1	2188	28	2160
X	DR200301	9	135.9	451.9	3167	66	3101

Table 7.1.1.28 St Helens: percentage occurrence of substratum (S), geomorphology (G) fauna (F) and major faunal types based on video scores at 1-second intervals

Substratum (S)	% occ.	Geomorphology (G)	% occ.
Fine sediments	0.0	Unrippled	6.6
Coarse sediments	**99.3**	Rippled	0.0
Gravel/pebble	0.0	Highly irregular	**92.5**
Cobble/boulder	0.1	Debris flow/rubble banks	0.0
Sedimentary rock	0.6	Subcrop	0.1
		Outcrop (low a)	0.3
		Outcrop (low b)	0.3
		Outcrop (high a)	0.2
		Outcrop (high b)	0.0
Fauna (F)	**% occ.**	**Fine scale habitat**	**% occ.**
No fauna	0.3	No distinction	13.5
Bioturbation	9.7	Fine detritus	1.7
Solitary/sedentary fauna	*17.9*	Coarse detritus	**43.1**
Crinoids	0.0	'Mattress-like' (likely pres of ophiuroids)	1.3
Octocorals	0.0	Bryozoan turf	**40.2**
Mixed fauna (low/ encrusting)	**58.9**	Bryozoan thicket	0.0
Sponge (small/low)	10.1		
Sponge (large/erect)	0.3		
Mixed fauna (erect)	1.2		
Mobile fauna	1.5		

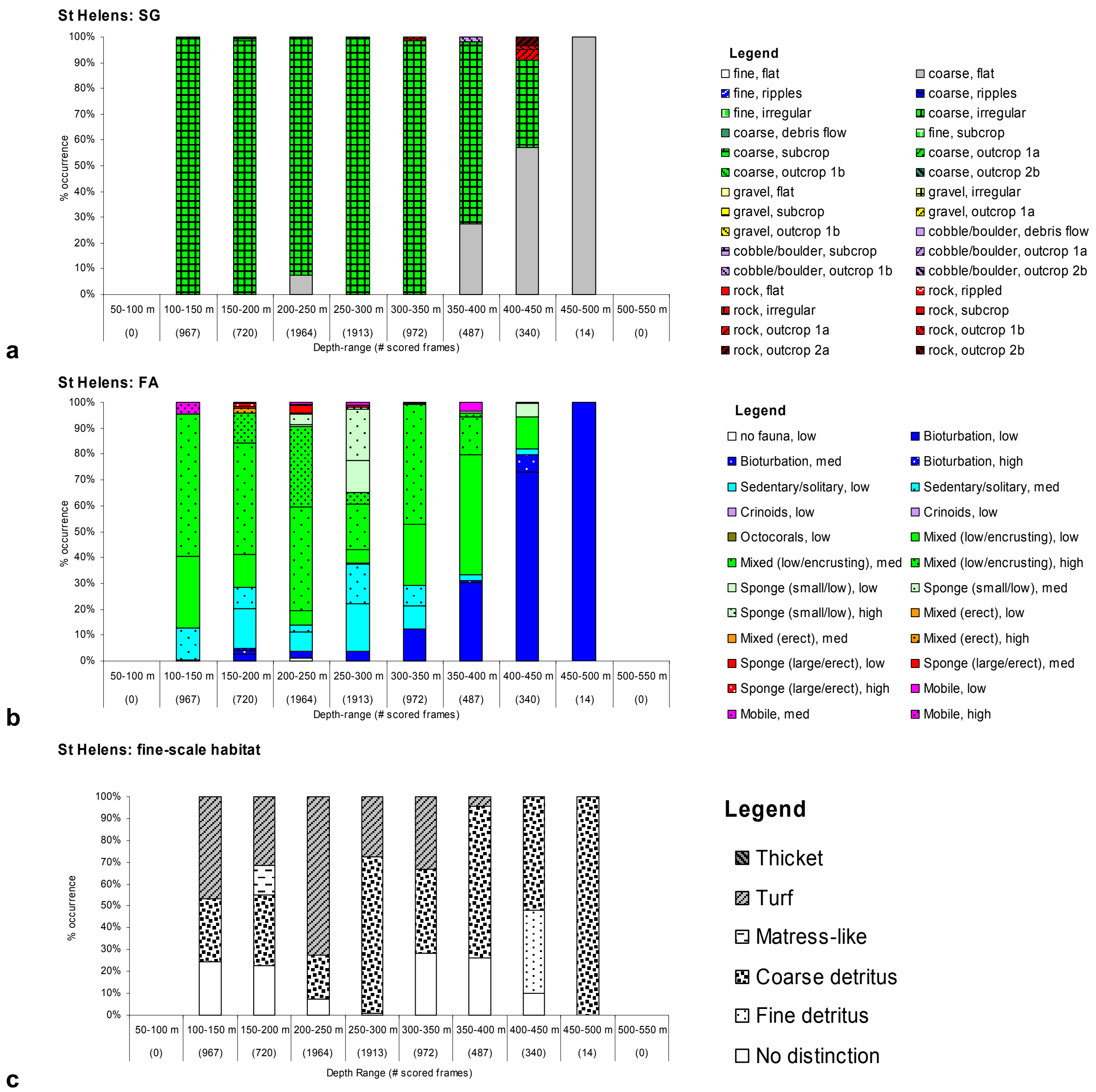


Figure 7.1.1.28 St Helens: histograms showing percentages of (a) combined substratum and geomorphology (=SG), (b) fauna and faunal abundance (=FA), and (c) fine scale habitat (a secondary split of low faunal types such as bryozoans, and 'detritus') in 50 m depth intervals based on video scores at 1-second intervals.

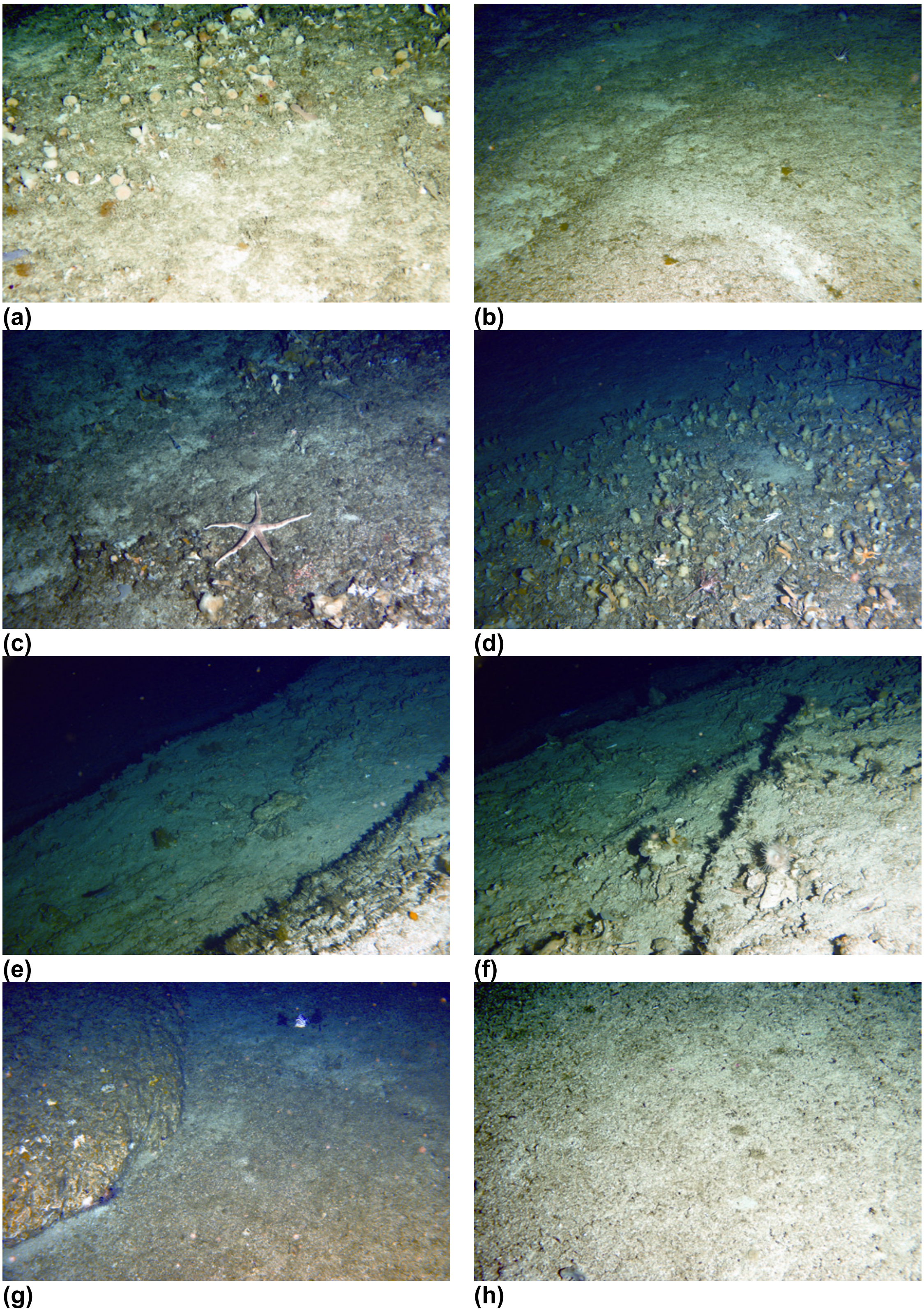


Figure 7.1.1.29 Seabed images from the 'St Helens' site. Depth in meters and transect number (T) is given for each (a) 239 m, T 8 (b) 266 m, T 8 (c) 287 m, T 7 (d) 317 m, T 9 (e) 364 m, T 9 (f) 373 m, T 9 (g) 443 m, T 9 (h) 449 m, T 9. See text for descriptions

Initial analysis

An initial analysis of intra- and inter-site differences was conducted to assess whether sampling had been conducted at sufficient intensity to provide generalised information about patterns in shelf-break habitat around the Tasmanian coast. This analysis proceeded with the assumption that results could be generalised if differences within site were smaller than those between sites, and if differences between sites followed a pattern. In particular, we anticipated a pattern in site differences with latitude down the west coast. This process led to the conclusion that sampling was adequate to proceed to more detailed analyses.

The initial analysis proceeded by segmenting individual transects into 50 m interval depth-bins; bins with < 100 video records were eliminated from all analyses. The use of individual transects enabled variation due to intra-site differences to be examined within depth zones (outer shelf, shelf break and upper slope) in a 2-way crossed analysis of similarity matrices (ANOSIM) of site x depth zone.

A 'global' analysis – useful to detect major differences within the data set as a whole – confirmed visual assessment of histograms showing (1) sites, averaged by depth zone, were generally similar to each other (i.e. inter-site differences were not greater than intra-site differences overall) significant difference at 0.1, but $R = 0.226$; and (2) depth zones, averaged over sites, were generally similar to each other (significant at 0.1, but $R = 0.255$; i.e. no strong differences between depth zones averaged by site). Pairwise comparisons of individual sites and depth zones detected the site to site differences immediately apparent in histograms, e.g. High Rocky, Low Rocky, Banks Strait and Babel being different to many other sites (significant at 0.1, $R > 0.6$) with greatest differences between the outer shelf and shelf break ($R > 0.4$). The BIOENV routine, that calculates a measure of agreement between the matrices of transect/ depth similarities in the video data and corresponding environmental data (here simply average latitude, longitude and depth x transect-depth sample) showed the strongest correlation to depth ($\rho = 0.317$), strong correlation with both latitude and longitude crossed with depth ($\rho = 0.268$ and $\rho = 0.215$, respectively), but only weak correlation with latitude or longitude alone ($\rho < 0.07$). Because there was no strong pattern of intra-site variation, transects within sites were pooled for further analysis.

The same suite of analyses as above were repeated using pooled transects, but here a comparison was done using (1) all transects, (2) only the cross-slope transects (along-slope transects removed), (3) all transects, but with data reduction to remove all variables contributing < 10% of data. Results from all three approaches were similar (based on cluster analysis), so further analysis used all transects with no data reduction. Overall, the results repeated those using individual transects: separate 1-way ANOSIMs showed no strong difference between all sites and none between depth zones, but several site-to-site differences in pairwise comparisons(significant at 0.1, $R > 0.6$), e.g. at Low Rocky, High Rocky, SW Cape and Babel.

Results of cluster analysis (not shown) split nine site groups at the 40% level of similarity. The depth effect was shown by many of the shallowest (100-150 m) and deepest sites (400-550 m) forming separate clusters. The similarity within and between the largest two clusters was driven by their relatively high proportions of bryozoans (turf and thicket) compared to all other clusters, and the dissimilarity between the largest two clusters by proportions of irregular and flat coarse sediments.

7.1.2 Shelf edge habitat distributions: coarse spatial scale

Multivariate analyses were used to examine patterns in the video data at a coarse scale: site by site, in 50 m depth bins. The initial analysis was of raw data to characterize each site independently. Subsequently, we merged some SGFf categories that were difficult to differentiate consistently, and eliminated SGFf combinations that made up only minor fractions of the total data. This assisted plotting, analysis and interpretation of the data set.

Data recoding

Analysis of the full dataset and all variables was appropriate for initial data exploration. However, the large numbers both of sites and variables (35 SG and 25 FA combination-scores and 6 ‘fine-scale’ scores) made it difficult to interpret the patterns and drivers in multivariate analysis, and made the results difficult to present graphically. Accordingly, the next step in analysis was to aggregate some of the similar S, G, F and ‘fine-scale’ variables to give a smaller number of categories: eight categories of SG combinations and five categories of combined FA and 'fine-scale' scores (Table 7.1.2.1). These recoded categories could be meaningfully combined and interpreted as habitat features.

Table 7.1.2.1 Recoded variables based on combinations of the S and G, and of F, A and fine-scale (f) categories scored in video data: "SG" and "epifauna" (see Appendix 3, section 13.3.2 for details of recoding).

SG	Descriptor
-99	No data
1	Flat, fine, sediments
2	Rippled, fine sediments
3	Irregular, fine sediments
4	Flat, coarse, sediments
5	Rippled, coarse sediments
6	Irregular, coarse, sediments
7	Subcropping rock (with or without veneer of sediments)
8	Outcropping rock or boulders

Epifauna (FAf)	Descriptor
-99	No data
1	No apparent epifauna – also includes bioturbation category, 'mattress' with no visible epifauna and biofilm
2	Matrix of coarse detritus with residual fauna – includes no fauna, bioturbation and mobile fauna categories in combination with on coarse detritus
3	Low/encrusting fauna – including ascidia, low abundance of low encrusting fauna
4	Turf/thicket – composed primarily of bryozoans and supporting other attached low fauna dominated by small sponges
5	Erect fauna – composed of a variety of groups including sponges, seawhips and large bryozoans, e.g. *Adeona grisea*

Habitat distribution by site

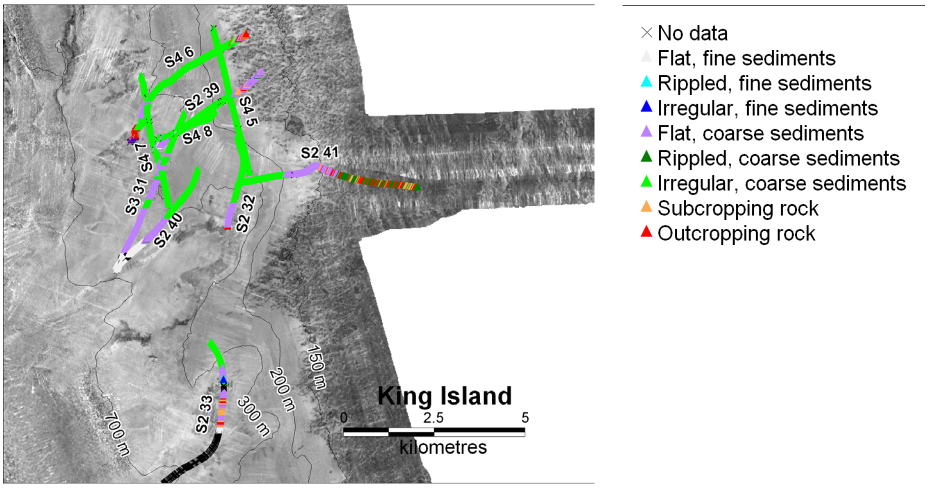
King Island (high crab / low trawl)

Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.1a and b) showed the spatial distribution of habitats. Irregular and flat coarse sediments formed long patches (up to 2 km). Long patches of sediments continue across the boundaries of canyons. Flat sediments were present on the deep upper slope and at the deepest section of shelf (below 150 m). In depths < 150 m, rocky outcrops and rippled coarse sediments are interspersed as small patches. On the deep upper slope, fine sediments existed as long patches (e.g. in 450-600 m at the end of transect S2-40). Rocky bottom was observed in two areas: on transect S4-6 sedimentary bedding planes exposed over a distance of ~400 m (relatively long in the context of rocky upper slope habitat) on a spur feature forming part of the northern flank of a canyon; and on transect S2-33 there were relatively short patches of subcrop and boulders in a canyon (Figure 7.1.2.1a). These patches of rocky bottom were generally consistent with the distribution of higher backscatter compared to surrounding sediments. There are several areas of high backscatter associated with the two relatively large canyon heads and a distinct shelf edge slump present at this site. They indicate that rocky bottom protrudes from mud-filled areas within these canyons.

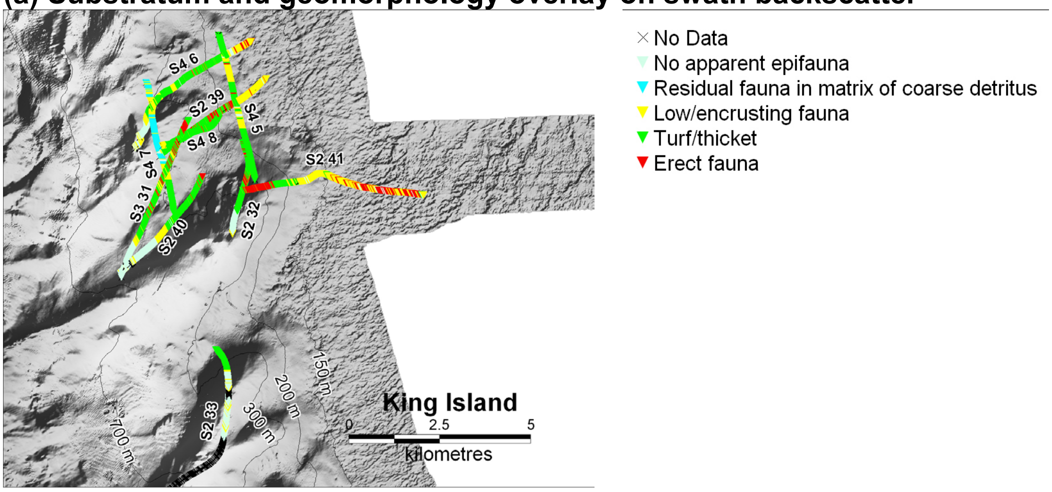
Bryozoan turf/thicket was dominant at the shelf edge where it formed patches of varied length: long in places (to 1.6 km in along slope and down slope transects), and short in others where they were interspersed with erect fauna. Small patches of low/encrusting fauna occurred on flat sediments outside the reef, above the main areas of bryozoans, and in association with rippled sediments among rocky outcrops of the shelf reef; they also occurred in small patches below the bryozoan turf/thicket. Below this, no apparent epifauna was observed on deep fine sediments (> 450 m). Erect fauna (in which sponges and bryozoans were dominant) was strongly associated with rocky reef on the outer shelf (Figure 7.1.2.1b).

At this site it was not possible to track a narrow depth range with along slope transects due to the highly complex topography. However, along slope transects were generally less variable than down slope transects with respect to SG, indicating a greater degree of structuring with depth (Figure 7.1.2.1a and b).

Several transect intersections between surveys were recorded at this site. This enabled comparison of the same location in April 2004, November 2004 and April 2005. Classifications were generally equivalent between these surveys with respect to SG and epifauna.



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

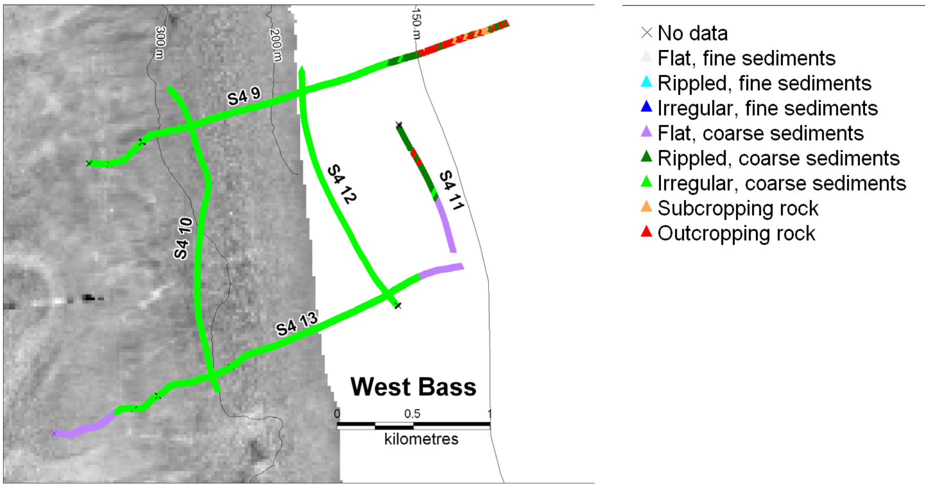
Figure 7.1.2.1 King Island: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

West Bass (high crab / low trawl)

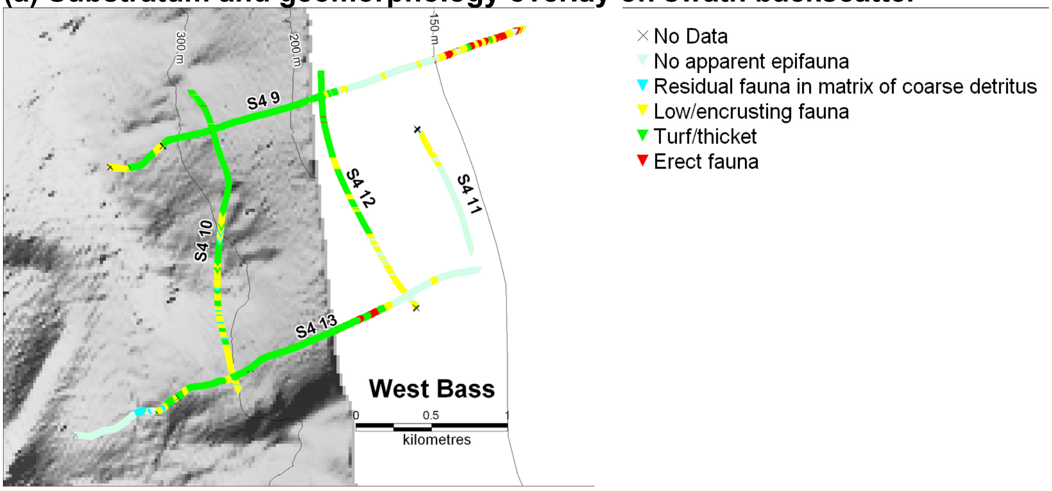
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.2a and b) show the spatial distribution of habitats. Irregular coarse sediments formed long contiguous patches on down slope and along slope transects (to > 2 km). Flat sediments are present on the deep upper slope (> 400 m) and at the deepest section of shelf (below 150 m). In depths approximately < 150 m, rippled coarse sediments are interspersed as small patches among rocky outcrops and subcrops. Rippled coarse sediments occur in a narrow depth band seaward of the rocky reef. No rocky bottom was observed in the shelf break and upper slope areas. This was consistent with the lack of higher backscatter across the entire site – with only a small area evident in the canyon to the south.

Bryozoan turf/ thicket patches were of various lengths, up to ~1km in along slope and down slope transects, being interspersed with small patches of low/encrusting fauna. Bryozoan turf/thicket occupied most of the deep shelf and shelf break and extended to the upper slope - from ~170 m to ~360 m. There was no apparent epifauna on the deep shelf outside the reef (~120-160 m) or on the open deep (> 400 m) sediments. Burrowing ophiuroids were observed on the former. Erect fauna (in which sponges and bryozoans were dominant) was strongly associated with rocky reef on the outer shelf to 120 m (Figure 7.1.2.2b).

Along slope transects tracked relatively narrow depth ranges at this site. They were similarly uniform, and corresponded to the down slope transects they crossed, with respect to SG and epifauna indicating the relatively low complexity at this site (consistent with the overall patterns in swath maps) (Figure 7.1.2.2a and b).



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

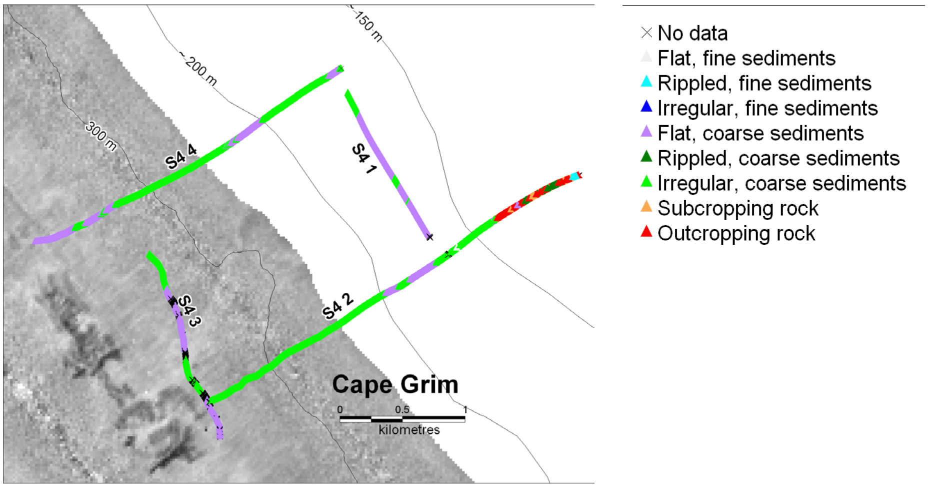
Figure 7.1.2.2 West Bass: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Cape Grim (high crab / high trawl)

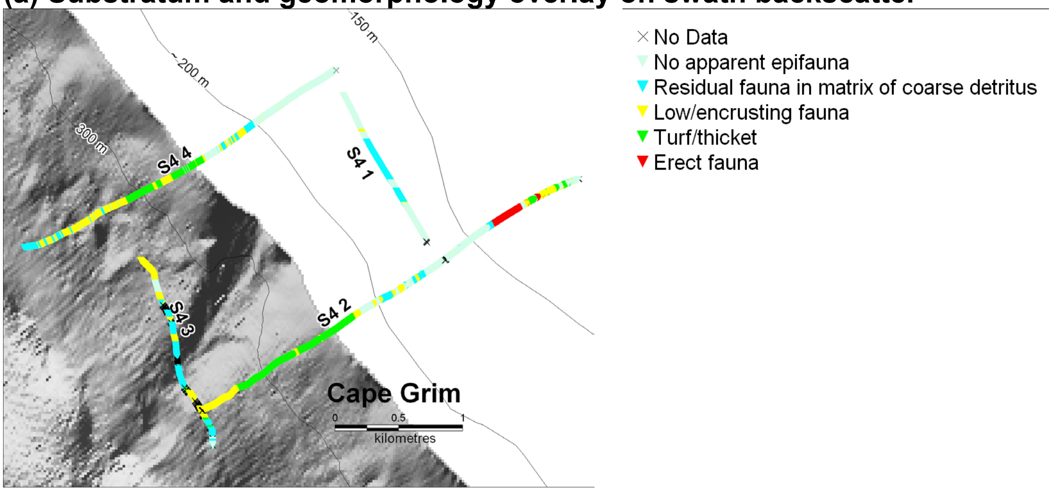
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.3a and b) show the spatial distribution of habitats. Irregular and flat coarse sediments form long contiguous patches on down slope and along slope transects (to at least 1.5 km). Flat sediments are present at the deepest section of shelf (from ~150 to 200 m) and on the shallow upper slope (~350 m). In depths approximately < 150 m, rocky outcrops, subcrops and rippled coarse sediments are interspersed as small patches. No rocky bottom was observed in the shelf break and upper slope areas. This was consistent with the lack of higher backscatter across the entire site – although distinct hard areas existed beyond transect S4-2 in ~400 to 480 m – partly in, but also adjacent to, a small canyon.

Bryozoan turf/thicket occupied the shelf break to ~200 to 320 m. Lack of epifauna in long patches on the deep outer shelf in ~150-200 m were areas occupied by ophiuroids. Erect fauna (in which sponges and bryozoans were dominant) was strongly associated with rocky reef on the outer shelf. Medium length patches of coarse detritus with residual fauna were seen in along slope transects on the deep shelf (~150 m) and upper slope in ~350-400 m (Figure 7.1.2.3b).

Along slope transects tracked relatively narrow depth ranges at this site. They showed a mix of flat and irregular coarse sediments, and similar patterns to corresponding down slope transects with respect to SG and epifauna indicating a relatively low complexity at this site (– consistent with the overall patterns in swath maps) (Figure 7.1.2.3a and b).



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

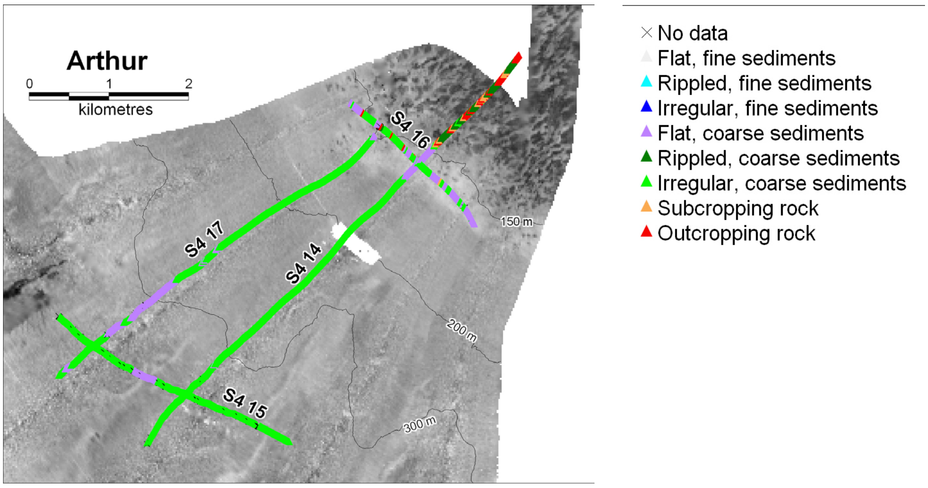
Figure 7.1.2.3 Cape Grim: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Arthur (high crab / high trawl)

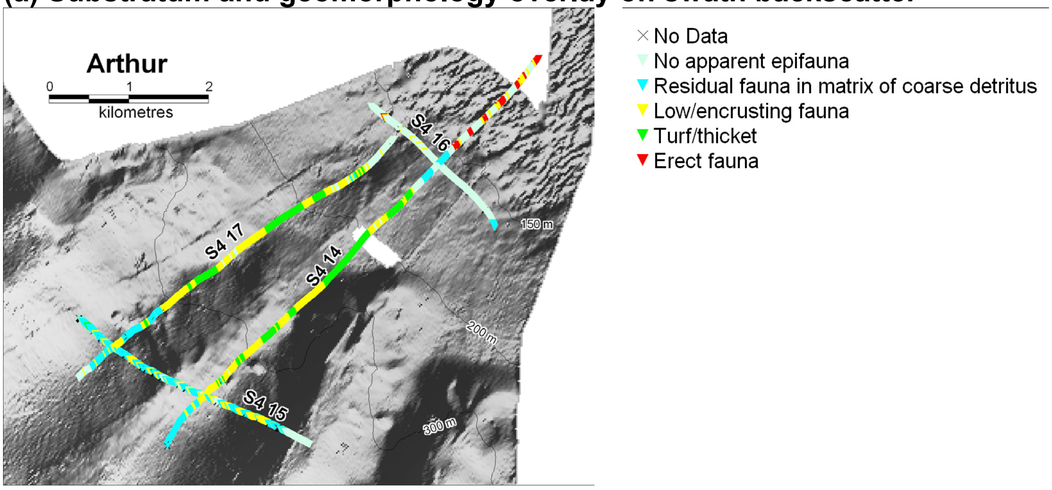
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.4a and b) show the spatial distribution of habitats. Irregular coarse sediments formed long contiguous patches on down slope and along slope transects (to at least 4.7 km). Small patches of flat sediments are present on the shallow upper slope and at the deepest section of shelf (below 150 m). In depths < 130 m, rocky outcrops, subcrops and rippled coarse sediments are interspersed as short patches. No rocky bottom was observed in the shelf break and upper slope areas. This was consistent with the lack of higher backscatter across the site in depths > 150 m – although distinct areas were present beyond transect S4-15 in ~400 to 500 m. Three small canyon heads present at this site appeared to be predominantly mud-filled based on the lack of backscatter within them (Figure 7.1.2.4a)

Bryozoan turf/thicket formed short to medium length patches, interspersed with low/encrusting fauna, over the shelf break to ~300 m (Figure 7.1.2.4b). Beyond this depth, the upper slope was predominantly covered by a matrix of coarse detritus with residual fauna. Erect fauna (in which sponges and bryozoans were dominant) was strongly associated with rocky reef on the outer shelf (out to ~130 m). Outside the reef, to about 170 m depth, there was either no apparent epifauna (where ophiuroids formed many small patches) or small patches of coarse detritus with residual fauna.

Along slope transects tracked relatively narrow depth ranges at this site. They showed a mix of irregular and flat coarse sediments, and similar patterns to corresponding down slope transects where they intersected, with respect to both SG and epifauna (Figure 7.1.2.4a and b).



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

Figure 7.1.2.4 Arthur: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Ling Hole (high crab / high trawl)

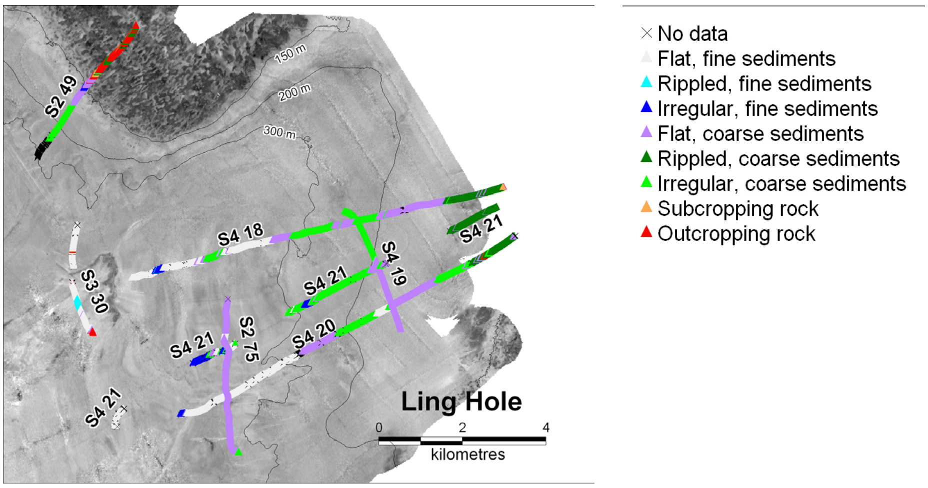
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.5a and b) show the spatial distribution of habitats. Data were collected on three occasions at this site during surveys 2, 3 and 4. This enabled a degree of temporal comparison where transects from different surveys intersect (S2-75 with S4-20 and 21).

Data from Surveys 3 and 4 show medium length (1 to 1.5 km) patches of coarse sediments make up most substrata on the shelf and shelf break, with a grade from rippled to flat to irregular with increasing depth to ~350 m. Flat fine sediments form long (to 3 km) patches below 350 m, with small patches of rippled fine sediments at the deep ends of down slope transects. The northernmost transect from Survey 2 (S2 49) commenced in a shallower depth to the other cross slope transects; it has rocky outcrops interspersed with rippled sediments in depths < 130 m, and is consistent with the distribution of intense backscatter. Hard rocky bottom was also observed on transect S3-30 in a deep section of the main canyon. There was not a clear correspondence with backscatter – but the main and localized area of high backscatter was missed by the transect. The remainder of the canyon is mostly sediment filled (Figure 7.1.2.5a).

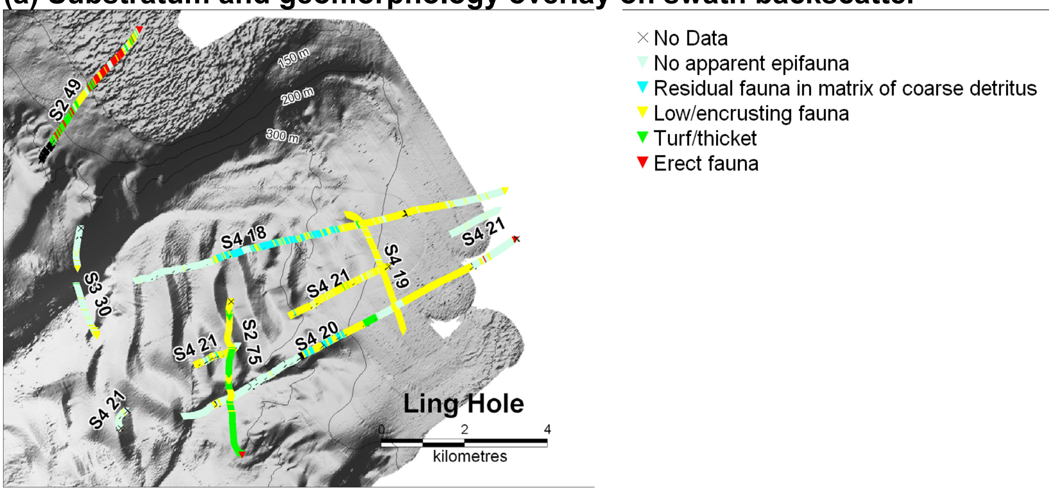
Data from Surveys 3 and 4 showed there was no apparent epifauna in the rippled shallow zone, or in most of the transect areas below ~400 m. Most of the remaining transect areas showed either low/encrusting or residual fauna in a matrix of coarse detritus, with most of the low/encrusting fauna occurring shallower, in ~150 to 250 m. The rocky outcrops of the northernmost transect harbour patches of erect and low/ encrusting fauna that give way to turf/thicket at the shelf break (Figure 7.1.2.5b).

Interestingly, quite different SG and epifauna was recorded during Survey 4 (April 2005) at the intersection point between transects S4-20 and S4-21 with S2-75 from Survey 2 (April 2004). In the intersection areas, flat coarse sediments appear to have been replaced by flat fine sediments, and live low/encrusting fauna by an absence of epifauna (Figure 7.1.2.5b). The video data for the intersection points were reviewed and checked, and the different scores confirmed (Figure 7.1.2.6).

At this site it was not possible to track a narrow depth range with along slope transects due to the highly complex topography. However, they were generally less variable than down slope transects with respect to SG and epifauna indicating a greater degree of structuring with depth (Figure 7.1.2.5a and b). Temporal differences confound down slope to across slope comparisons to some extent.

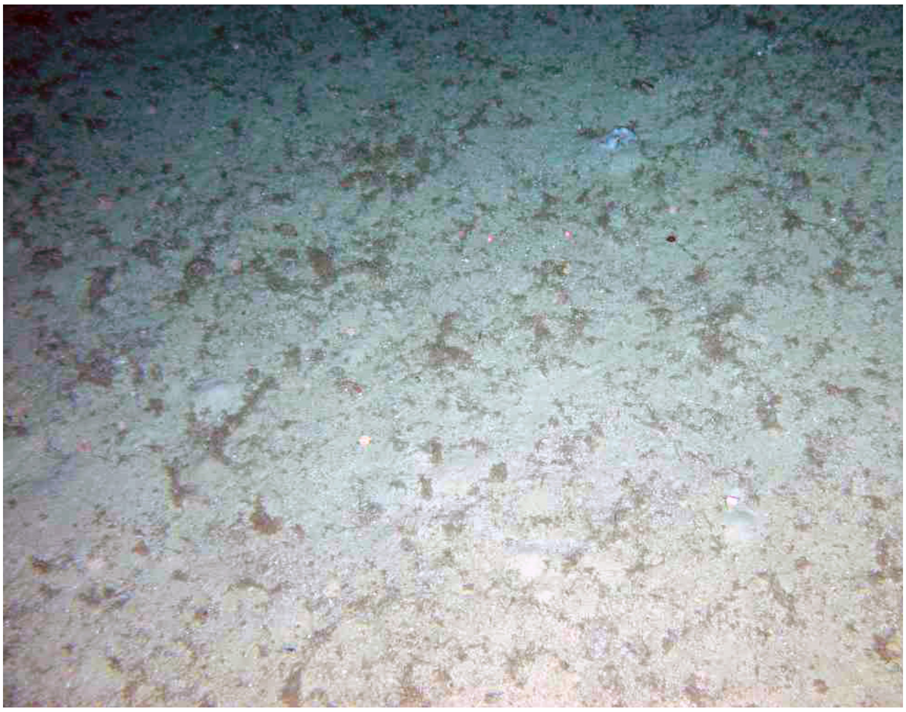


(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

Figure 7.1.2.5 Ling Hole: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.



(a) April 2004: Low/encrusting fauna at low to moderate density (S2-75; 460 m)

(b) April 2005: Bare sediments with detritus in places (S4-20; 464 m)

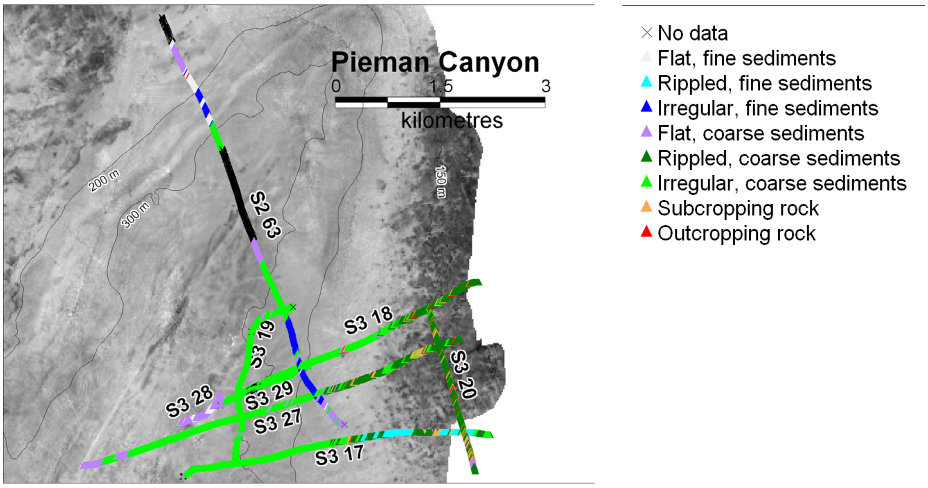
Figure 7.1.2.6 Cross-over section of two video transects taken one year apart at the Ling Hole

Pieman (high crab / high trawl)

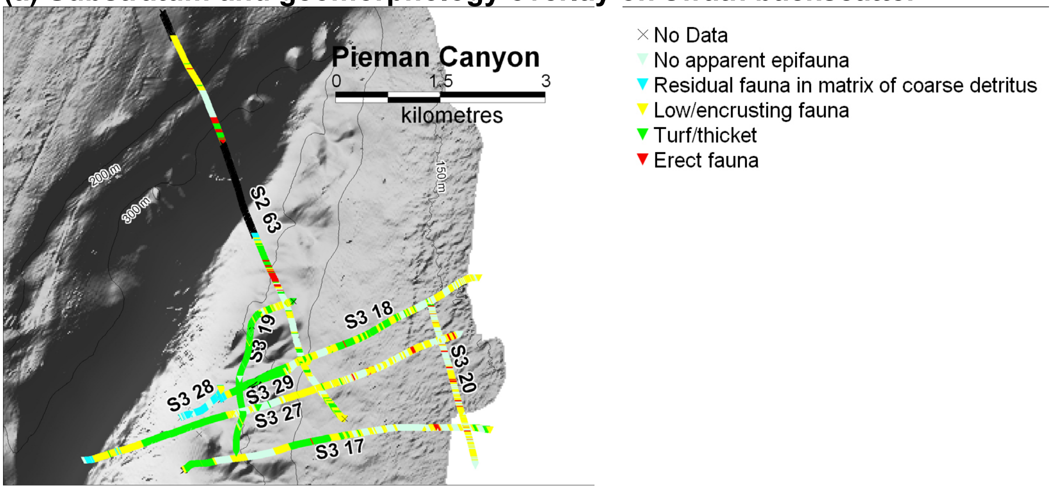
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.7a and b) show the spatial distribution of habitats. Irregular coarse sediments form long contiguous patches on down slope transects (to at least 2.0 km) from the outer shelf to the upper slope (~150 to 400 m). Short patches of flat fine and coarse sediments occurred on the upper slope (> 400 m), and at the shelf break (on the flanks of the major canyon present at this site). Short patches of rippled fine sediments occurred on the outer shelf at the southern flank of the canyon. Rippled coarse sediments and rocky subcrops and outcrops are interspersed to form short patches on the outer shelf (~130 to 150 m). Isolated short patches of rocky bottom were observed at the shelf break, but none on the upper slope, or in the canyon. Areas of higher backscatter were present in the canyon base, but were not covered by a video transect (Figure 7.1.2.7a).

Bryozoan turf/thicket formed mostly short with some medium length (to 1.2 km) patches mainly at the shelf break below 250 m. These were interspersed with many short and some medium length patches (to 500 m) of low/encrusting fauna, mainly over the outer shelf and shelf break, but with some also at the deepest end of transects (350 to 400 m). A matrix of coarse detritus with residual fauna predominated the relatively short sections of transects at upper slope depths (> 400 m). Erect fauna occurred in few, scattered short patches together with areas of low/encrusting and no apparent epifauna; these were associated with the patchy rocky reef on the outer shelf (out to ~150 m). Erect fauna was also observed in short patches in the canyon associated with coarse sediments. Dense aggregations of ophiuroids were observed in two distinct patches classed as 'no apparent epifauna' in association with irregular fine sediments on the canyon flanks (Figure 7.1.2.7b).

Along slope transects tracked relatively narrow depth ranges at this site. They showed equivalent patterns to corresponding intersections with down slope transects with respect to SG and epifauna. Note that the two series of data were collected on different surveys (April 2004 and November 2004) and results indicted stability between surveys at this site.



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

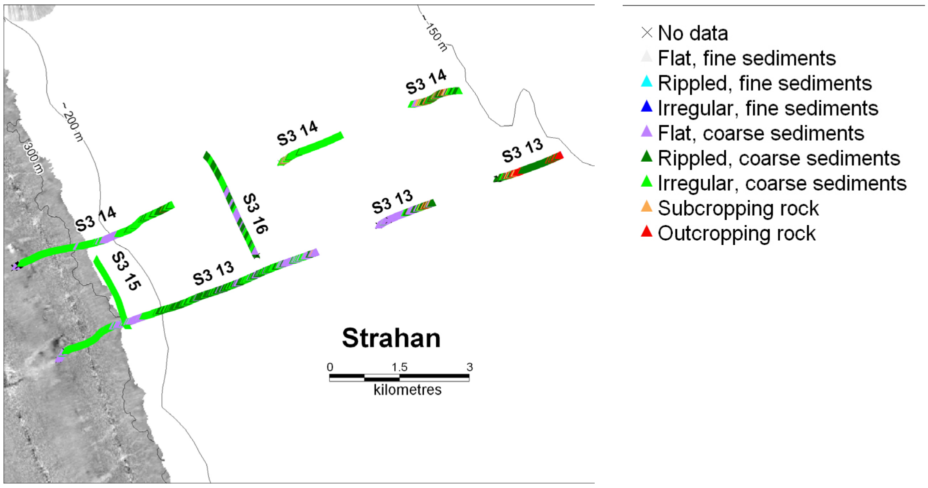
Figure 7.1.2.7 Pieman: map of survey site showing attributes overlaid on seabed(a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Strahan (high crab / high trawl)

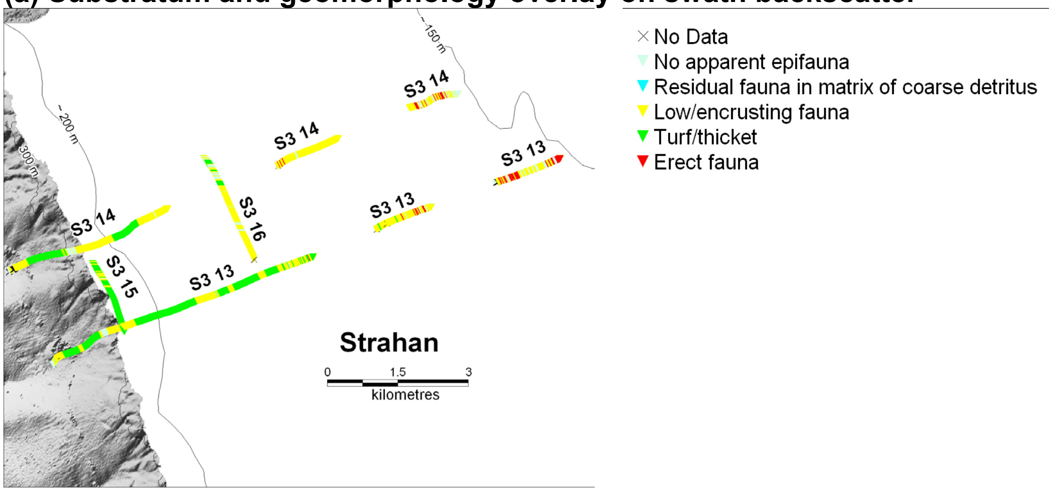
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.8a and b) show the spatial distribution of habitats. This site has a relatively gently sloping shelf, steep slope and no prominent canyons – down slope transects are broken because of the long distance over the shelf. Interspersed short patches of flat, irregular and rippled coarse sediments are prominent – occupying the deep shelf from ~150 to 170 m in down slope and along slope transects. Below this, moderate length (up to 1.8 km) patches of irregular coarse sediments are present on the shelf break and shallow upper slope. Short patches of flat coarse sediments were present at the shelf edge (~190 m) and at the end of transects in ~400 m. In depths < 150 m, rocky outcrops, subcrops and rippled coarse sediments are interspersed as short patches. Small patches of rocky bottom were observed on the deep shelf in ~150 m. There was limited swath coverage at this site to permit comparison with backscatter and evaluate the presence of canyons (Figure 7.1.2.8a).

Bryozoan turf/thicket and low/encrusting fauna formed short to medium length (to 1.3 km) patches, over the deep shelf and shelf break from ~150 to 300 m – with turf/thicket becoming more abundant with increasing depth. Beyond this depth, the upper slope was predominantly covered by low/encrusting fauna, with no apparent epifauna at the deepest areas of the transects around 400 m. Erect fauna was strongly associated with rocky reef on the outer shelf (inside 150 m). Outside the reef, to about 170 m depth, there was either no apparent epifauna (where ophiuroids formed many small patches) or small patches of coarse detritus with residual fauna. Short patches with no epifauna at the shelf break (~210 m) were characterized by burrowing ophiuroids. (Figure 7.1.2.8b).

Along slope transects tracked relatively narrow depth ranges at this site. They showed similar patterns of SG and epifauna to corresponding down slope transects where they intersected.



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

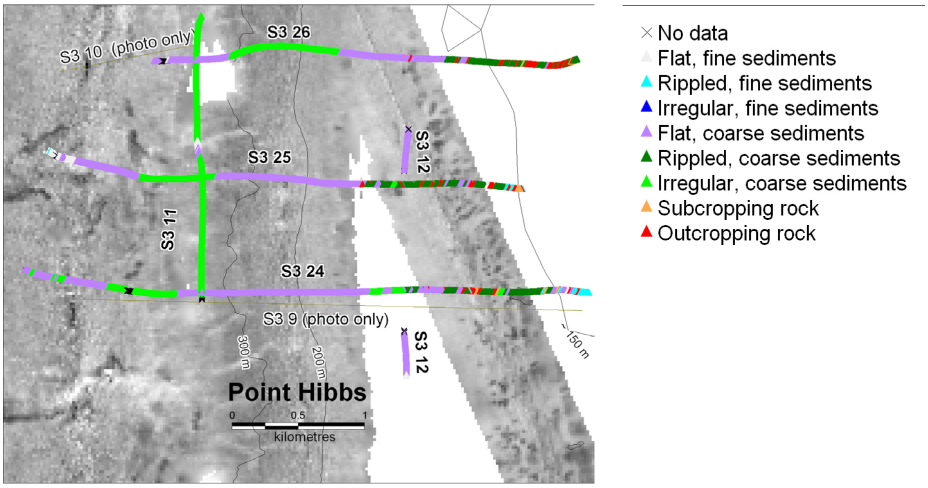
Figure 7.1.2.8 Strahan: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Point Hibbs (high crab / low trawl)

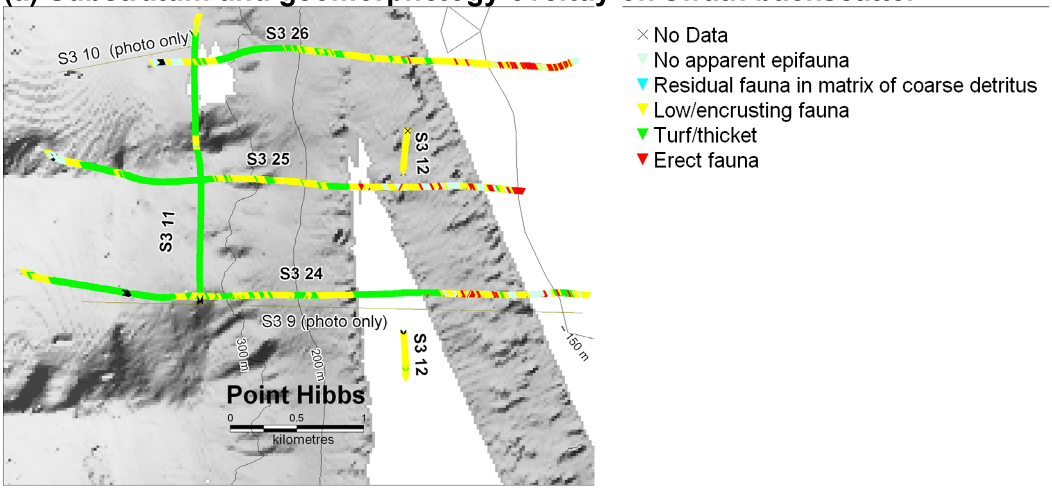
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.9a and b) show the spatial distribution of habitats. Flat and irregular coarse sediments formed medium length contiguous patches on down slope and along slope transects (to ~1.0 km) over the depth range of 150-400 m. Flat coarse sediments were more prevalent than at most other sites, but here the shelf was gently sloping to a relatively steep shelf break. Irregular coarse sediments were mainly in the 230 to 330 m range at the shelf break. Flat fine sediment occurred at the deep end of one transect in ~400 m in a small canyon. In depths < 150 m, rocky outcrops, subcrops and rippled coarse sediments were interspersed as short patches. No rocky bottom was observed in the shelf break and upper slope areas. Areas of higher backscatter were present beyond transects ~> 300 m but were not surveyed by video. Two small canyon heads present at this site appeared to be predominantly mud-filled based on the lack of high backscatter within them (Figure 7.1.2.9a)

Bryozoan turf/thicket formed mainly medium length patches (up to ~1.0 km), interspersed with low/encrusting fauna, mainly over the shelf break and including the shelf break from ~145 m to ~380 m. This is slightly deeper than at most other sites. The short transect lengths beyond this depth showed a transition to no apparent epifauna in depths from ~400-450 m. Erect fauna was strongly associated with rocky reef on the outer shelf (out to ~150 m) (Figure 7.1.2.9b).

Along slope transects tracked relatively narrow depth ranges at this site. They showed mainly irregular coarse sediments along the deep transect (~320-380 m) and flat coarse sediments along the shallow transect (~150-160 m). The pattern between the along slope transects and the intersections with corresponding down slope transects were similar, although SG scores conflicted to a minor degree (irregular coarse sediments vs. flat coarse sediments) as did epifauna scores (low/encrusting fauna vs. turf/thicket). This suggested either some degree of inconsistency in scoring of categories or error in geolocation.



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

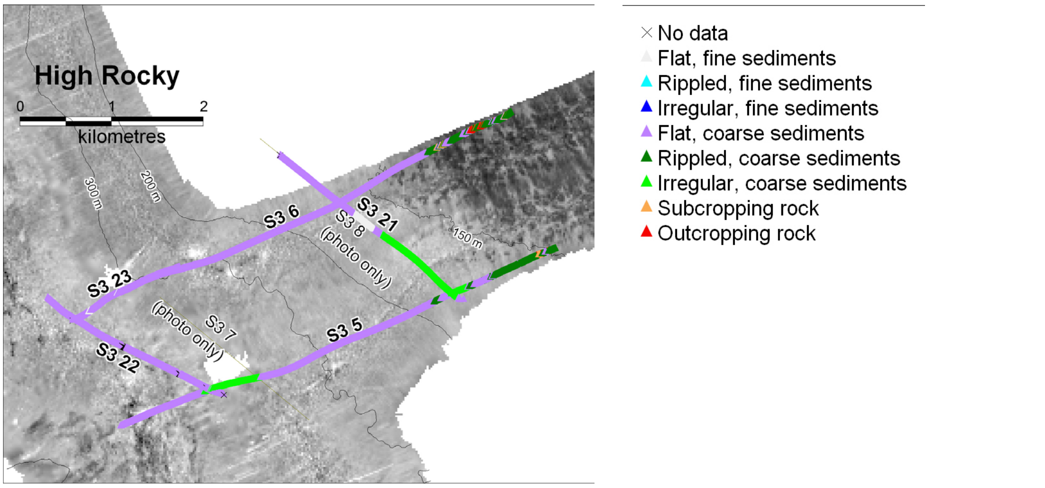
Figure 7.1.2.9 Point Hibbs: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

High Rocky (low crab / low trawl)

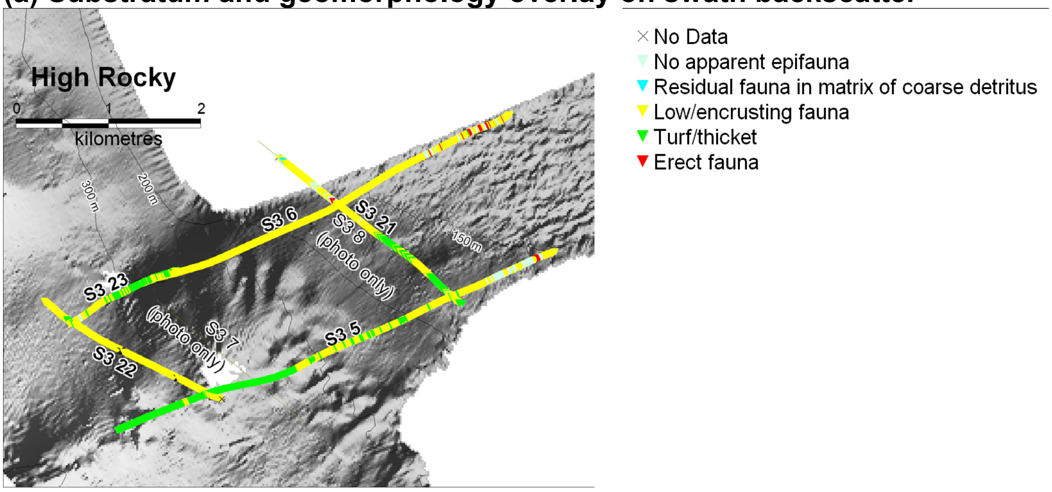
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.10a and b) show the spatial distribution of habitats. The areas observed by video transect were predominantly flat coarse sediments, which formed long contiguous patches on down slope and along slope transects (to 4.2 km). These extended from about 145 to 370 m depth. Medium patches (0.5 to 1 km) of irregular coarse sediments were present on the shelf break (~230-280 m) and at the deepest section of shelf (below 160-170 m). In depths < 145 m, rocky subcrop with some outcrop, and rippled coarse sediments were interspersed as short patches. No rocky bottom was observed in the shelf break and upper slope areas, although there were areas of higher backscatter across the site in depths > 330 m, including an area crossed by transect S3-5. One small canyon head present at this site appeared to be predominantly mud-filled to ~350 m depth based on the lack of high backscatter within it (Figure 7.1.2.10a)

Low/encrusting fauna was dominant and formed several long patches (to 3 km), interspersed with mostly small patches of bryozoan turf/thicket on the deep shelf and shelf break within the canyon. Bryozoan turf/thicket was present in longer patches (to 1 km) on the southernmost transect in ~200-370 m and the along slope transect in ~150 to 170 m. No data were taken beyond 400 m. Short patches of erect fauna were strongly associated with rocky reef on the outer shelf (out to ~145 m); these were interspersed with longer patches of low/encrusting fauna and shorter patches where no epifauna was observed (Figure 7.1.2.10b).

Along slope transects tracked relatively narrow depth ranges at this site. The deepest (~400 m) showed continuous flat coarse sediments, and the shallower (150-170 m) showed a transition from flat to irregular coarse sediments, the former with low/encrusting fauna, the latter with turf/thicket. Classification of SG and epifauna along slope transects were similar to corresponding down slope transects where they intersected.



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

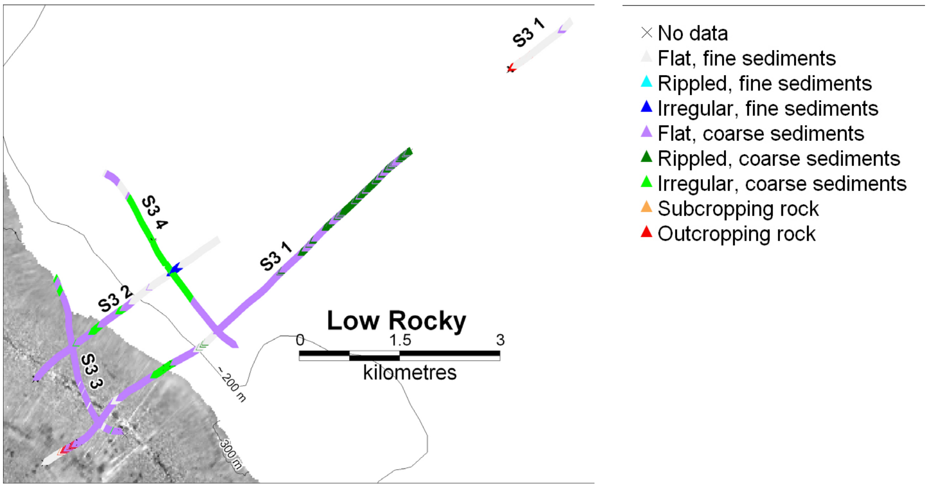
Figure 7.1.2.10 High Rocky: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Low Rocky (low crab / high trawl)

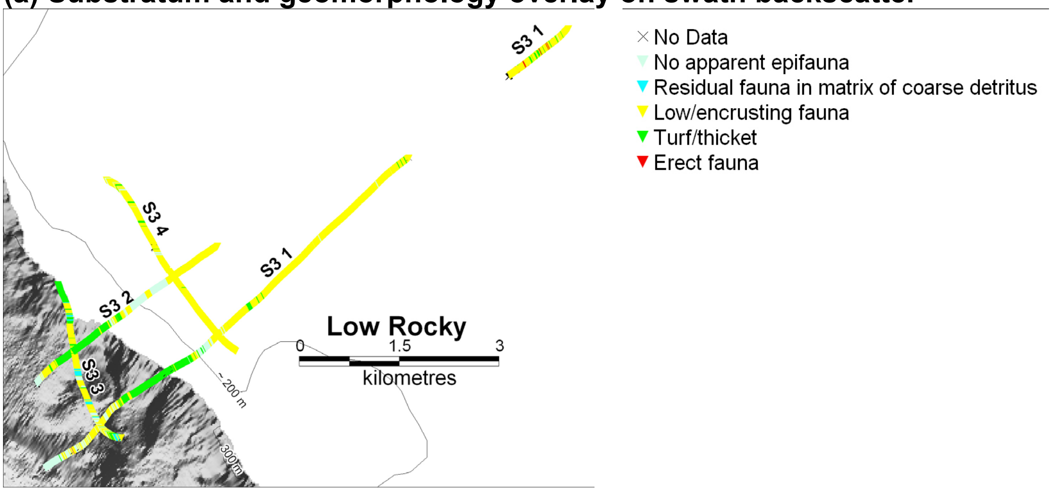
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.11a and b) show the spatial distribution of habitats. The areas observed by video transect were predominantly flat coarse sediments, which formed medium length patches on down slope and along slope transects (to 1.2 km). These extended from about 160 to 420 m depth. Smaller patches (0.5 km) of irregular coarse sediments were present on the shelf break (~280-320 m) and at the deepest section of shelf (160-170 m) on the along slope transect. In a wide area around 160 m depth, many short patches of rippled coarse sediments were observed. Flat fine sediments were observed in medium length patches at the shallowest point of transects (150 m), on the outer shelf (160-180 m) and at the deepest point of transects in > 470 m. Some rocky outcrop was observed out to depths of at least 150 m (broken transect) and on the upper slope at a steep drop off in 430-470 m. There was relatively little swath coverage underlying the video transects, but part of a small canyon was visible on the upper slope. The steep rocky slope corresponded precisely with an area of high backscatter.

Low/encrusting fauna was dominant and formed several long patches (to ~2 km), interspersed with small patches of bryozoan turf/thicket on the deep shelf (to ~170 m). Bryozoan turf/thicket was present in long patches (to 1 km) in ~200-370 m. It was unclear whether the true reef edge was surveyed by the inner sections of video transects where only very short patches of erect fauna and rocky reef were present. Most outer shelf was characterized by low/encrusting fauna with areas of no apparent fauna at the shelf break. On the upper slope, below the bryozoan zone, small patches of no apparent fauna and low/encrusting fauna were observed (Figure 7.1.2.11b).

Along slope transects tracked relatively narrow depth ranges at this site (although the deeper transect dropped into a canyon head at its southern end). The deepest (~360 to 420 m) showed virtually continuous flat coarse sediments, while the shallower (160-170 m) had a mix of irregular and flat coarse sediments. Classification of SG and epifauna along slope transects were similar to corresponding down slope transects where they intersected, except for the intersection of the northern cross slope transect that variously recorded rippled and irregular sediments (Figure 7.1.2.11a and b).



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

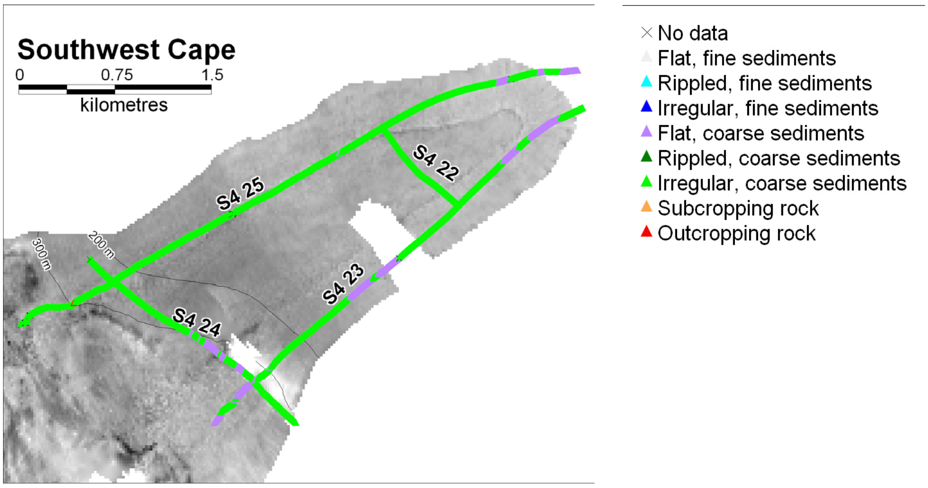
Figure 7.1.2.11 Low Rocky: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Southwest Cape (low crab / low trawl)

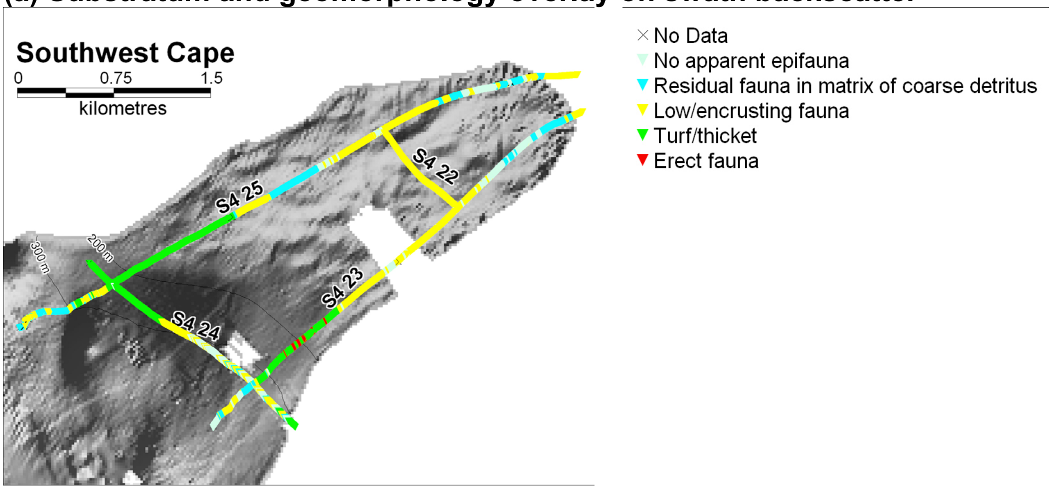
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.12a and b) show the spatial distribution of habitats. Irregular coarse sediments formed long contiguous patches on down slope and along slope transects (to ~2 km). Small patches of flat coarse sediments made up the remainder. Only one extremely small (metres in length) rocky outcrop was observed (in 320 m depth). High backscatter was observed in many places on the upper slope, but these were not crossed by video transects. A depression feature present at this site appeared to be predominantly mud-filled based on the lack of backscatter within it (Figure 7.1.2.12a).

Bryozoan turf/thicket formed short to medium length patches (to 1 km), interspersed with erect fauna on the outer shelf and over the shelf break 170-280 m. Beyond this depth, the upper slope was predominantly covered by small patches of low/encrusting and residual fauna in coarse detritus. The gently sloping outer shelf (160-170 m) was dominated by short to medium length (~500 m) patches of low/encrusting fauna, at the shallower end of which dense populations of ophiuroids were observed. A mixture of no apparent epifauna, residual fauna in detritus, and low/encrusting fauna was observed in the shallowest depths sampled (150-160 m) (Figure 7.1.2.12b).

Only the shallower along slope transects tracked relatively narrow depth range at this site. It showed irregular coarse sediments, and low/encrusting fauna (with ophiuroids). The deep along slope transect covered the depth range from 240 to 340 m, sampling a localised depression in the topography. Classification of SG and epifauna along slope transects were equivalent to corresponding down slope transects where they intersected (Figure 7.1.2.12a and b).



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

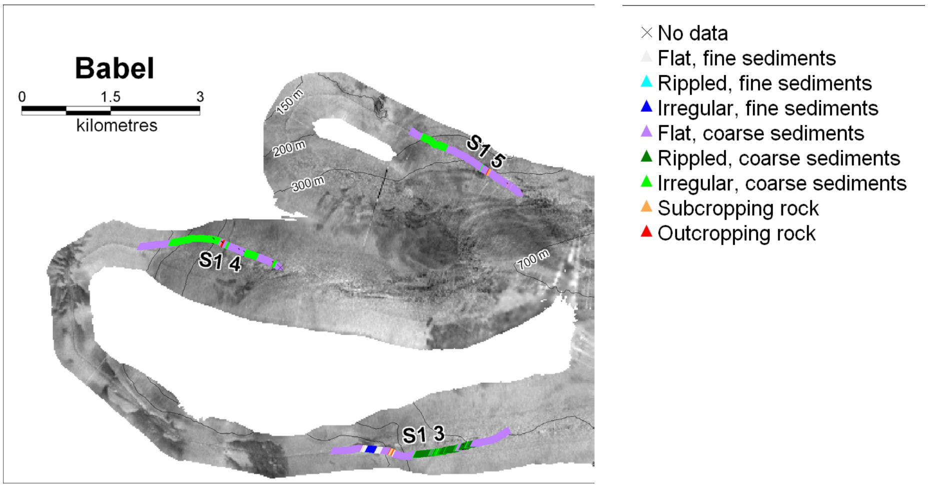
Figure 7.1.2.12 Southwest Cape: map of survey site showing attributes overlaid seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Babel (high crab / low trawl)

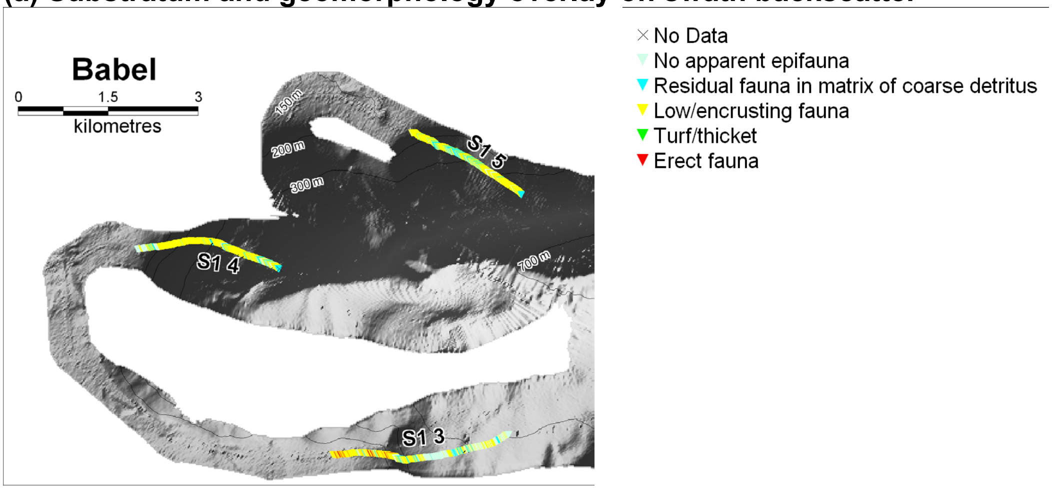
Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.13a and b) show the spatial distribution of habitats. The east coast sites were sampled on the first (proof of concept) survey before the systematic sampling design of along and across shelf transects was implemented. Thus, video data was collected on cross-shelf transects only, and distances between transects were greater than on the west coast sites.

The northern two transects sampled the head of a major canyon at this site. Flat coarse sediments formed medium length patches (to 600 m) on the outer shelf and upper slope. Short to medium length patches (400-800 m) of irregular coarse sediments dominated the deep outer shelf and shelf-break (170-300 m) with intermittent short patches on the upper slope. Short outcropping and subcropping rocky patches were observed in approximately 300 m depth. These were consistent with areas of higher backscatter. The southernmost transect (S1-3) sampled a gently sloping region between canyon heads. It showed flat coarse sediments in medium length patches (to 600 m) on the outer shelf (~130 m) and upper slope (> 290 m), with a rippled and irregular coarse sediments interspersed over the shelf-break (230-290 m). Short patches of rippled and flat fine sediments and subcropping rock were observed on the deeper outer shelf (~170 m) (Figure 7.1.2.13a)

Low/encrusting fauna formed medium length patches, interspersed with residual fauna in a matrix of coarse detritus and no apparent epifauna on all transects. Erect fauna was observed in short patches on the outer shelf on transect S1-3. (Figure 7.1.2.13b).



(a) Substratum and geomorphology overlay on swath backscatter



(b) Epifauna overlay on swath bathymetry

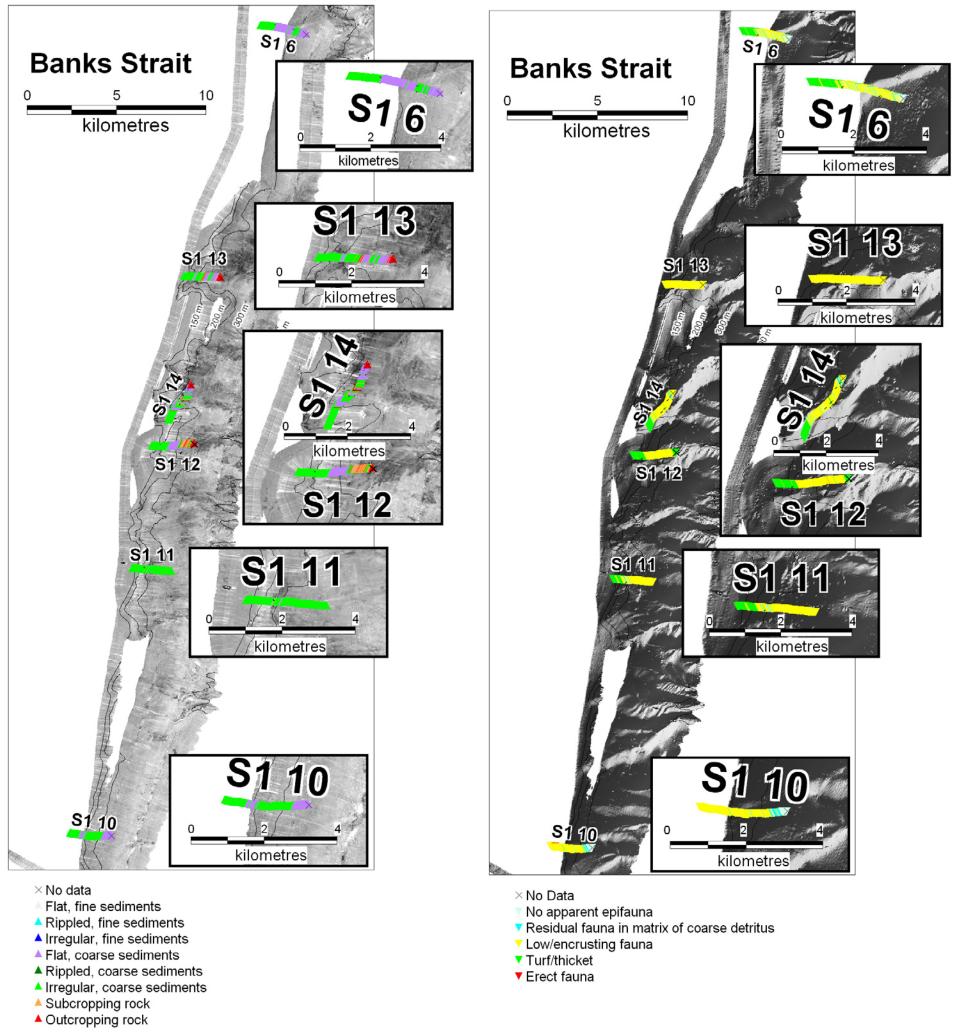
Figure 7.1.2.13 Babel: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Banks Strait (high crab / low trawl)

Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.14a and b) show the spatial distribution of habitats. The east coast sites were sampled on the first (proof of concept) survey before the systematic sampling design of along and across shelf transects was implemented. Thus, video data was collected on cross-shelf transects only, and distances between transects were greater than on the west coast sites. Irregular coarse sediments formed medium to long patches (to 1 km) on the outer shelf and shelf-break. Short to medium length patches (to 700 m) of flat coarse sediments dominated depths >300 m. Short patches of out- and subcropping rock were observed at the deep end of three transects (S1-12 to 14) (Figure 7.1.2.14a)

Low/encrusting fauna formed medium to long patches (to 1 km), interspersed with no apparent epifauna and short patches of bryozoan turf/thicket and on all transects on the shelf-break and upper slope (> 200 m). Bryozoan turf/thicket formed medium length patches (to 800 m) on the outer shelf. On the southernmost transect (S1-10) a short patch of residual fauna in coarse detritus was observed at 350-370 m depth (Figure 7.1.2.14b).

For the analyses Bank Strait was sub-divided into north (transects S1-6 and S1-13) and south (transects S1-10, S1-11, S1-12 and S1-14).



(a) Substratum and geomorphology overlay on swath backscatter

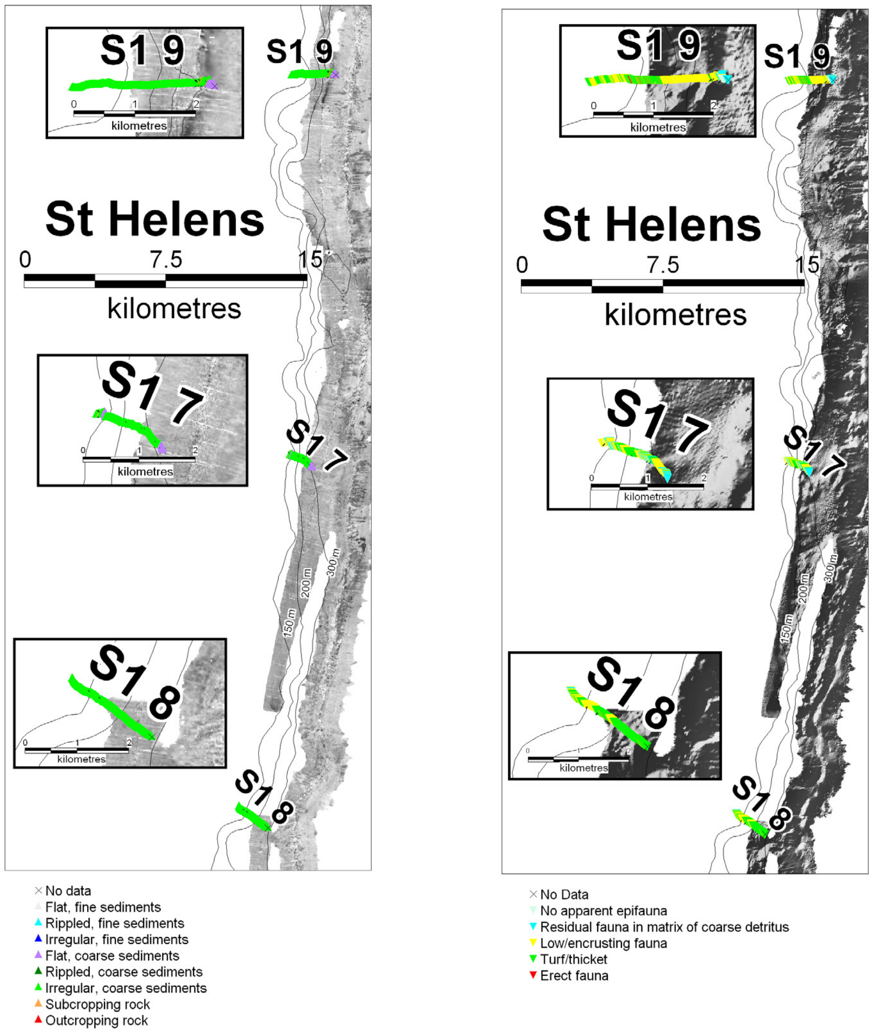
(b) Epifauna overlay on swath bathymetry

Figure 7.1.2.14 Banks Strait: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

St Helens (high crab / low trawl)

Thematic mapping of recoded video data (substratum plus geomorphology – SG, and epifauna) overlaid on seabed backscatter and bathymetry (Figure 7.1.2.15a and b) show the spatial distribution of habitats. The east coast sites were sampled on the first (proof of concept) survey before the systematic sampling design of along and across shelf transects was implemented. Thus, video data was collected on cross-shelf transects only, and distances between transects were greater than on the west coast sites. Irregular coarse sediments dominated this site (patches > 2km), with few short patches of flat coarse sediments at the deep end of transects (> 350 m). No clear canyon heads were observed in this site and the backscatter of the region was relatively low throughout (Figure 7.1.2.15a).

Bryozoan turf/thicket and low/encrusting fauna formed short to medium length patches, with the former more dominant on the shelf-break (~200-300 m) and the latter on the outer shelf and upper slope. A matrix of coarse detritus with residual fauna was observed at the deep end of transects (> 350 m). Erect fauna was observed in short patches on the shelf-break (230-250 m) on transect S1-8 (Figure 7.1.2.15b).



(a) Substratum and geomorphology overlay on swath backscatter

(b) Epifauna overlay on swath bathymetry

Figure 7.1.2.15 St Helens: map of survey site showing attributes overlaid on seabed (a) backscatter and (b) bathymetry. Each attribute is scored at 1-second intervals and mapped thematically: (a) substratum and geomorphology; (b) epifauna.

Depth distribution of habitats across sites

The proportions of substratum and geomorphology (SG), and epifauna (FAf) were plotted for each 50 m depth bin, by site (Figure 7.1.2.16).

Substratum and geomorphology

Rocky outcrop and subcrop was observed on the outer shelf (< 150 m) in all western sites (note the 100-150 m depth range was not sampled at Low Rocky and SW Cape). In the east, rocky substrata were recorded mostly on the upper slope (>300 m) with the highest percentages in depths > 400 m. Rippled coarse sediments were mostly observed on the shelf (< 200 m) in western sites, with the bulk of this substratum type in < 150 m. Babel was the only eastern site where rippled sediments were observed on the shelf-break (200-300 m). Flat coarse sediments were most commonly observed on the outer shelf (150-200 m) and on the upper slope (> 300 m), except for 4 sites – Point Hibbs, High Rocky, Low Rocky and Babel – where flat coarse sediments also dominated the shelf-break. Irregular coarse sediments replaced the fine coarse substrata on the shelf-break (200-300 m) except for the aforementioned sites. In the north-western sites (north of Ling Hole) this substratum type was observed in high percentages from 150 m depth on the outer shelf to 400 m (450 for Arthur) on the upper slope. Fine sediments were rarely observed at depths shallower than 400 m.

Epifauna

Erect fauna was mostly associated with rocky substrata in the shallow outer shelf in western sites; there was little erect fauna associated with rocky substrata present at deep eastern sites. In addition, a small percentage of erect fauna extended over the shelf-break and into the upper slope in association with the bryozoan turf/thicket at Pieman and King Island.

Turf/thicket was most abundant on the west coast of Tasmania on the shelf-break reaching into the upper slope (200-350 m). There was a north-south depth trend with turf/thicket occurring at shallower depth in the north (150-350 m) than in the south (200-350 m); two sites, Arthur and Ling Hole were quite different with low percentage of turf/thicket through all depth ranges.

Moderate abundance of turf/thicket were observed on the outer shelf and into the shelf-break (< 250 m) in the eastern sites. Low/encrusting fauna was observed at moderate percentages through all depth ranges, being least common in the shelf-break zone where turf/thicket was observed.

Coarse detritus with residual fauna was most commonly observed on the upper slope > 300 m with low percentages at Cape Grim, Ling Hole, SW Cape and all eastern sites in shallower depth. This category was absent from Strahan, Point Hibbs and High Rocky.

An absence of epifauna was commonly associated with the rippled sediments on the outer shelf (< 150 m), and with the flat fine sediments in the deeper part of the outer shelf (> 400 m). Sites from Cape Grim to Strahan had 'no epifauna' reaching into the shelf-break (< 250 m).

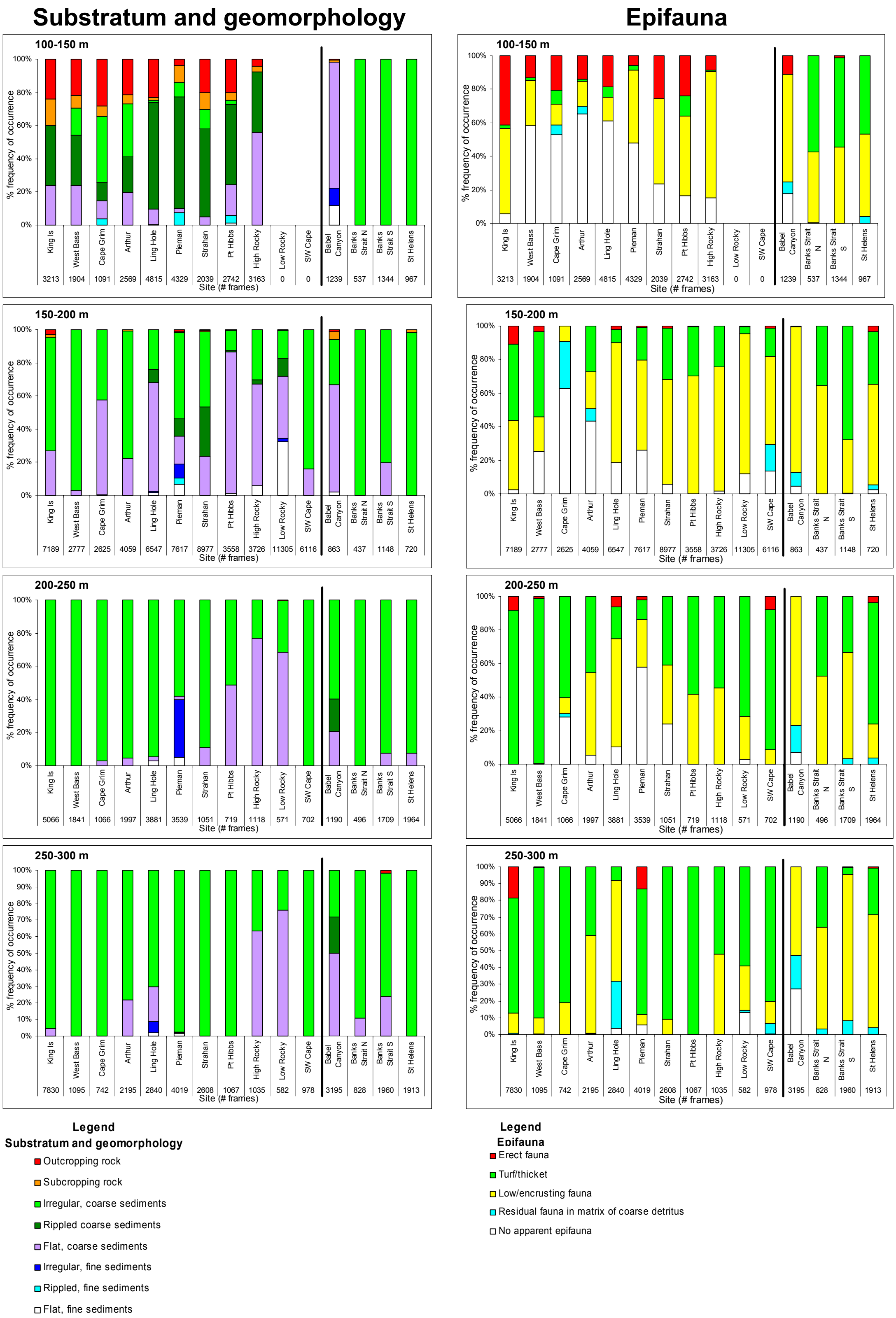
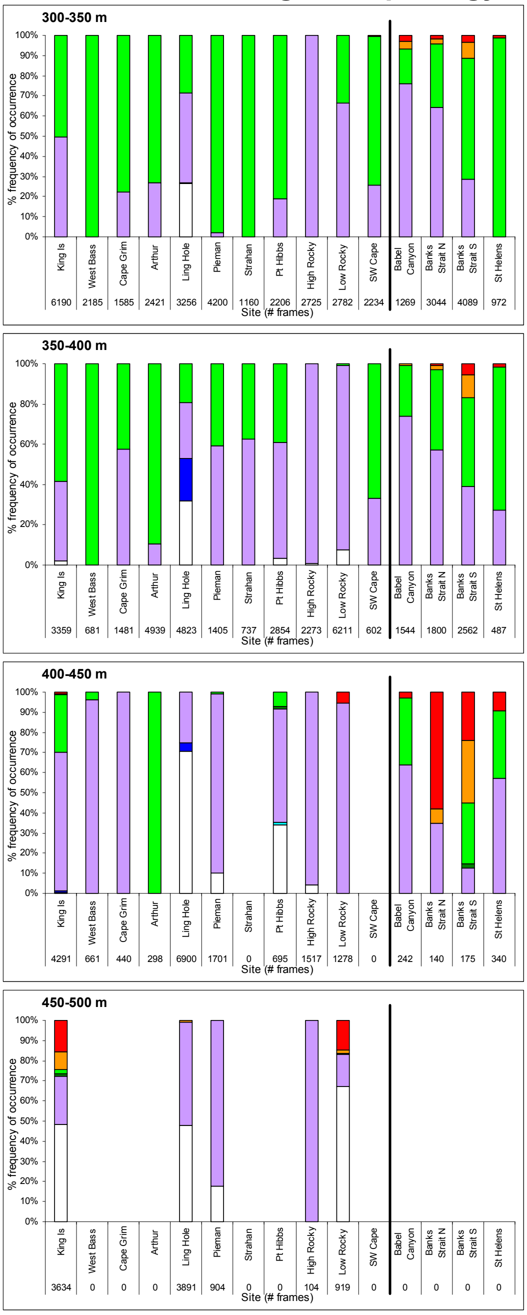
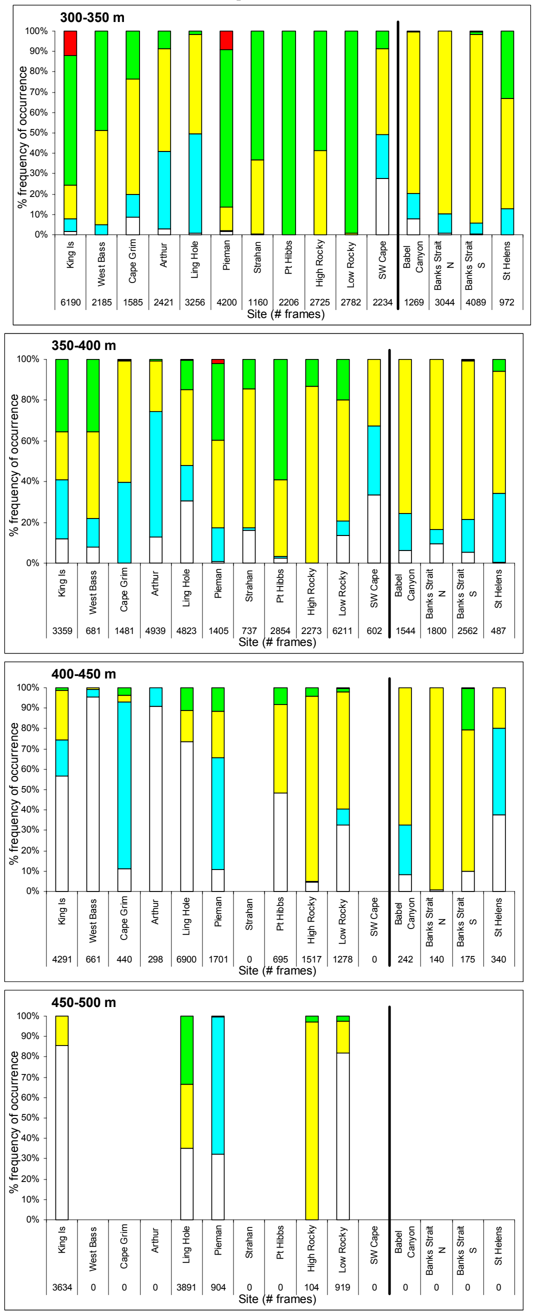


Figure 7.1.2.16 (pg1/2) Histograms of substratum and geomorphology (SG) and epifauna (FAf) scores by depth for each site

Substratum and geomorphology



Epifauna



Legend
Substratum and geomorphology

- Outcropping rock
- Subcropping rock
- Irregular, coarse sediments
- Rippled coarse sediments
- Flat, coarse sediments
- Irregular, fine sediments
- Rippled, fine sediments
- Flat, fine sediments

Legend
Epifauna

- Erect fauna
- Turf/thicket
- Low/encrusting fauna
- Residual fauna in matrix of coarse detritus
- No apparent epifauna

Figure 7.1.2.16 (pg 2/2) Histograms of substratum and geomorphology (SG) and epifauna (FAf) scores by depth for each site

Analysis of recoded data

Cluster analysis identified 7 groups at 50% similarity (Figure 7.1.2.17): four large groups (1, 2, 4, 7) of which 2 (4 and 7) have 2 and 3 major sub-divisions respectively, two small groups (3 and 5) and one outlier (6). The robustness of the aggregated variables is confirmed by the similarly of this clustering to that using original SG and FAf scores. Furthermore, these clusters separated clearly in a 2-dimensional MDS of low stress (0.17 – Figure 7.1.2.18).

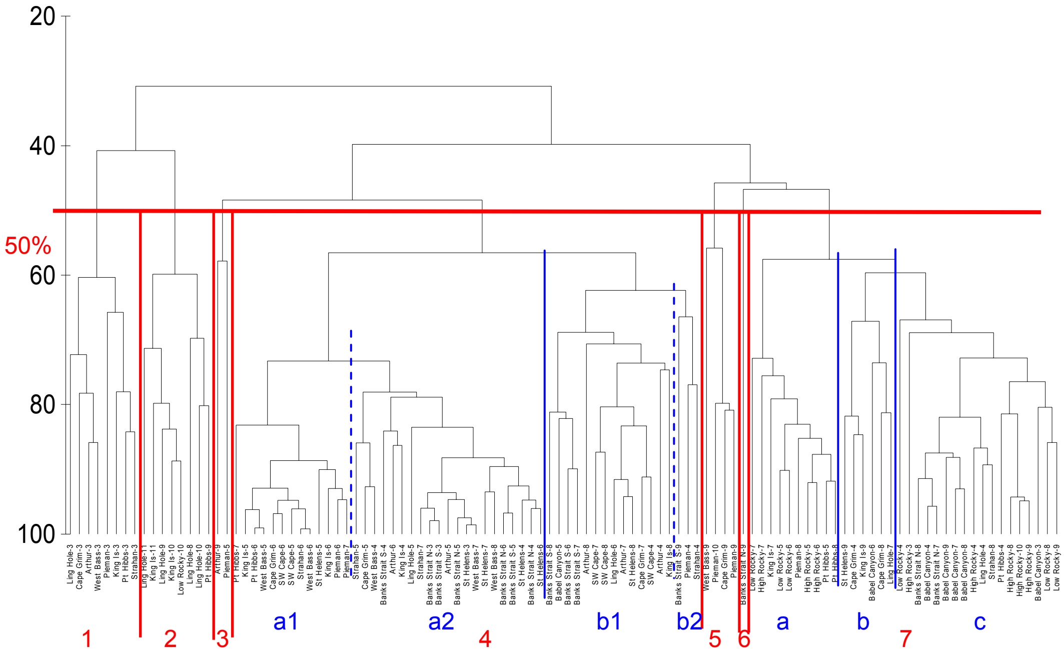


Figure 7.1.2.17 Cluster analysis of the recoded video data (SG and FAf) summarised by site and depth category. Groups 1 to 7 were identified at similarity 50%; for the interpretation groups 4 and 7 were further sub-divided as indicated.

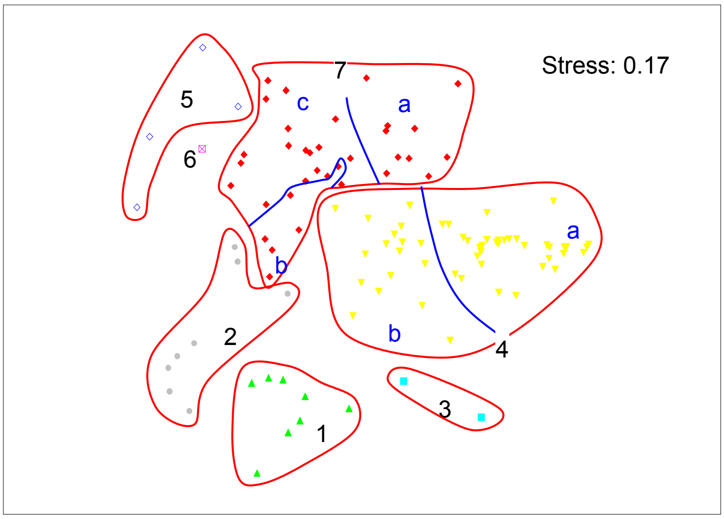


Figure 7.1.2.18 Two-dimensional MDS representation of the recoded video data (SG and FAf) summarised by site and depth category. Groups 1 to 7 identified in the cluster analysis are shown.

The groups identified by the cluster and MDS analyses are described below, and their spatial distribution is shown in a stylised map (Figure 7.1.2.19). The video-scores mentioned in the descriptions were identified visually from histograms and confirmed using the SIMPER routine in Primer (Clarke and Gorley 2001); they contributed at least 90% to the similarity within each group:

- **Group 1** 8 sites: West coast shallow (100-150 m); high abundance of rippled coarse sediments and rock, areas with relatively high proportions of low/encrusting fauna, no fauna and erect fauna.

- **Group 2** 8 sites: West coast deep (350 & 400-550 m); relatively high proportions of no apparent epifauna, and flat fine (and some coarse) sediments. Differs from all close groups mainly in having flat sediments with no fauna. The 350 m Ling Hole sample (high crab / high trawl) is included in group 2 as an anomalous shallower site with rippled sediments and no fauna.

- **Group 3** 2 sites: West coast (1 deep Arthur 400-450 m, 1 shallow Pieman 200-250 m) **outliers**. Irregular coarse sediments with no fauna.

- **Group 5** 4 sites: West coast deep (400-500 m) high proportions of flat coarse sediments with a matrix of coarse detritus with residual fauna;

one site (West Bass-9) has a high proportion of no apparent epifauna – an outlier within this group at similarity 57%.

- **Group 6** 1 site: Banks Strait North characterized by a large proportion of rock, virtually all with low/encrusting fauna. (Well founded outlier**).**

- **Group 4** 51 sites with predominantly irregular coarse sediments and a high proportion of turf/thicket or low/encrusting fauna. The group may be split into 2 distinct sub-groups (4a and b) at similarity 57%:

  - **4a**: 34 sites with high proportion of irregular coarse sediments with turf/thicket, and low/encrusting fauna. A further subdivision at 74% similarity aids description of the patterns:

    - **4a1 – Core turf/thicket;** 13 sites, entirely coarse sediment, highly dominated by irregular (~≥80%); highly dominated by turf/thicket (~≥80%), rest low/encrusting fauna with erect often present; shelf break (200-350 m)

    - **4a2 – Edge of core thicket/turf;** 21 sites, entirely coarse sediment, mostly irregular; high proportion of turf/thicket (~30-60%), rest is mostly low/encrusting fauna (mostly bounding the core turf/thicket zone; 150-250 m and 300-400 m)

  - **4b**: 17 sites with high proportion of irregular and flat coarse sediments with low/encrusting and residual fauna in coarse detritus. A further subdivision at 67% similarity aids description of the patterns

    - **4b1** – 14 sites with predominantly coarse sediment (some rock), mostly irregular but 20-40% flat; high proportions of low/encrusting and residual fauna in coarse detritus; shelf break to upper slope (150-400 m)

    - **4b2 – odd group**; 3 sites, mixed substrata (variously inc. rippled coarse sediments and rock); dominated by low/encrusting fauna (55-70%) (150/400 m)

- **Group 7** 34 sites: virtually all coarse sediments, with majority flat (50-100%) and remainder mostly irregular geomorphology; epifaunal types were not consistently distributed in sites within this group, but as a whole, low/encrusting fauna occurred in high proportions. The group may be split into three sub-groups (7a, b and c) at a similarity level of 61%:
    - **7a** – 10 sites of moderate to high proportion of turf/thicket (40-75%), rest low/encrusting fauna (up to 50%)
    - **7b** – 6 sites of no turf/thicket, ~40-90% coarse detritus with residual or no fauna, rest low/encrusting fauna.
    - **7c** – 18 sites of mostly low/encrusting fauna with small percentages of turf/thicket or coarse detritus with residual fauna.

The BIOENV routine, that calculates a measure of agreement between the matrices of site/depth similarities based on recoded video data and corresponding environmental data (here simply average latitude, longitude and depth x site-depth sample) showed the strongest correlation to depth (ρ = 0.309), and moderately strong correlation with latitude crossed with depth (ρ = 0.224), reconfirming the results from the initial analyses.

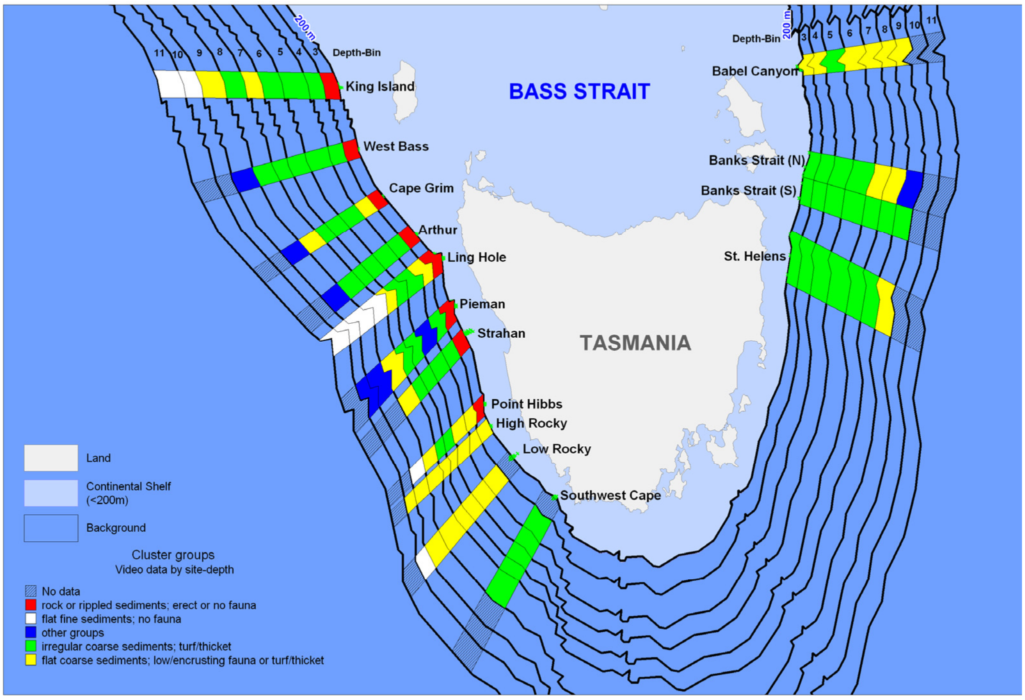


Figure 7.1.2.19 Stylised map of the distribution of the groups identified in a cluster analysis over depth-ranges and sites.

7.1.3 Shelf edge habitat distributions: fine spatial scale

A grid-based analysis summarised video, acoustic and commercial trawl data at a finer scale suited to integrating the swath and photographic data: 500 m x 500 m cells. There were a total of 418 cells where both multibeam swath and video data existed. The data attributed to each consisted of percentage of the recoded SG and FAf categories, average, maximum and minimum depth, average latitude and longitude, average and standard deviation of backscatter and slope from the swath data, and number of trawl lines in all reported years (1996-2003) and in the years of the surveys (2001-2003). Cells containing less than 100 video frames were excluded. Unfortunately, swath data was incomplete for the shallowest areas of five sites (see thematic maps in previous section) resulting in the exclusion much of the shallow video data.

These gridded data could be used for comparing sites and sub-biomes using a 2-way ANOSIM analysis based on the video data and based on environmental data (excluding latitude/longitude which would confound the analysis). However, the incomplete coverage of data, particularly the lack of shallow swath data, was a weakness that appeared to reduce the power of the analysis.

Analysis of gridded data gave similar results to ANOSIM analyses of recoded transect data: sites averaged by sub-biome were generally similar to each other, i.e. inter-site differences were not greater than intra-site differences overall) significant difference at 0.1, but R = 0.181, in a ‘global’ analysis – useful to detect major differences within the data set as a whole. Also, the sub-biomes, averaged over sites, were generally similar to each other (significant difference at 0.1, but R = 0.243). Pairwise comparisons of individual sites and depth zones again detected similar site to site differences as the initial analyses: High Rocky, Low Rocky, Babel and St Helens being different to many other sites (significant at 0.1, R > 0.6).

The ANOSIM analysis of the environmental factors, excluding latitude and longitude showed that the sites averaged by sub-biome were generally similar to each other (i.e. inter-site differences were not greater than intra-site differences overall) significant difference at 0.1, but R = 0.292, in a ‘global’ analysis. (A clearly significant difference with R = 0.584 between sub-biomes averaged over sites was probably due to the inclusion of depth in the environmental factors, i.e. depth confounded this analysis). Pairwise comparisons of individual sites showed stronger and different patterns to the ones seen in the video data. Babel was significantly different to all other sites (sign = 0.1, R > 0.6) – apparently due to its relatively steep slope and high proportion of rocky bottom (high backscatter). Other significant results with R>0.6 were found between Southwest Cape and Arthur (high vs. medium slope) as well as Southwest Cape and both Banks Strait sites (low vs. high backscatter), and between Low Rocky and King Island (medium vs. high slope – at > 300 m depth. Strahan was significantly different from most other sites (five western sites and Babel R > 0.6; three eastern sites 0.4 < R < 0.6), but this appears to be an anomaly caused by low swath coverage under video transects.

Comparing the ANOSIM results from the video data and the environmental data showed there was little correspondence of site differences between the two analyses. We attribute this to the restricted swath coverage relative to video transects and associated limited overlap between the two data series.

An exception was Babel Island, which was significantly different from many other sites based on both data sets.

Cluster analysis of the video data identified 15 groups at a similarity level of 35% (Figure 7.1.3.1). Nine of the 15 groups contained between 16 and 102 grid-cells, one group clustered four grid-cells and five outlier groups with two or one grid-cell. We used the SIMPER analysis to determine the video-scores contributing most (>90%) to each cluster (Figure 7.1.3.1).

The groupings are similar to those observed in the site-depth analysis, with many corresponding clusters. For example the outer shelf group 1 of the site-depth analysis corresponds to groups 13, 14 and 15 here; all grid-cells on the outer shelf, typified by rippled coarse sediments and low/encrusting fauna (groups 13 and 14) or outcropping rock with erect fauna (group 15). Corresponding to groups 4a and 7a in the site-depth analysis, there were two groups typified by turf/thicket, one with irregular coarse substrata (group 3), the other with flat coarse substrata (group 5). The former of these occurred mostly on the shelf-break, the latter on the upper slope.

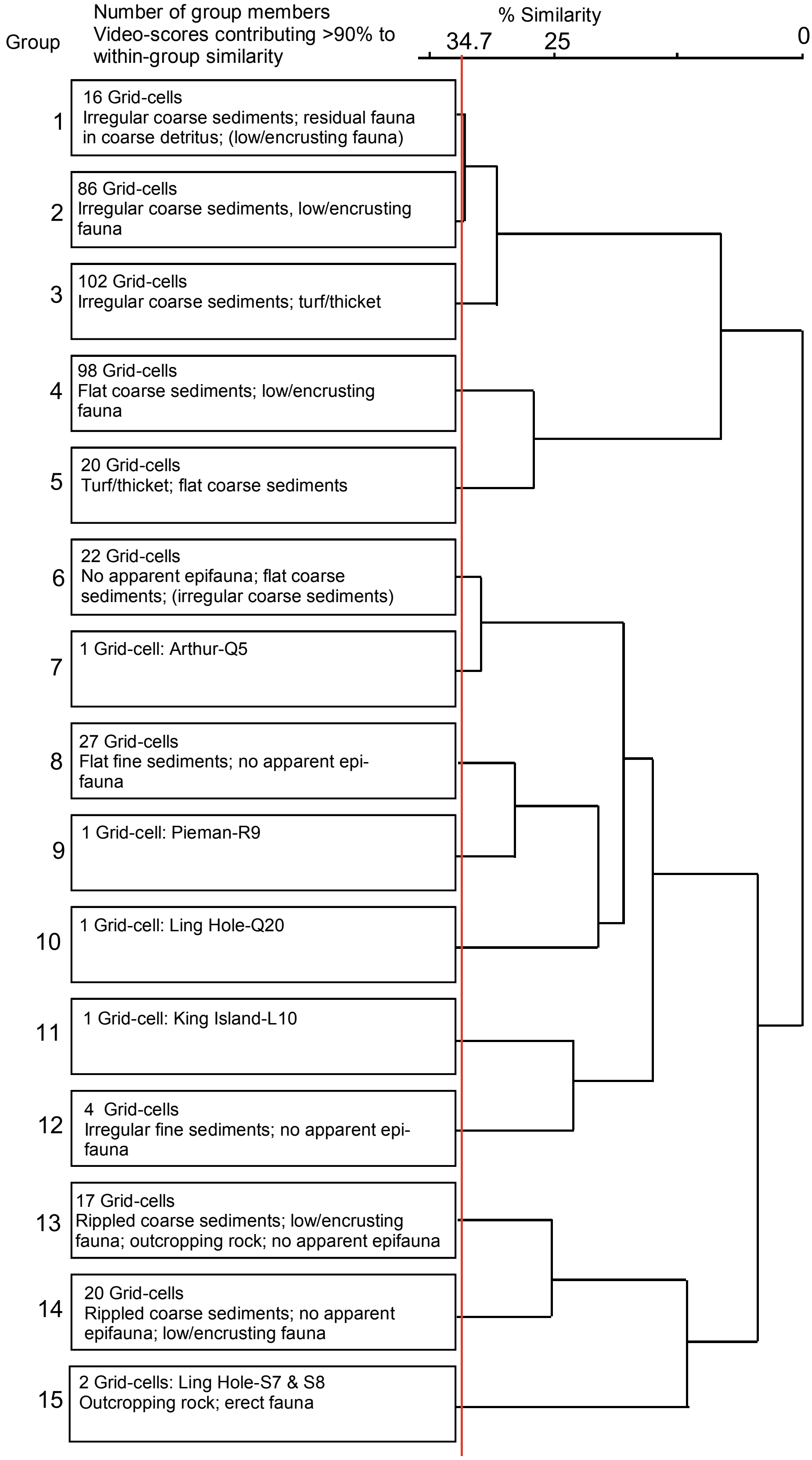


Figure 7.1.3.1 Cluster analysis of the gridded video data at 34.7% similarity. Groups are described by the video-scores contributing most (>90%) to the within-group similarity.

By summarising the data in this format we had greater power in determining environmental factors driving the patterns in the video data, using the BIOENV analysis. Instead of only using depth and GIS position, we also had factors relating to backscatter intensity (average and its standard deviation) and slope (average and standard deviation), as well as the number of trawl lines crossing each cell over all reported years (1996 and 2003) and in the years of the surveys (2001-2003). The establishment of these links between the swath data and the observed video habitats provides a theoretical basis for the interpretation of habitat types from swath data in the absence of videos.

The BIOENV result showed a good correlation between combined backscatter, average and minimum depth (ρ = 0.310) (normalised Euclidean distance) with the Bray-Curtis similarity matrix underlying the cluster analyses; the second best result shows correlation with these variables and number of trawl lines (1996-2003) (ρ = 0.305).

Creating separate matrices for substratum and geomorphology (SG) and epifauna (FAf) enabled their correlation with environmental variables to be assessed separately in a BIOENV. We found that the combination of backscatter with average and minimum depth was a good predictor for observed SG scores (ρ = 0.331). However, none of the environmental factors were shown to be good predictors of the epifauna score – best result: ρ = 0.148 for minimum depth, a result that appears to be linked to the lack of shallow swath data (leading to truncation of transects at their shallow ends and the inability to include rocky reef, one of the key underlying features structuring the results from the entire video data set – Section 7.1.2).

7.1.4 Shelf edge habitat distributions: microhabitat scale

'Microhabitat-scale' physical features and structural epifauna (less than metres in size, typically < 1 m, and only visible in photographic images) provided the finest scale at which to describe seabed habitat types. Our ability to measure physical features at these scales – especially those making up 'hard bottom' – is relevant to understanding (1) their potential roles as refuges for mobile fauna (including giant crabs and other commercially important species), and (2) to interpreting their likely vulnerability to fishing impact, in this case trawling.

Microhabitat – fauna

Bryozoan 'forests', recorded from the shelf-break south-west of King Island over 35 years ago by Wass et al (1970), were shown to form low relief (to ~200 mm high), and often dense, microstructure in long patches in their core distributional range at the shelf edge (~200 to ~350 m). Photographic data showed they formed mature communities composed predominantly of articulated zooidal and articulated branching forms, with erect branching forms also common at depths > 200 m (e.g. in our images from King Island, Bone and James pers. com.). There were large numbers (100s) of bryozoa species, and many await scientific description; Bock (1982) noted that the bryozoan fauna of southern Australia is in need of revision. Consequently, it was not possible to achieve species identification, or an estimate of the number of species making up the communities, from photographs (Bone & James pers. comm.). Bryozoans were not limited to the west coast shelf break and upper slope, but also present on the outcropping rocky reefs of the outer shelf where they formed turf and thicket interspersed with the large fenestrate fan-shaped bryozoan *Adeona* together with large sponges and seawhips (our 'mixed erect fauna').

A great diversity of other sessile animals was associated with the bryozoan fauna, mostly small sponges and ascidians, but also corals, hydroids and a variety of minor taxa. The sponge component was extraordinarily diverse, with a total of only 14 sled samples from King Island, Ling Hole, Pieman, Banks Strait and Big Horseshoe Canyons yielding 165 species representing 65 genera, 41 families, and 10 orders (Schlacher et al., 2007). Similarly, the ascidians were specious, with 30 species (including two new species) identified from the same locations as the sponges (P. Mather, pers. comm.). Many different types of small mobile fauna also live among the structure provided by this assemblage; the most numerous groups included crustaceans, in particular squat lobsters that shelter amongst the bryozoans, molluscs, a variety of echinoderms such as asteroids and ophiuroids, and fishes. (The mobile species are discussed in greater detail in Section 7.4.1.)

In some key respects, the western Tasmanian study area differed to other known continental shelf and slope environments off eastern/ southeastern Australia. At our east coast sites, the bryozoan community was less dense with lower relief, while the low/ encrusting community was more often dominated by solitary ascidians. This was confirmed by our benthic sled collections that yielded 14 ascidian species in one sample from Banks Strait, compared to only 11 species in 3 samples at King Island, 6 species in one sample at the Ling Hole and 7 species in two samples at Pieman (P. Mather, pers. comm.). At another known location, the Big Horseshoe canyon (eastern Bass Strait), large sponges, echinoderms and cnidarians (seapens and corals) were the dominant structural fauna at corresponding depths: sponges create dense beds of large individuals at 120 m and at 300-400 m, while the stalked crinoid (*Metacrinus cyaneus*) forms dense stands in 200-300 m. At greater depths (> 700 m), many species of octocorals (especially gold corals) live on hard bottom.

Microhabitat – physical structures

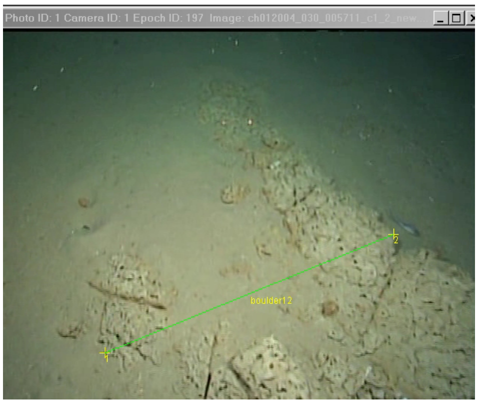
Determining the dimensions (length, width and height) of hard substrate features such as rock outcrops and subcrops was possible using calibrated stereo imagery. These data were collected on all surveys, and a representative subsample of features measured to provide an overview for the study area. The results provide the means to assess gear accessibility (especially to trawls), and to interpret this in the context of habitat vulnerability (Section 7.2).

The subsample of features to measure was based on a database query of the video observations of hard bottom; this was used to locate and then select stereo clips of typical examples of hard bottom features across a range of depths and sites (Table 7.1.4.1 and Figure 7.1.4.1). These included the high relief outcrops of the inner margins of the fishery (~150 m), to low relief ledges, slabs and boulders occurring in the mid to outer margins (~200-500 m). Measurements quantified width, length and height where possible.

The need for measurement accuracy for this purpose is less demanding than testing the effectiveness of a stereo video system to measure giant crabs *in situ* for stock-assessment purposes (Section 7.5). Calibrations and testing of measurement accuracy were done prior to and during surveys and are described in detail in Section 7.5.3. The measurement accuracy was determined to be in the order of +/- 10 - 20% for boulder and rocky ledge/ edge features (Section 7.5.3). These error bounds include all measurements, including the poorest (most distant and lowest resolution).

Table 7.1.4.1 Size of 'hard bottom' seabed features off the west coast of Tasmania. Refer 'Image ID' column to Figure 7.1.4.1 to visualize the type of feature and measurement made.

Image ID	Survey	Op	Site	Depth (m)	Feature	Measure	Size (m)
1	3	30	Ling Hole	527	outcrop/subcrop	width	1.55
2	3	30	Ling Hole	527	outcrop	height	0.51
3	2	33	King Island	433	edge	height	0.96
4	2	33	King Island	433	edge	thickness	1.28
5	2	33	King Island	478	edge	height	0.98
6	2	33	King Island	483	slab	length	1.09
7	2	33	King Island	483	slab	width	0.67
8	2	33	King Island	497	boulder	width	1.13
9	2	33	King Island	497	edge	height	2.32
10	2	33	King Island	471	boulder	length	3.16
11	2	33	King Island	471	boulder	length	0.91
12	2	33	King Island	471	boulder	length	0.67
13	2	33	King Island	471	boulder	length	1.64
14	4	6	King Island	457	edge	width	0.70
15	4	6	King Island	457	slab	length	2.41
16	4	6	King Island	457	slab	width	0.91
17	4	6	King Island	457	slab	width	0.75
18	4	6	King Island	457	slab	width	1.57
19	4	6	King Island	457	slab	width	0.25
20	4	6	King Island	457	slab	length	2.30
21	4	6	King Island	457	slab	width	0.47
22	4	6	King Island	457	slab	length	0.74
23	4	6	King Island	457	slab	length	6.86
24-26	4	6	King Island	155	undercut reef	length	>6.00
27	4	6	King Island	155	undercut reef	height	0.63
28	4	6	King Island	155	low edge	height	0.48
29	4	6	King Island	155	undercut reef	length	4.71
30	4	6	King Island	155	boulder subcrop	height	1.17
31	4	6	King Island	155	undercut reef	height	1.22
32	4	6	King Island	155	undercut reef	height	1.47
33	4	6	King Island	155	flat top ledge to base	height	3.10
34	4	6	King Island	155	flat top ledge to base	height	1.51
35	4	6	King Island	155	slab	length	9.84
36	4	6	King Island	155	outcrop top to sediment base	height	1.65
37	4	6	King Island	155	outcrop top to base	height	2.20
38	3	1	Low Rocky	439	boulder subcrop	height	0.94
39	3	1	Low Rocky	439	boulder subcrop	height	1.78
40-1	3	30	Ling Hole	153	boulder	width	0.74
40-2	3	30	Ling Hole	153	boulder	width	0.65
40-3	3	30	Ling Hole	153	boulder	width	0.59
40-4	3	30	Ling Hole	153	boulder	height	0.62
41	3	1	Low Rocky	401	subcrop on ridge	height	1.39
42	3	1	Low Rocky	401	subcrop on ridge	width	2.75
43	3	1	Low Rocky	399	edge	height	0.42



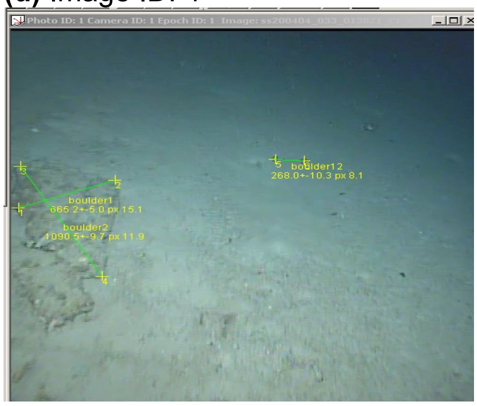
(a) Image ID: 1

(b) Image ID: 2

(c) Image ID: 3

(d) Image ID: 4

(e) Image ID: 5

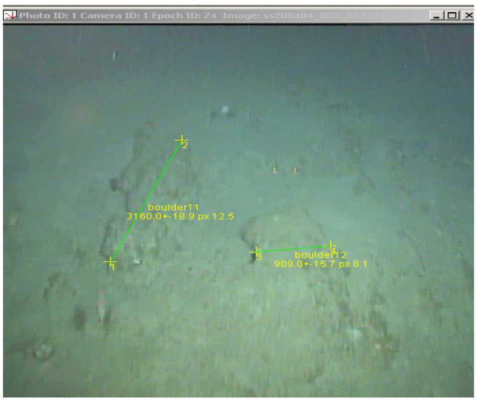


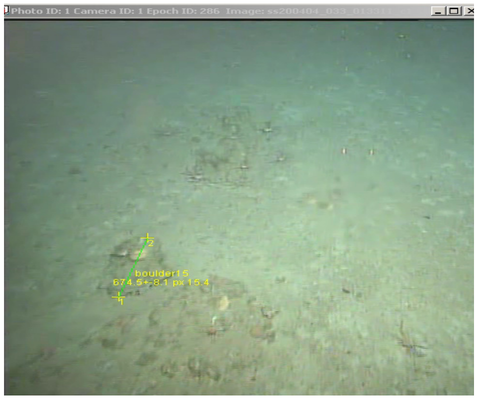
(f) Image ID: 6 & 7

(g) Image ID: 8

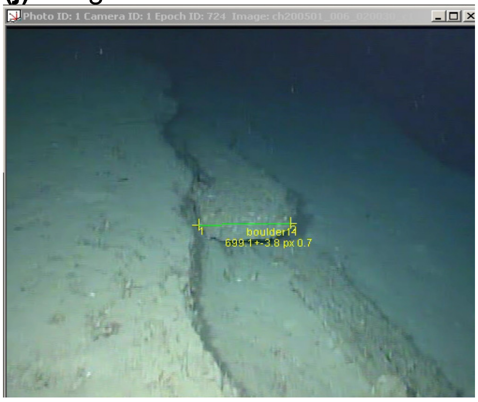
(h) Image ID: 9

Figure 7.1.4.1 (pg 1/5) Images of seafloor structure measured using stereo techniques with number reference to measurements in Table 7.1.4.1

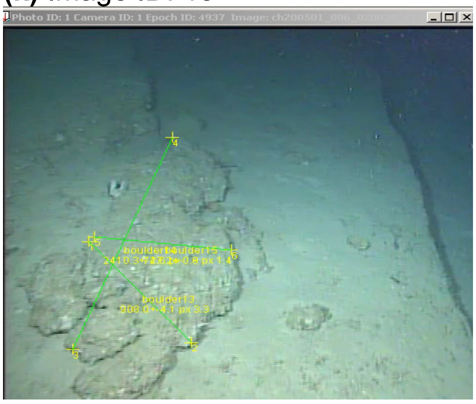


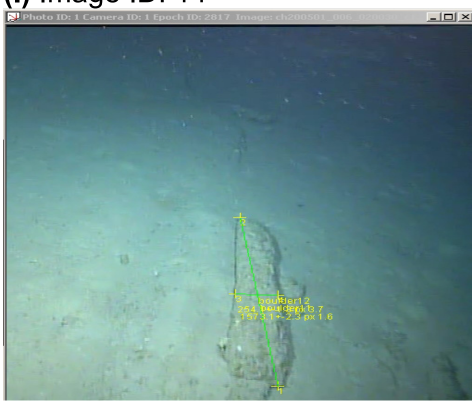


(i) Image ID: 10 & 11 **(j)** Image ID: 12

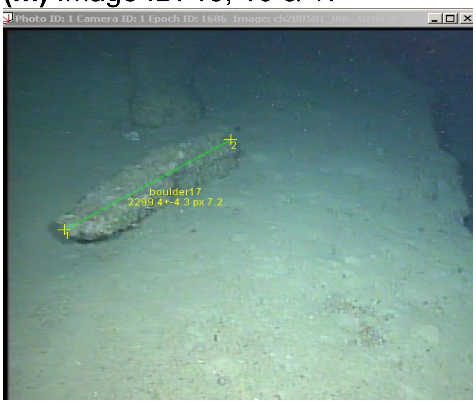


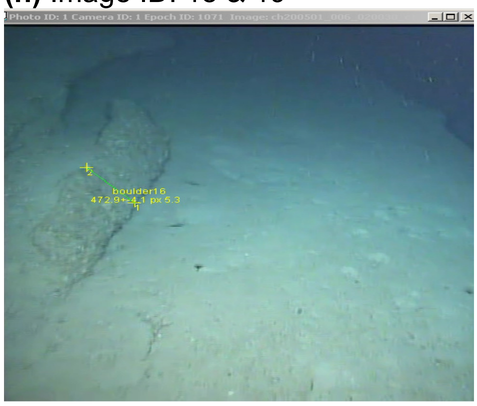
(k) Image ID: 13 **(l)** Image ID: 14





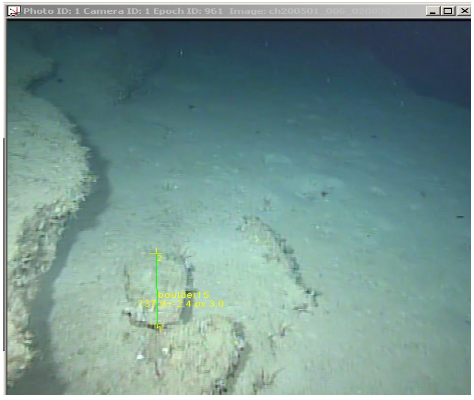
(m) Image ID: 15, 16 & 17 **(n)** Image ID: 18 & 19





(o) Image ID: 20 **(p)** Image ID: 21

Figure 7.1.4.1 (pg 2/5) Images of seafloor structure measured using stereo techniques with number reference to measurements in Table 7.1.4.1



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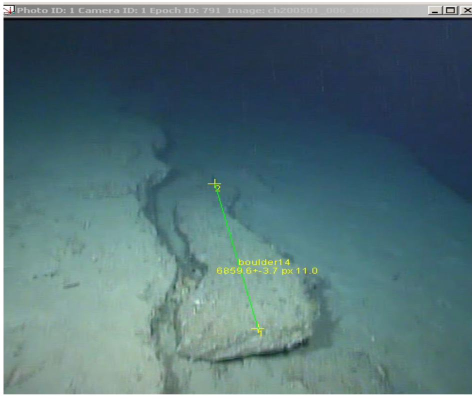

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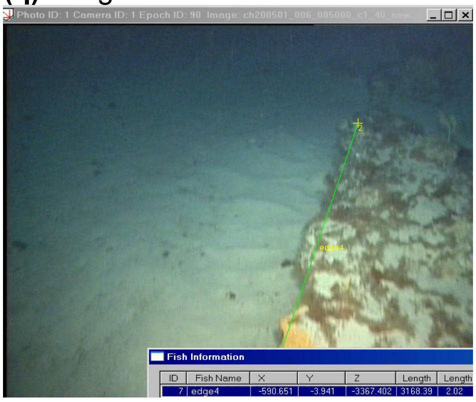

(s) Image ID: 25

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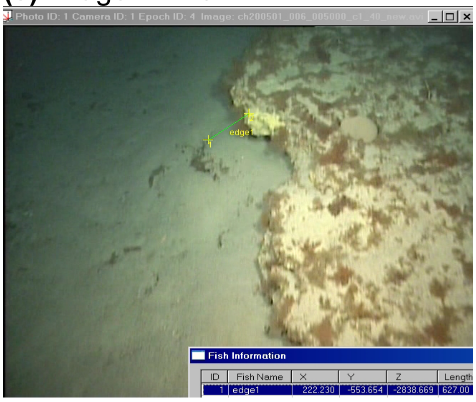

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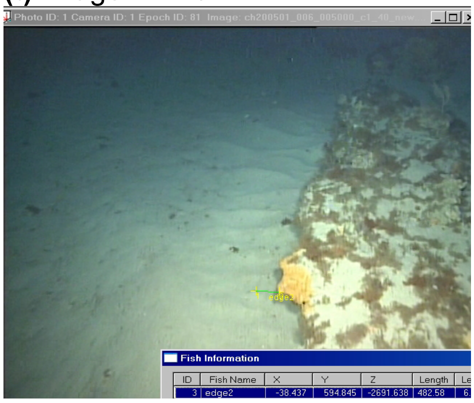

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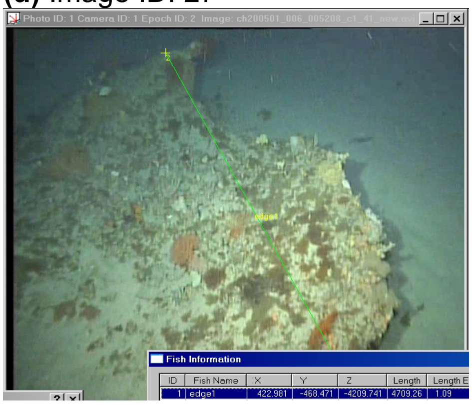

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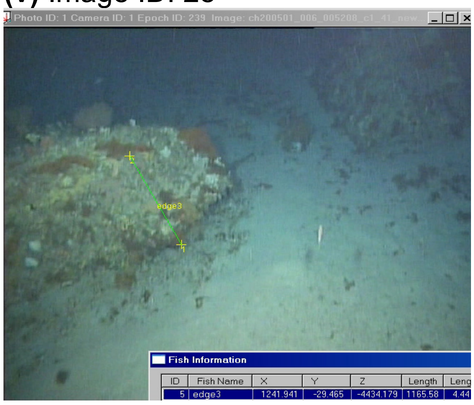
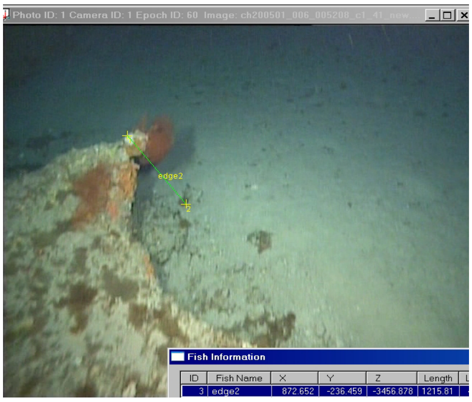


(x) Image ID: 30

Figure 7.1.4.1 (pg 3/5) Images of seafloor structure measured using stereo techniques with number reference to measurements in Table 7.1.4.1



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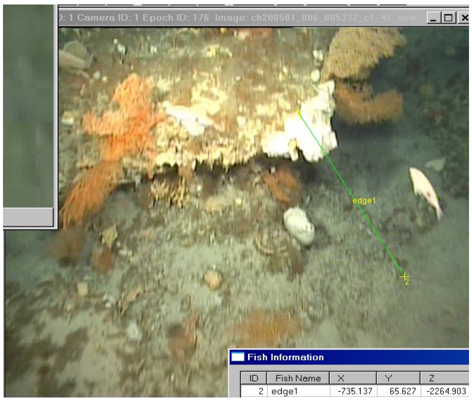
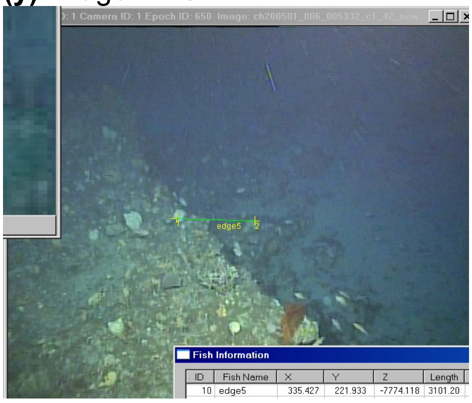
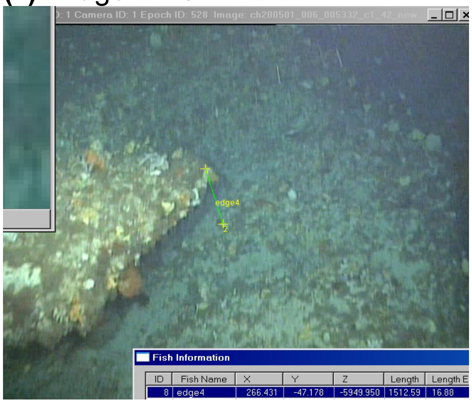


(z) Image ID: 32



(aa) Image ID: 33



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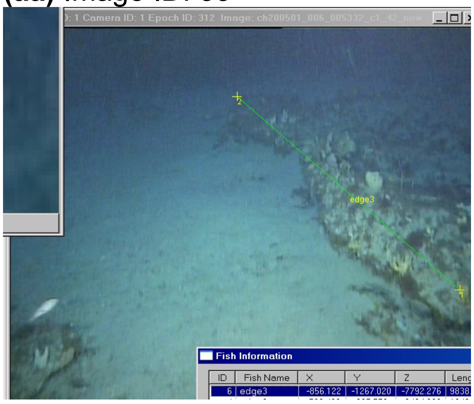
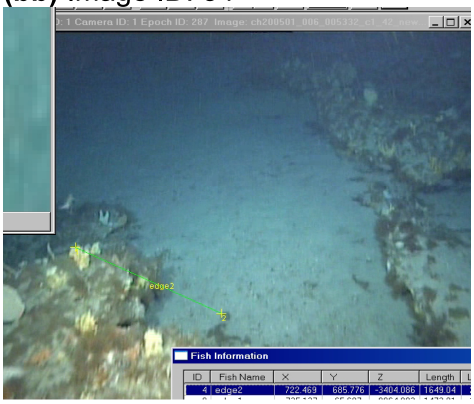


(cc) Image ID: 35



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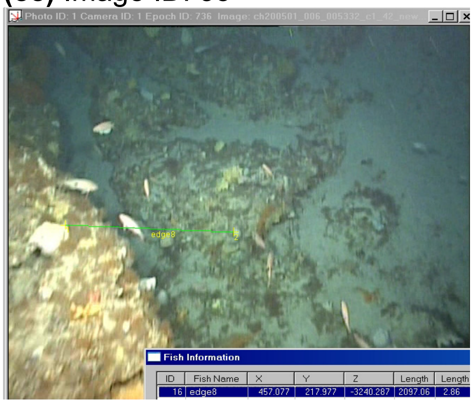

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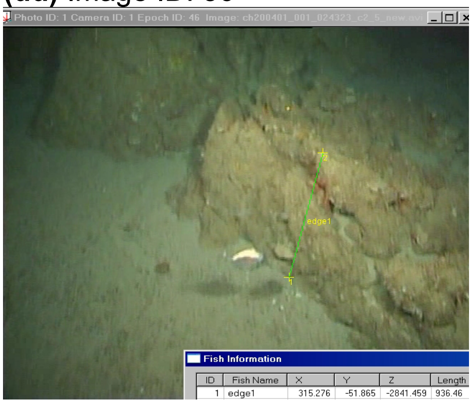
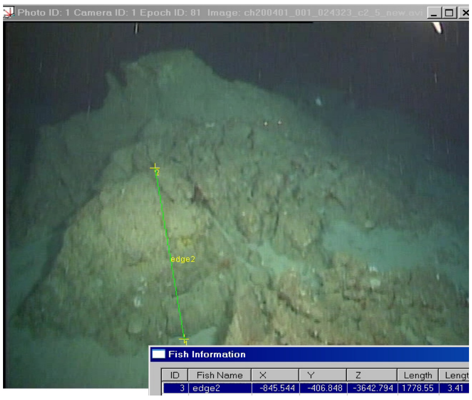
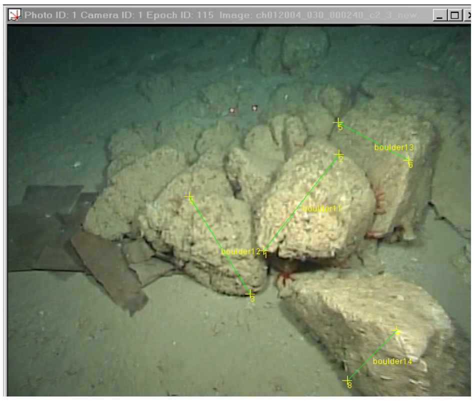


(ff) Image ID: 38

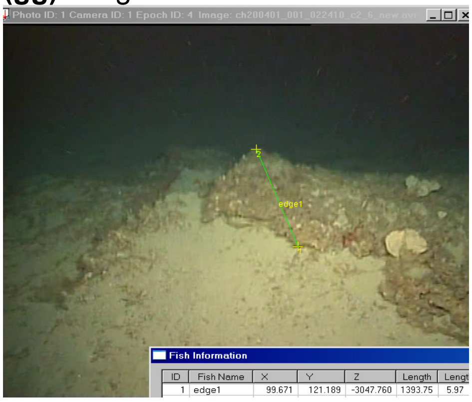
Figure 7.1.4.1 (pg 4/5) Images of seafloor structure measured using stereo techniques with number reference to measurements in Table 7.1.4.1



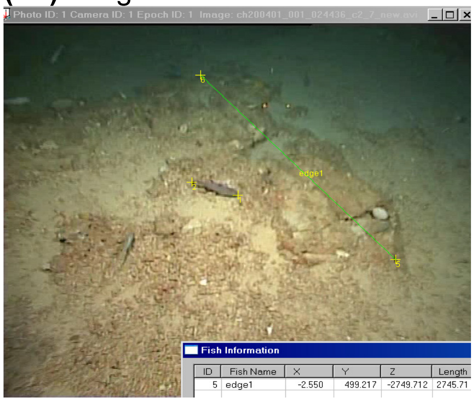
(gg) Image ID: 39



(hh) Image ID: 40



(ii) Image ID: 41



(jj) Image ID: 42

Figure 7.1.4.1 (pg5/5) Images of seafloor structure measured using stereo techniques with number reference to measurements in Table 7.1.4.1.

This selection of images shows that the hard bottom structures, which provide microhabitats for a variety of sessile and mobile fauna, consist of a mix of:

- rocky edges/ ledges where sedimentary rock strata are exposed – these are often long (with individual ridges tracked for ~250 m off King Island in 400-500 m depth) and most often relatively low relief, mostly < 3 m high and < 1 m high in places, e.g. along the predominant ridge features seen in the study area (at King Island).

- slabs – flat boulders formed by the erosion and scouring of sedimentary rock edges that break away. These are known to form flows, particularly around canyon heads, where they are referred to as 'slabby bottom' by fishers. Slabs are found predominantly on the upper slope, generally in proximity to other structure, particularly edges and steep, current swept seabed, and vary in size from small pieces (~250 mm) to large elongate structures (> 6.8 m) (e.g. at King Island, Figure 7.1.4.1, l, m, n, o, p, q).

- boulders found on shelf (e.g. at Ling Hole, Figure 7.1.4.1, hh) and upper slope (e.g. at King Island, Figure 7.1.4.1, i, j, k) where they are in patches or scattered amongst slabs and outcrops. They vary in size from ~600 mm to > 3 m in width and height.

- isolated rocky outcrops (rocks distinctly emerging from surrounding sediments, often with steep edges and/ or undercuts) (e.g. at Low Rocky, Figure 7.1.4.1, ff, and gg) and sub-crops (rock just protruding from surrounding sediments) (e.g. at Low Rocky, Figure 7.1.4.1, jj)

- large rocky banks or 'reefs': predominantly on the outer shelf (to ~150 m) where they are typically high relief (to 0.5 to 3 m) and relatively craggy with steep faces, large crevices and undercuts (e.g. Figure 7.1.4.1, y, z, bb, dd and ee), and often with intervening low relief flat pavements and or patches of heavily rippled sediments.

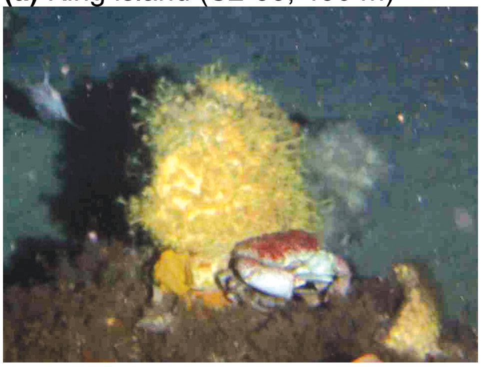
Microhabitat used by giant crabs

Images provided insights into the microhabitats used by giant crabs, and a range of examples are shown here for juveniles (Figure 7.1.4.3) and adults (Figure 7.1.4.2).

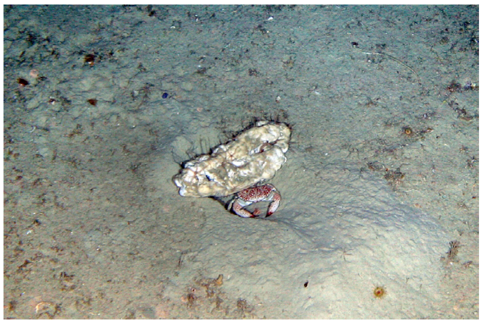
We did not observe any obvious flight response by giant crabs as the camera approached (e.g. running or active burrowing), although some large adults adopted an aggressive posture (Figure 7.1.4.2a and b). On this basis, it is assumed that observations of giant crab association with microhabitats were not affected by disturbance from the camera – although a bias in the data is likely to be an underestimate of association with microhabitat features where crabs, especially juveniles, are less easy to see when sheltering. Juvenile (small) crabs were seen in bryozoan epifauna but appeared mostly to be associated with burrows, small cracks, or small ledges (Figure 7.1.4.3), with one individual at the base of a large anemone (Figure 7.1.4.3.e). Note that we were not able to confidently distinguish all juvenile *P. gigas* from *Carcinoplax sp.,* a smaller species with similar colouration occurring in the same depth range, meaning some observations may be of the latter species. Many adult *P. gigas* appeared to be resting, being either associated with epifauna (e.g. large sponges) (Figure 7.1.4.2.c and d), centimetre-scale low-relief ledges and undulations, (Figure 7.1.4.2.e to i), or partially buried in sediment (Figure 7.1.4.2j and k). Others appeared not to be resting and were presumed to be actively foraging on open, relatively bare sediments (Figure 7.1.4.2.l to p). None were seen on or immediately adjacent to the hard bottom, rocky features documented in the previous section.

(a) King island (S2-33; 436 m)

(b) King Island (S4-8; 283 m)

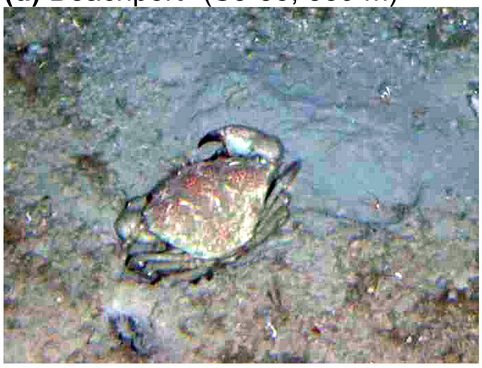


(c) High Rocky (S3-6; 146 m)

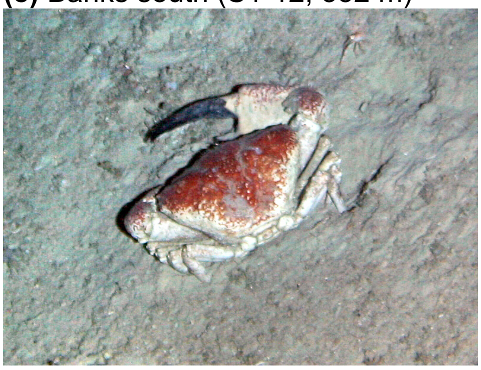


(d) Beachport* (S3-35; 339 m)

(e) Banks south (S1-12; 352 m)



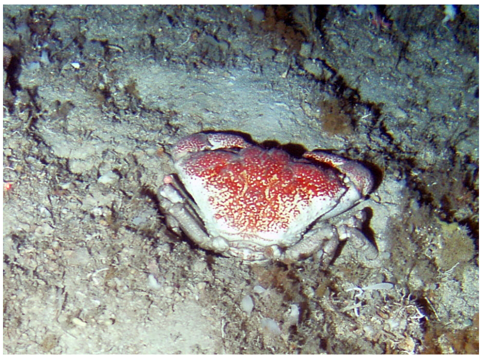
(f) West Bass (S4-9; 363 m)



(g) King Island (S4-7; 375 m)

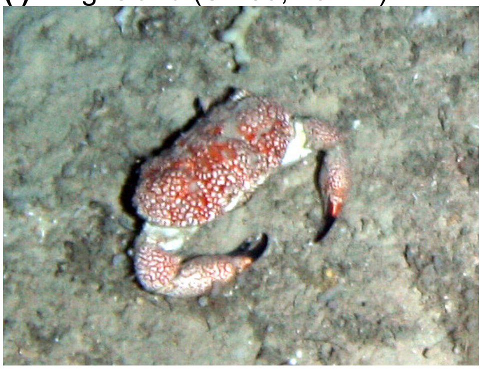
(h) King Island (S4-7; 256 m)

Figure 7.1.4.2 (pg 1/2) Examples of microhabitat use by giant crabs (*P. gigas*); see text for details



(i) King Island (S2-39; 291 m)

(j) West Bass (S4-10; 320 m)



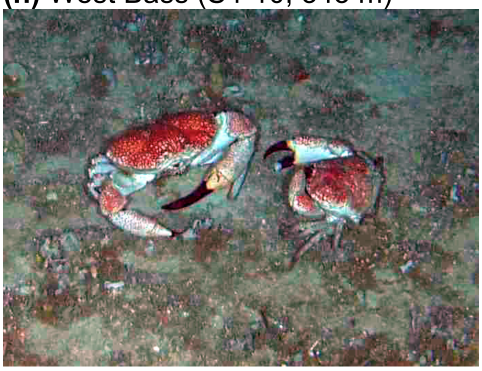
(k) Arthur (S4-17; 352 m)

(l) West Bass (S4-10; 333 m)

(m) Cape Grim (S4-4; 328 m)

(n) West Bass (S4-10; 343 m)

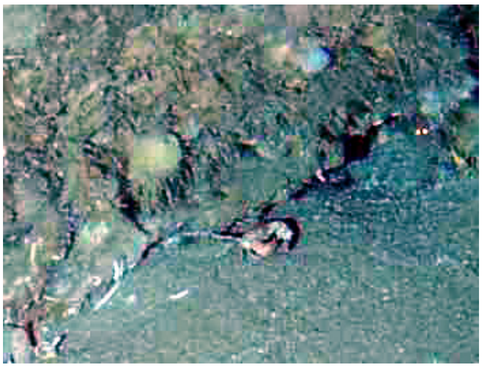
(o) Low Rocky (S3-1; 158 m)



(p) Pieman (S2-63; 310 m)

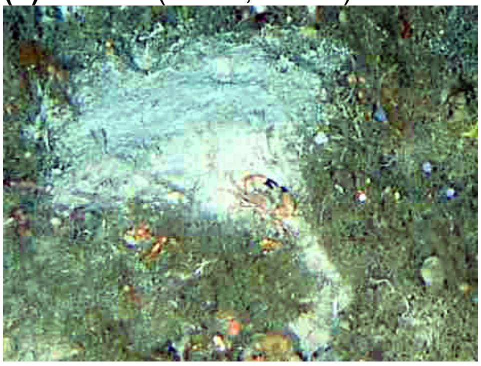
Figure 7.1.4.2 (pg 2/2) Examples of microhabitat use by giant crabs (*P. gigas*); see text for details

(a) Pieman (S2-63; 443 m)



(b) Pieman (S2-63; 446 m)

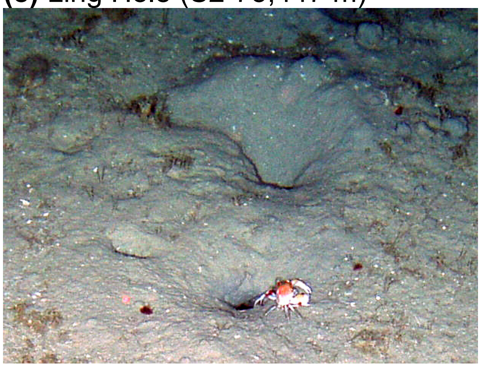
(c) Pieman (S2-63; 446 m)



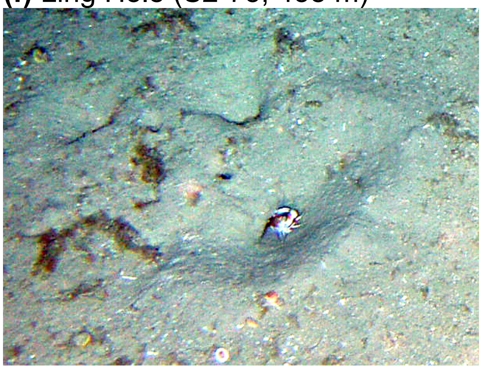
(d) King Island (S2-39; 223 m)

(e) Ling Hole (S2-75;447 m)

(f) Ling Hole (S2-75; 458 m)



(g) Ling Hole (S2-75; 464 m)



(h) Ling Hole (S2-75;523 m)

Figure 7.1.4.3 Microhabitat associations of small crabs (*P. gigas* or *Carcinoplax sp.):* (a) in crevice (b, c) under ledge, (d) near excavation amongst bryozoans, (e) at base of anemone, (f-h) in burrows on bare sediment

The entire carapace of one adult crab was covered in sediment indicating it may recently had been nearly completely buried (Figure 7.1.4.2.m); none were observed fully buried *in situ,* but obviously these would have been difficult to detect. Of the 75 confirmed giant crab observations (large individuals), most (> two thirds) were seen where there was no apparent epifauna (45%) or where there was detritus with residual fauna (24%) (Table 7.1.4.2). This is interpreted as a real difference because despite the camouflage provided by structured epifauna, adult giant crabs were generally conspicuous. Overall, we don't believe there was any substantial degree of under-sampling of adult giant crabs by video – although the extent to which adults completed bury in soft sediments or completely concealed beneath rocky overhangs remains unknown.

Table 7.1.4.2 Association of large giant crabs (*Pseudocarcinus gigas*) with types of epifauna as observed by video

Recoded fauna (FAf)	Fine-scale fauna	Number of observations	%
No apparent epifauna	no fauna	25	33
	bioturbation	5	7
	ophiuroid mattress	4	5
Residual fauna in matrix of detritus		18	24
Low/encrusting fauna		7	9
Bryozoans	turf	13	18
	thicket	3	4

The observation that giant crabs were most frequently observed associated with microhabitat features within broader habitat classed as having no apparent epifauna emphasises the value of these features (including structural epifauna, centimetre-scale low-relief ledges and burrows). These features appear to provide shelter to juveniles from predators and also shelters for adults during periods of rest. There was no evidence that the microhabitats provided by high relief rocky banks (reefs), slab or boulder fields, rock outcrops, or rocky edges crevices and overhangs are important. The distribution of large crabs in relation to epifauna types indicates that local-scale movement, presumably for foraging, occurs within both structured and open types. Whether or not this indicates a preference for open habitats is not assessed from these data because (1) the relative proportions of each type would need to be calculated with respect to factors that may confound the interpretation, e.g. background crab abundance, depth, season, proximity of refuges, in/ out of canyons; and (2) the possibility that carrion from trawl discarding (Section 7.2.4) was attracting crabs into areas that are more likely to be clear sediments.

7.1.5 Discussion: habitats and their distribution on the Tasmanian shelf edge

A spatial overlap of the trap fishery for giant crab (*Pseudocarcinus gigas*) and the bottom trawl fishery occurring at the edge of the continental shelf (~150 to 500 m depths) off western Tasmania provided the focus for this study. A total of 72 successful photographic transects in this depth range at 15 sites spanning the main area of the crab fishery from King Island in the north to SW Cape in the south (with some comparative sites on the east coast) enabled us to identify the suite of benthic habitat types present.

Seabed habitat types, at the fine spatial scale (m to km) recorded by camera and visible in photographic images, were identified as being predominantly a variety of coarse and fine sediments supporting four categories of sessile fauna: (1) a distinct 'thicket or turf' dominated by emergent bryozoans but also comprised of small erect sponges and ascidians; (2) a distinct mat of low and/ or encrusting forms composed predominantly of bryozoans and sponges; (3) an indistinct 'residual' low and encrusting microfauna (irresolvable by camera) in association with detritus; and (4) a distinct absence of epifauna (although often with burrows and tracks indicating an active bioturbating infauna). Consolidated rocky bottom types – tentatively identified in images as types of limestone – made up a relatively low fraction of seabed habitat. These formed rocky banks, variously of low and high relief (~0.5 to 5 m height), which support a fauna of large, erect forms including seawhips and soft and large hard bryozoans as well as large sponges.

Three components of the overall, 'coarse scale', distributions of habitat types were observed in the video data. These were: (1) a distinct depth related stratification which was present at all sites; (2) a variation in the depth pattern with location down the west coast, but without a strong latitudinal trend; (3) a distinct difference in proportions of habitat types between the east and west coasts.

Depth stratification of habitat type, apparent in simple inspection of the mapped habitat data, was confirmed by strong depth effects consistently detected by analyses of initial, recoded and gridded data. BIOENV analyses showed that average depth and minimum depth contributed to the largest, and significant, correlations between environmental variables and habitat distribution, while ANOSIM showed a general consistency of habitat composition within biomes (depth zones) across sites.

The shallowest stratum was characterized by rocky limestone banks that formed an extensive patchwork of 'reefs' on the deep shelf of the west coast, mostly in depths < 150 m (extending beyond this only at King Island), intervened by relatively large patches of coarse sediment characterized mostly by no fauna and low/ encrusting fauna. Much of this sediment was rippled indicating a strong current influence.

At the shallow ends of transects, reefs were high outcrops with relief estimated to be up to 5 m high; they tended to grade to lower relief rocky edges or isolated patches (~0.5 to 3 m high) at their outer extents where they give way to sediment plain. This pattern was consistently observed at nine of the 11 west coast sites (with no samples from the remaining two). Swath data, available at several sites, showed reef areas were extensive, e.g. extending inshore by ~40 km at King Island and ~25 km at Strahan.

Sea-ward of the reef, coarse sediments form a 'corridor' out to the shelf edge in ~170 to 200 m depths. This habitat stratum is relatively small (narrow) but varies considerably in width – being almost non-existent at the northwestern corner of the Ling Hole (300 m wide) to more than 6 km wide at Low Rocky. In this respect, it co-varies with the overall width of the outer shelf (150-200 m depths). It is characterised by a mix of habitat types: flat, irregular and rippled sediments and all fauna categories in various proportions.

On the shelf break (here defined approximately by the 200-300 m depth range) and the shallow part of the upper slope (~300-400 m depth) is a relatively distinct stratum of coarse sediments supporting the bryozoan-based community. This is a low relief (~≤ 30 cm high), structurally complex, highly species-rich community of small-bodied epifaunal animals including sponges, ascidians and hydroids that attach to or are in close physical association with a matrix of hard and soft bryozoans, predominantly articulated zooidal and articulated branching forms, with erect branching forms common below 200 m depth. Its core depth range was between approximately 200 and 350 m depth. This habitat has fine-spatial scale heterogeneity in patch size and appearance: in many locations the bryozoan community completely blankets the underlying sediment, forming long contiguous patches along camera transects (to 1.6 km in length), while in other locations it is more patchy, characterised by numerous smaller patches (10-100 m in length) intervened by sediments either with low/ encrusting fauna, or without epifauna.

As a habitat stratum however, the width of the bryozoan turf/thicket habitat ranges from less than 1 km (Cape Grim, Pieman, Southwest Cape) to more than 3 km (King Island, Strahan). In places, the bryozoan community has relatively high relief (to ~30 cm), being composed of taller component fauna, and in others relatively low relief (~< 5 cm); these were termed ‘thicket’ and ‘turf’ respectively, following the terminology of experts (Drs Y. Bone and N. James, pers. comm.). The shallow and deep boundaries of the bryozoan habitat were not distinct, but marked by transitions of low/encrusting fauna characterized by relatively low density and low vertical relief. At greater depths (~> 400 m) beyond the bryozoan habitat, habitats were coarse/ fine sediments with either the indistinct ‘residual’ microfauna in association with detritus, or a distinct absence of epifauna.

While the general pattern of depth stratification was evident at all sites (including the east coast), the actual depths of strata varied between sites, and some strata were absent at some sites. These variations had a weak but not significant latitudinal trend. The most conspicuous variation was the generally deeper distribution of bryozoan turf/ thicket toward the southern end of the west coast. There were also lower proportions of bryozoan turf/ thicket in the central west coast sites (Cape Grim, Arthur, Ling Hole, Pieman) compared to those at the north and south (possibly related to trawl distribution – see following Section).

There were conspicuous differences between the east and west coasts, with the east coast characterized by a narrow outer shelf (150-200 m depths) and steeper shelf-break, a lack of rocky reef based communities on the outer shelf, and considerably more rocky bottom on the shelf break and upper slope. Bryozoan turf/ thicket communities extended up onto the shelf and had a different composition, with fauna comprised mostly of solitary ascidia in a matrix of coarse detritus and hard low/encrusting fauna. The west coast’s largest canyons (King Island, Ling Hole and Pieman) lack the dominant structural fauna known to exist at the Big Horseshoe canyon (eastern Bass Strait) at corresponding depths: dense beds of large individual sponges at 120 m and at 300-400 m, and dense stands of the stalked crinoid (*Metacrinus cyaneus*) in 200-300 m.

Habitats can also be defined as the places where individual animals live, here termed 'microhabitats'. For benthic animals, these are typically either physical features or structural epifauna, are measured at metre or sub-metre scale, and in the depth range of interest to this study, only visible via photographic images. Microhabitats are relevant to understanding their potential roles as refuges for mobile fauna (including giant crabs and other commercially important species), and to interpreting their likely vulnerability to fishing impact, in this case trawling (Section 7.2).

Based on the microhabitats where crabs were observed, we infer that structural epifauna, centimetre-scale low-relief ledges and undulations, and burrows were important to giant crabs. Burrows enabled juveniles to hide (e.g. from predators), while low-relief ledges and undulations providing shelters for resting adults, presumably between periods of foraging. No giant crabs were observed in the larger crevices and overhangs of high relief rocky banks (reefs), slab and boulder fields, rock outcrops, and rocky edges, suggesting that these microhabitats are relatively unimportant.

About two thirds of the 75 large giant crabs were seen on relatively clear seabed (little or no structural epifauna) indicating that local-scale movement, presumably for foraging, occurs on both structured and unstructured types, but it cannot be determined whether this indicates a preference for unstructured habitats, or is due to other causes such as being attracted to carrion from trawl discarding. Overall, we don't believe there was any substantial degree of under-sampling of adult giant crabs by video – although the extent to which adults completed bury in soft sediments or are completely concealed beneath rocky overhangs remains unknown.

7.2 Evaluate habitat resistance and resilience to impact from fishing gears based using the semi-quantitative 'Ecological Risk Assessment' framework

7.2.1 Background — the ERAEF

In an attempt to assess the ecological impacts of fishing across all of Australia's Commonwealth fisheries, the Australian Fisheries Management Authority (AFMA) commissioned a risk assessment. That project, the "Ecological Risk Assessment for Effect of Fishing" (ERAEF), developed a methodology (Hobday et al 2006) to assess threatened, endangered and protected species, target and by-product species, communities, and habitats, and applied it to each Commonwealth fishery resulting in a series of 31 reports in October 2006. The otter trawl sub-fishery of the Commonwealth Southern and Eastern Scalefish and Shark Fishery (SESSF) was assessed as part of the ERAEF by Wayte et al. (2006). The Tasmanian Giant Crab Fishery was not assessed because, despite occurring in Commonwealth waters, it is managed as a state fishery, i.e. not by AFMA.

A central concept of the ERAEF, which has three stages – Level 1 (scoping), Level 2 (PSA) and Level 3 (detailed targeted studies), is to successively screen out lower risk fishing activities and ecological interactions at stages one and two, thereby identifying the highest risk activities and interactions as the highest priority for detailed research and management response. The role of the PSA is to more rigorously evaluate the fishery activities identified in the Level 1 scoping as being potentially high risk. Similarly, only the units (e.g. habitats, species, communities) identified as 'high risk' by the PSA (Level 2) stage are considered in more detail at Level 3.

The ERAEF methodology developed for habitats is applied here to assess the vulnerability of the habitat types overlapped by the demersal (otter) trawl fishery and the giant crab trap fishery. Although Wayte et al. (2006) assessed the impacts from otter-trawl fishing on habitats in a semi-quantitative 'Productivity-Susceptibility Analysis' (PSA) at Level 2 in the ERAEF, it is re-assessed here because habitats are identified at a greater spatial resolution than during the ERAEF.

7.2.2 ERAEF scoring of habitats

The five general habitat types identified in section 7.1 are comprised of 60 fine scale habitats defined by unique combinations of substratum, geomorphology, fauna and faunal abundance within biomes (depth zones). Thus, for the PSA, habitats were classified by recoded SG and FAf scores from the video data either from the outer shelf (100-200 m) or upper slope (200-700 m); the shelf-break is not distinguished in the ERAEF terminology (Table 7.2.2.1). Each habitat type was ranked for vulnerability (low, medium or high) against a series of attributes related to 'availability', 'encounterability', 'selectivity' (when multiplied together = susceptibility) and 'productivity'. Ranks are sub-fishery (gear) dependent, with the rank score for each attribute derived via a series of tables and decision rules (Wayte et al. 2006). A final risk rating is calculated from a 2-dimensional plot of susceptibility and productivity, with risk (high, medium or low) determined by Euclidian distance. Vulnerability scores were then combined into an overall risk rating for the trawl and crab fisheries separately (Table 7.2.2.1). For the otter trawl fishery we used the decision rules detailed in Wayte et al (2006); for the crab trap fishery we adapted the decision rules listed in Furlani et al (2006).

Assessment of the demersal trawl fishery indicated 25 of the 70 habitat types were potentially high risk, 25 medium, and 20 low. The high risk habitats were identified by the presence of either erect fauna or turf/thicket – faunal types that may be completely removed by trawls, and believed to have low productivity, i.e. being slow to recover from impact – but only where they were present on substrata accessible by the gear (sediments or low sub-cropping rock bottom). Contributing to the 'high' results for trawling are high scores for the availability and encounterability attributes: a high overlap of trawl effort with many habitats, and a high degree of impact from a mobile gear which is relatively heavy with a large footprint. The medium risk habitat types were low/encrusting or infaunal types ('no apparent epifauna') predominantly on the upper slope due to the intrinsically slower rate of productivity at depths below 200 m. Other epifauna on outcropping rock had a medium risk ranking based on the low expected encounterability of this substratum by trawl gear. All low risk habitats were based on low/encrusting, residual or infaunal types ('no apparent epifauna') on the outer shelf.

Assessment of the giant crab fishery indicated 6 of the 60 habitat types were potentially high risk, 23 medium, and 41 low. The high risk habitats were characterised by erect fauna on the outer shelf which could be crushed or removed by traps, and slow to recover. Medium vulnerability was assigned to all habitats with turf/thicket and to habitats with erect fauna on the outer shelf where recovery is expected to be faster than on the upper slope. Contributing to the few 'high' results for trapping compared to trawling are low scores for the availability and encounterability attributes reflecting a low overlap of overall trap effort with many habitats, and a low degree of impact from a static gear which is relatively light with a small footprint. All low vulnerability habitats related to low/encrusting, residual or infaunal types ('no apparent epifauna').

Table 7.2.2.1 (pg1/2) Habitat types encountered identified from the video data based on recoded substratum & geomorphology, and epifaunal categories by ERA sub-biome (outer shelf: 100-200 m; upper slope: 200-700 m)

Sub-biome (ERAEF)	Substratum and geomorphology	Epifauna	ERAEF-PSA overall risk rating	
			Otter Trawl	Trap
outer shelf	Flat, fine sediments	No apparent epifauna	Low	Low
upper slope	Flat, fine sediments	No apparent epifauna	Med	Low
outer shelf	Flat, fine sediments	Residual fauna in matrix of coarse detritus	Low	Low
upper slope	Flat, fine sediments	Residual fauna in matrix of coarse detritus	Med	Low
outer shelf	Flat, fine sediments	Low/encrusting	Low	Low
upper slope	Flat, fine sediments	Low/encrusting	Med	Low
outer shelf	Flat, fine sediments	Turf/thicket	High	Med
upper slope	Flat, fine sediments	Turf/thicket	High	Med
outer shelf	Flat, fine sediments	Erect	High	Med
upper slope	Flat, fine sediments	Erect	High	High
outer shelf	Rippled, fine sediments	No apparent epifauna	Low	Low
upper slope	Rippled, fine sediments	No apparent epifauna	Med	Low
outer shelf	Rippled, fine sediments	Low/encrusting	Low	Low
upper slope	Rippled, fine sediments	Low/encrusting	Med	Low
outer shelf	Rippled, fine sediments	Turf/thicket	High	Med
outer shelf	Rippled, fine sediments	Erect	High	Med
outer shelf	Irregular, fine sediments	No apparent epifauna	Low	Low
upper slope	Irregular, fine sediments	No apparent epifauna	Med	Low
upper slope	Irregular, fine sediments	Residual fauna in matrix of coarse detritus	Med	Low
outer shelf	Irregular, fine sediments	Low/encrusting	Low	Low
upper slope	Irregular, fine sediments	Low/encrusting	Med	Low
outer shelf	Irregular, fine sediments	Turf/thicket	High	Med
upper slope	Irregular, fine sediments	Turf/thicket	High	Med
outer shelf	Irregular, fine sediments	Erect	High	Med
upper slope	Irregular, fine sediments	Erect	High	High
outer shelf	Flat, coarse sediments	No apparent epifauna	Low	Low
upper slope	Flat, coarse sediments	No apparent epifauna	Med	Low
outer shelf	Flat, coarse sediments	Residual fauna in matrix of coarse detritus	Low	Low
upper slope	Flat, coarse sediments	Residual fauna in matrix of coarse detritus	Med	Low
outer shelf	Flat, coarse sediments	Low/encrusting	Low	Low
upper slope	Flat, coarse sediments	Low/encrusting	Med	Low
outer shelf	Flat, coarse sediments	Turf/thicket	High	Med
upper slope	Flat, coarse sediments	Turf/thicket	High	Med
outer shelf	Flat, coarse sediments	Erect	High	Med
upper slope	Flat, coarse sediments	Erect	High	High
outer shelf	Rippled, coarse sediments	No apparent epifauna	Low	Low

Table 7.2.2.1 (pg1/2) **Habitat types encountered identified from video.**

Sub-biome (ERAEF)	Substratum and geomorphology	Epifauna	ERAEF-PSA overall risk rating	
			Otter TW	Trap
upper slope	Rippled, coarse sediments	No apparent epifauna	Med	Low
outer shelf	Rippled, coarse sediments	Residual fauna in matrix of coarse detritus	Low	Low
upper slope	Rippled, coarse sediments	Residual fauna in matrix of coarse detritus	Med	Low
outer shelf	Rippled, coarse sediments	Low/encrusting	Low	Low
upper slope	Rippled, coarse sediments	Low/encrusting	Med	Low
outer shelf	Rippled, coarse sediments	Turf/thicket	High	Med
upper slope	Rippled, coarse sediments	Turf/thicket	High	Med
outer shelf	Rippled, coarse sediments	Erect	High	Med
outer shelf	Irregular, coarse sediments	No apparent epifauna	Low	Low
upper slope	Irregular, coarse sediments	No apparent epifauna	Med	Low
outer shelf	Irregular, coarse sediments	Residual fauna in matrix of coarse detritus	Low	Low
upper slope	Irregular, coarse sediments	Residual fauna in matrix of coarse detritus	Med	Low
outer shelf	Irregular, coarse sediments	Low/encrusting	Low	Low
upper slope	Irregular, coarse sediments	Low/encrusting	Med	Low
outer shelf	Irregular, coarse sediments	Turf/thicket	High	Med
upper slope	Irregular, coarse sediments	Turf/thicket	High	Med
outer shelf	Irregular, coarse sediments	Erect	High	Med
upper slope	Irregular, coarse sediments	Erect	High	High
outer shelf	Subcropping rock	No apparent epifauna	Low	Low
upper slope	Subcropping rock	No apparent epifauna	Med	Low
outer shelf	Subcropping rock	Low/encrusting	Low	Low
upper slope	Subcropping rock	Low/encrusting	Med	Low
outer shelf	Subcropping rock	Turf/thicket	High	Med
upper slope	Subcropping rock	Turf/thicket	High	Med
outer shelf	Subcropping rock	Erect	High	Med
upper slope	Subcropping rock	Erect	High	High
outer shelf	Outcropping rock	No apparent epifauna	Low	Low
upper slope	Outcropping rock	No apparent epifauna	Med	Low
outer shelf	Outcropping rock	Low/encrusting	Low	Low
upper slope	Outcropping rock	Low/encrusting	Med	Low
outer shelf	Outcropping rock	Turf/thicket	Med	Med
upper slope	Outcropping rock	Turf/thicket	Med	Med
outer shelf	Outcropping rock	Erect	Med	Med
upper slope	Outcropping rock	Erect	Med	High

7.2.3 Spatial distribution of ERAEF PSA risk

Depth distribution

Summarising the risk scores for each sub-biome identified in the present study (Table 7.2.3.1) showed that the shelf-break (200-300 m) is the area of highest risk in respect of both fisheries: > 50% of all frames on the shelf-break rated as high risk for trawl, and as medium risk for trap. The outer shelf habitats were mostly not vulnerable to either fishing method.

Table 7.2.3.1 Summary of vulnerability ranking of habitats for the SESSF Otter-trawl and the Giant crab Fisheries for each sub-biome, presented as percentage of the number of video frames scored

Sub-biome	Depth range	# video frames scored	SESSF Otter-Trawl Fishery			Tasmanian Giant Crab Fishery		
			High (%)	Med. (%)	Low (%)	High (%)	Med. (%)	Low (%)
outer shelf	100-200	97633	20.71	3.786	**75.51**	0	24.49	**75.51**
shelf-break	200-300	59797	**56.55**	43.45	0	4.84	**51.74**	43.42
upper slope	300-500	104612	25.30	**74.70**	0	1.17	24.25	**74.58**

To visualise the distribution of the risk scores over depth and by site, we plotted the distribution of the habitats by their overall risk rating for the SESSF otter-trawl and the Tasmanian giant crab fishery by site for each of the eight main depth ranges sampled in this study (Figure 7.2.3.1).

For the otter trawl fishery, the high risk scores follow the same pattern as the depth distribution of turf/thicket (section 7.1.3). It is predominantly on the west coast of Tasmania on the shelf-break reaching into the upper slope (200-350 m). There was a north south depth trend with the high risk score being shallower in the north (150-350 m) and deeper in the south (200-350 m); two sites, Arthur and Ling Hole, were quite different with rather low percentages of high risk habitats through all depth ranges. Moderate abundance of high risk habitats were observed on the outer shelf and into the shelf-break (< 250 m) in the eastern sites. Where high risk habitats are rarer, the distribution of medium and low risk habitats follows the sub-biomic division at 200 m, with the medium risk habitats deep and the low risk habitats shallow.

The trap fishery poses a high risk to only a low percentage of habitats throughout the depth zones. The medium risk scores follow the same pattern as the depth distribution of turf/thicket (section 7.1.3) and as the high risk scores in the otter-trawl fishery described above.

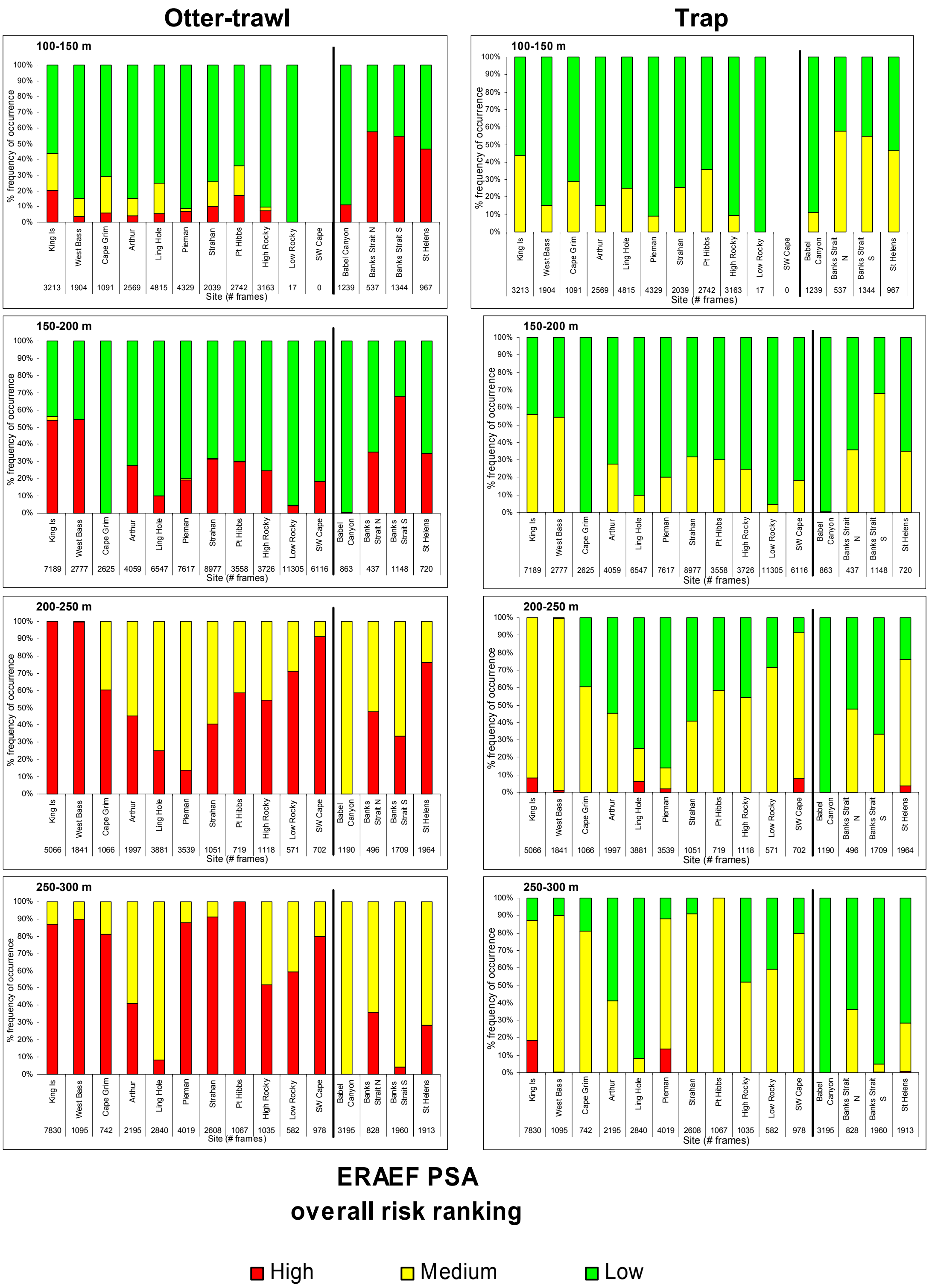


Figure 7.2.3.1 (pg 1/2) Histograms of the ERAEF-PSA overall risk ranking for the SESSF otter-trawl and the Tasmanian giant crab trap fishery by depth for each site

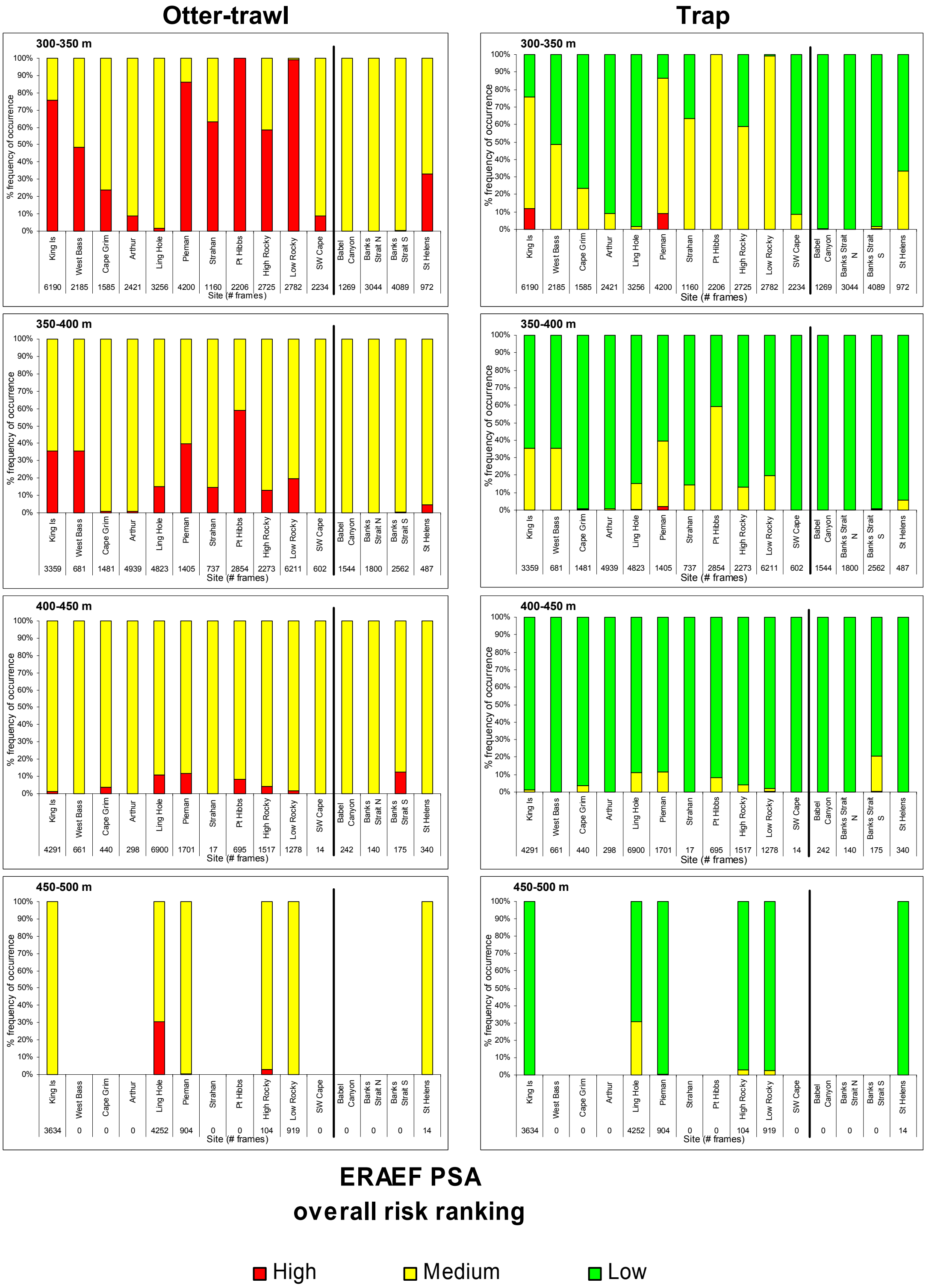


Figure 7.2.3.1 (pg 2/2) Histograms of the ERAEF-PSA overall risk ranking for the SESSF otter-trawl and the Tasmanian giant crab trap fishery by depth for each site

Mapped distribution by site

Thematic mapping of habitat distributions at the scale of one-second video-frames, coded by risk rating, produces complex patterns of patch structure (Figure 7.2.3.2). In the overall dataset, the most important feature is the long patches of habitat at high risk from demersal trawl on the shelf-break and reaching into the upper part of upper slope (to 350 m) that coincide with the stratum characterized by bryozoan turf/ thicket. Other patches of habitats scored as being high risk to trawl are short, and are mostly on the outer shelf where sediment habitats supporting bryozoan turf/ thicket or erect fauna exist between multiple small patches of rocky outcrop and are therefore at no risk of being encountered by trawl gear. These fine scale patterns can be effectively visualised in a stylised illustration in which 50 m depth bins are shown as near-equally spaced strata, and the area mapped at each site widened to a corridor so that the thematic mapping can be seen at the scale of the Tasmanian fishery Figure 7.2.3.3. The illustration is not conservative because mapping displays the dominant risk rating (> 50% occurrence) per stratum, i.e. to be mapped as high risk a stratum must contain > 50% high risk habitat. It clearly shows the band of highly vulnerable bryozoan turf/thicket habitats on the shelf-break and shallowest part of the upper slope along the west Tasmanian coast (strata 4 to 7; 150 - 350 m depth), with less vulnerable habitats either side.

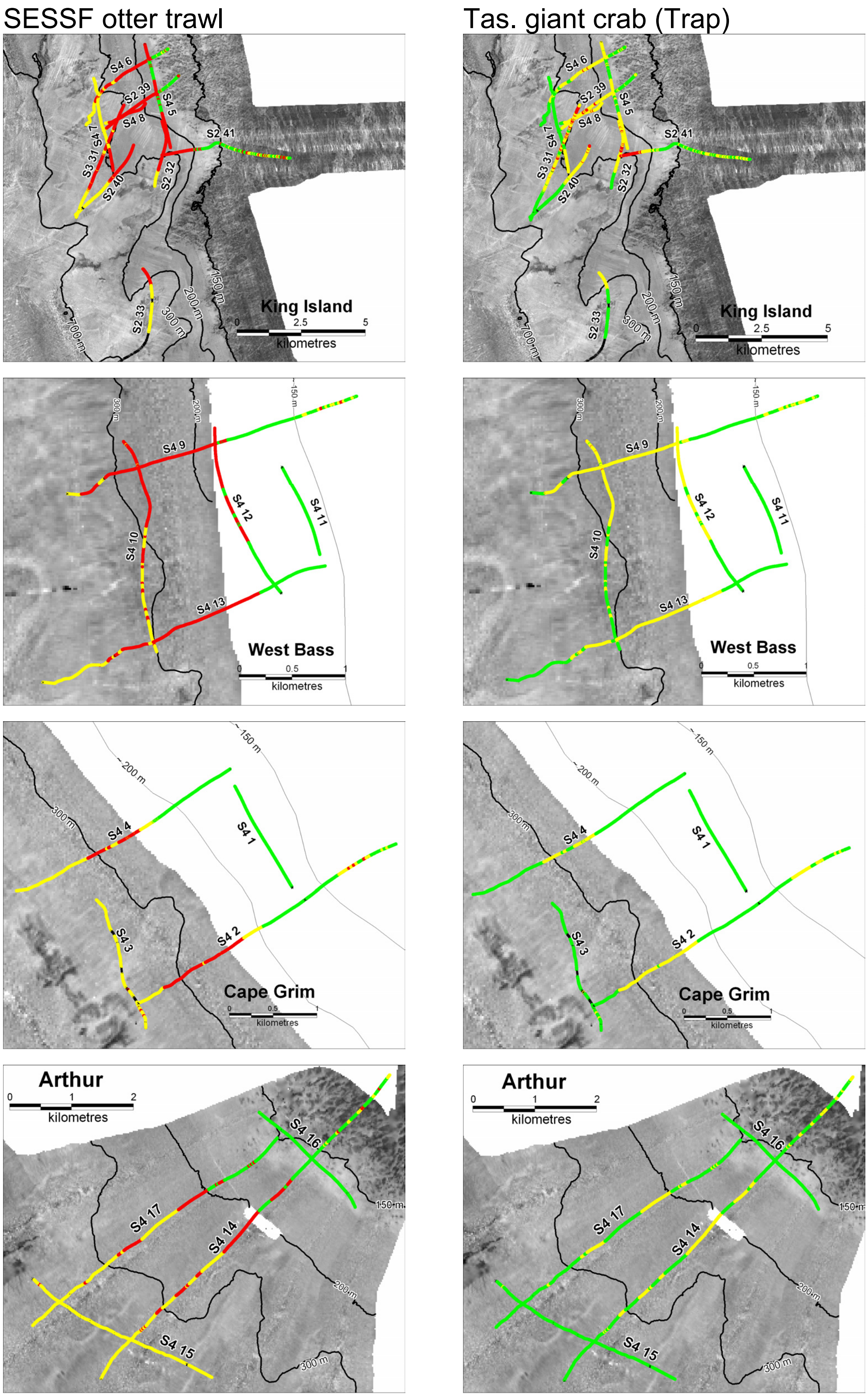


Figure 7.2.3.2 (pg 1/4) Thematic maps of risk score for habitat types overlaid on swath backscatter for SESSF otter trawl and Tasmanian giant crab fishery. Habitats identified in video data with risk based on ERAEF methodology (red: high, yellow: medium, green: low)

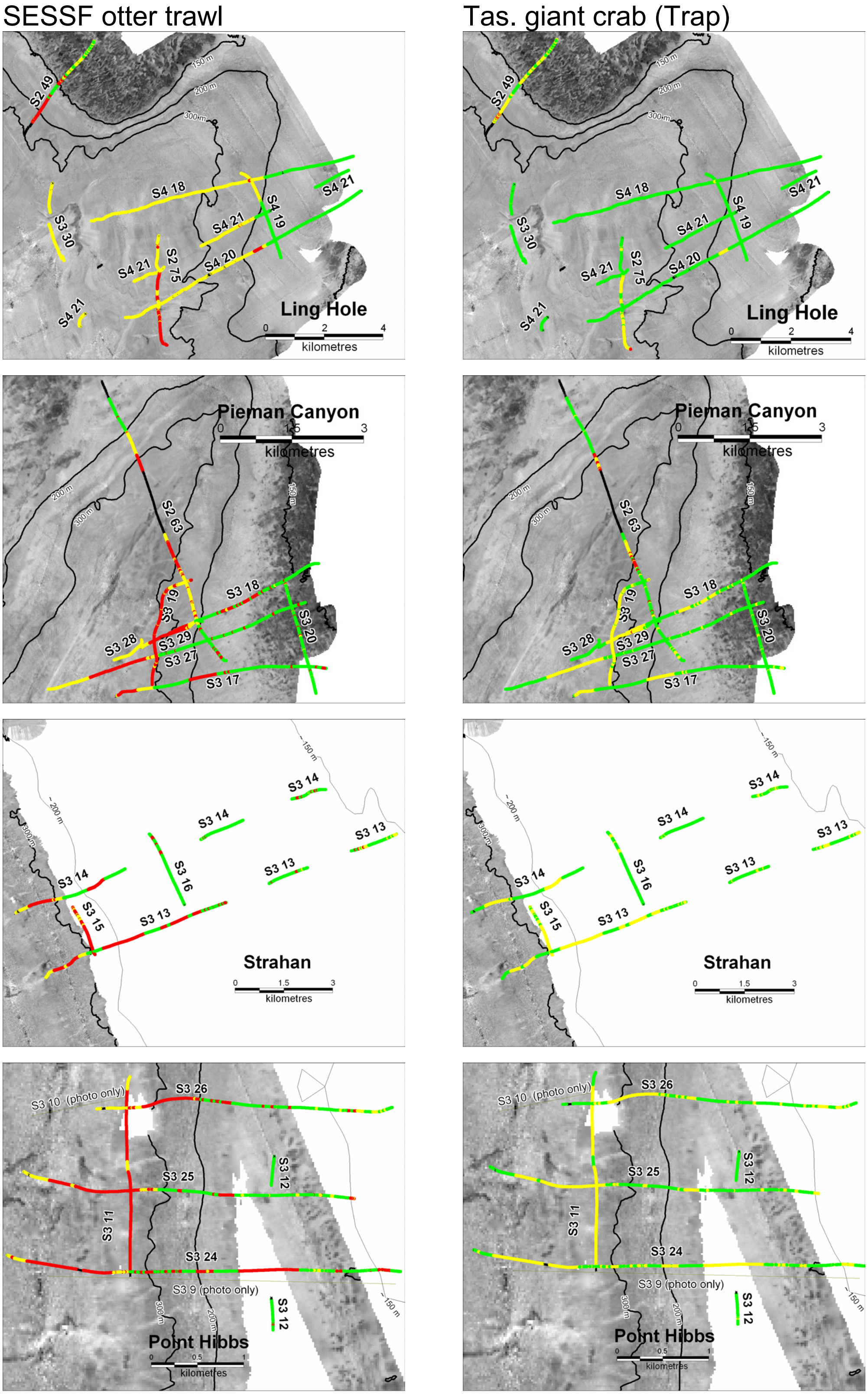


Figure 7.2.3.2 (pg 2/4) Thematic maps of risk score for habitat types overlaid on swath backscatter for SESSF otter trawl and Tasmanian giant crab fishery. Habitats identified in video data with risk based on ERAEF methodology (red: high, yellow: medium, green: low)

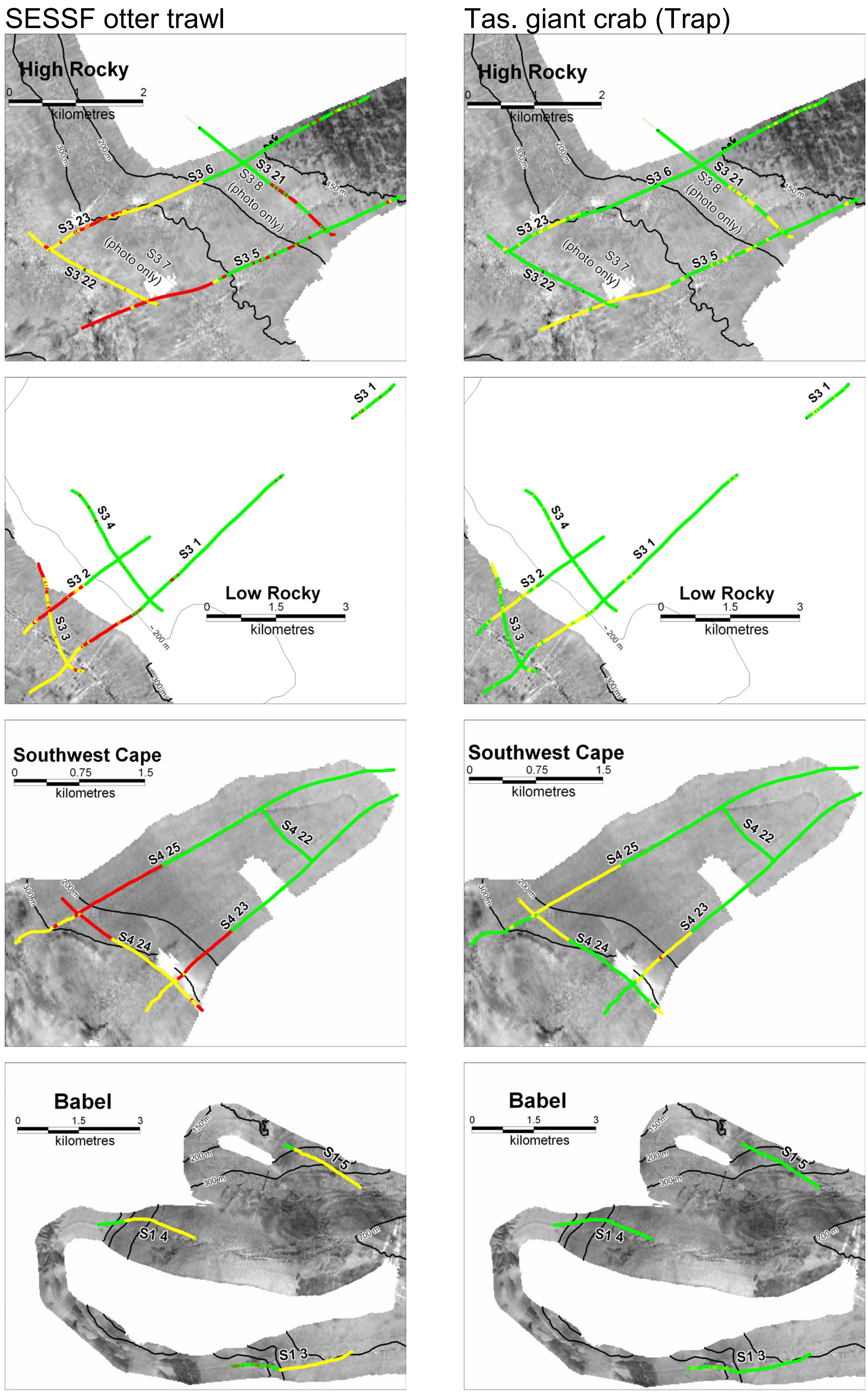


Figure 7.2.3.2 (pg 3/4) Thematic maps of risk score for habitat types overlaid on swath backscatter for SESSF otter trawl and Tasmanian giant crab fishery. Habitats identified in video data with risk based on ERAEF methodology (red: high, yellow: medium, green: low)

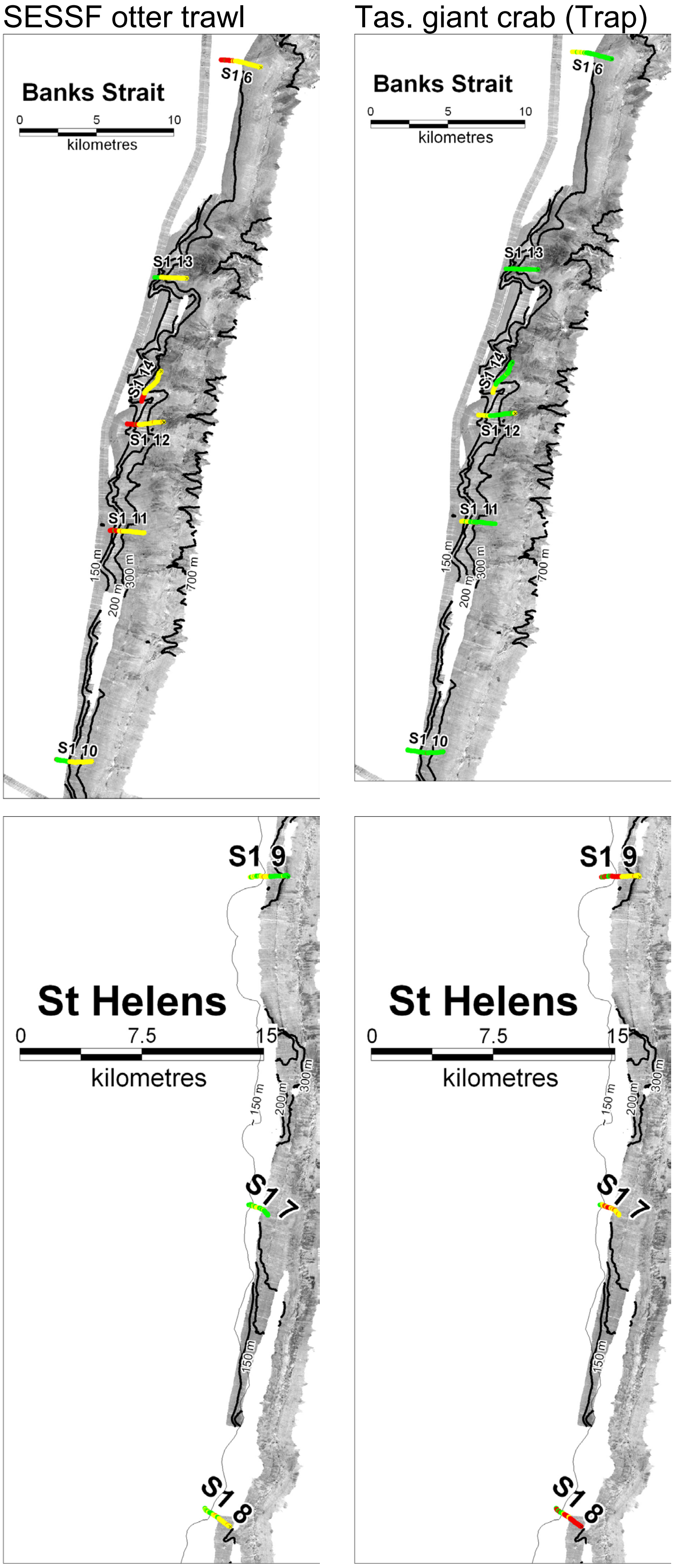
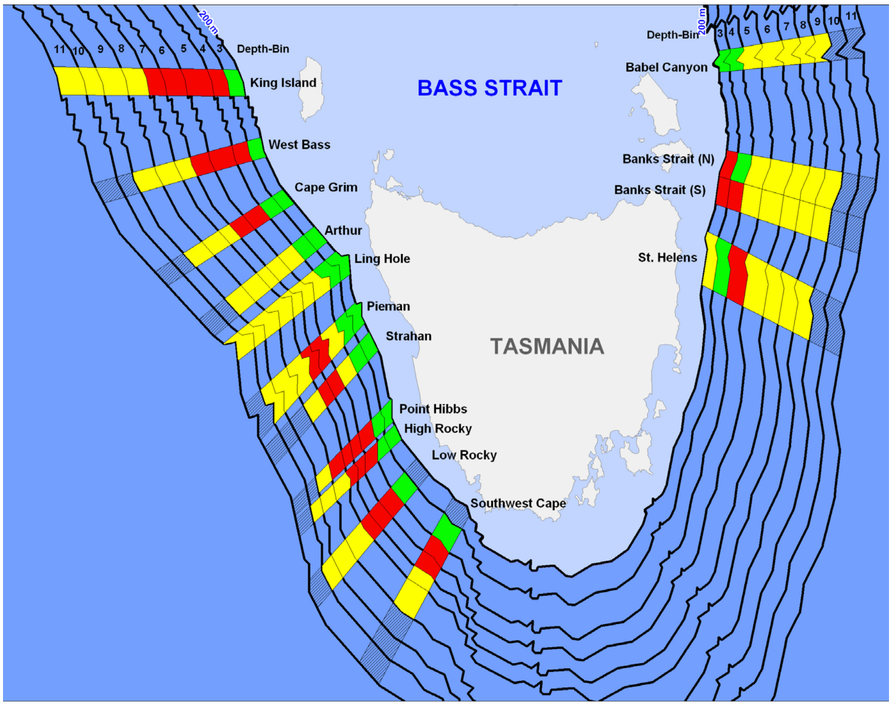


Figure 7.2.3.2 (pg 4/4) Thematic maps of risk score for habitat types overlaid on swath backscatter for SESSF otter trawl and Tasmanian giant crab fishery. Habitats identified in video data with risk based on ERAEF methodology (red: high, yellow: medium, green: low).

(a)



(b)

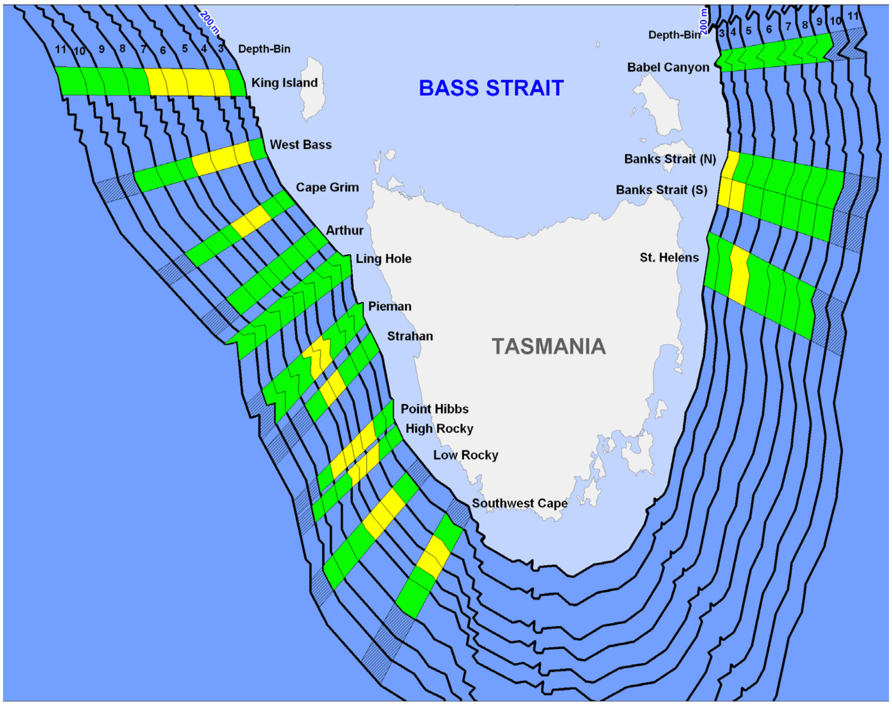


Figure 7.2.3.3 Stylised distribution map of the overall ERAEF risk rating for (a) SESSF otter trawl fishery and (b) the Tasmanian giant crab fishery. Thematic mapping displays data in 50 m depth bins divided into near-equally spaced strata using a replicated 200 m isobath; the area mapped at each study site is widened to a corridor. Risk rating based on >50% frames for each depth/site-cell; red: high risk, yellow: medium risk; green: low risk.

7.2.4 Human impacts on habitats

Gear marks

Clearly defined gear marks were observed and noted in 8671 video-frames, only 3.2% of the total 267701 of frames scored. Of these 20% were observed on the outer shelf (< 200 m), 7% on the shelf-break and 73% on the upper slope (54% in the 350-450 m depth range). Thus the shelf-break, which was identified as highly vulnerable to trawl gear and moderately vulnerable to traps, shows the least amount of gear marks. Even when the along-shelf transects are excluded (where gear marks are observed over longer patches consistent with the tow direction of trawls), the percentage distribution of gear marks over the sub-biomes changes only marginally — 15% outer shelf, 11% shelf-break, 74% upper slope (52% in the 350-450 m depth range).

Images of gear marks observed on the seabed (Figure 7.2.4.1) come mainly from demersal trawls. Regular and parallel raking patterns are diagnostic for the rubber discs or rollers of a trawl footrope (images a to d), while the single wide furrow at Pt. Hibbs and Banks Strait (images e, f) is consistent with the single pass of a trawl door, and closely resembles marks seen elsewhere and validated as being from a trawl door. However, the causes of drag marks at the Ling Hole and off St Helens (images g, h) are less easy to determine. The former is consistent with a dragging net – moderately wide, without furrows and heavy enough to remove the surface sediment and fauna. The latter is consistent with a trap dragged along the bottom – narrow, with furrows and only heavy enough to remove parts of the surface sediment and fauna. We also observed the marks left by the epibenthic sled that was used for scientific sampling of the invertebrate community at King Island, Ling Hole and Pieman; two wide furrows with about 1 m spacing (see following section).

The images of trawl impact validate elements of the methodology applied in the ERAEF assessment – relatively low impact of bottom trawling on sediment plains lacking structural epifauna (images a to e) – where at King Island (images a to c) bioturbating infauna can be seen to be forming pits and burrows over the trawl tracks. But potentially high impact by trawling and potentially other bottom contact methods through the complete removal of delicate epifauna (images f to h).

(a) King island (S2-40; 530 m)

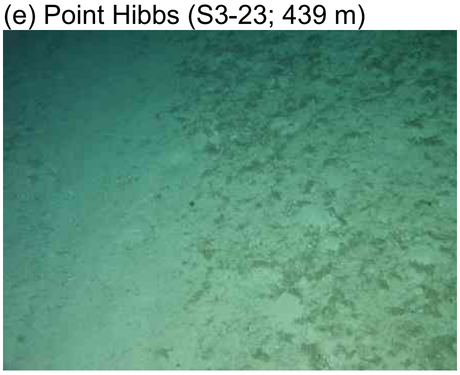
(b) King island (S2-40; 539 m)

(c) King Island (S2-40; 525 m)

(d) Ling Hole (S4-20; 430 m)

(e) Point Hibbs (S3-23; 439 m)

(f) Banks Strait (S1-14; 331 m)



(g) Ling Hole (S2-75; 484 m)

(h) St Helens (S1-8; 134 m)

Figure 7.2.4.1 Example images of gear marks observed on the seafloor; (a) to (d) regular raking patterns most likely caused by rollers on footrope of demersal trawl; (e) to (h) drag marks and furrows potentially caused by traps or trawl doors dragging along the seafloor.

The distribution of observed gear marks showed a good overall correspondence with areas recorded by logbooks as having trawl effort, including at some locations where there was both concentrations of observations and recorded effort (maps not shown to preserve confidentiality under the 5-boat rule). In places there was evidence of a correspondence between faunal type, trawl effort and observed marks, e.g. at the Ling Hole and Arthur. Notes for individual sites are listed below. However, the great majority of images from transects through trawled areas did not show identifiable gear marks.

King Island: A few gear marks were observed in locations on all transects, with a small concentration at the deep end of two transects. Logbook data indicated low trawl effort in both time periods (1996-2003 and 2001-2003), and no effort in the northern part of the study site. Some gear marks were from the scientific sled; others are not from trawls, and based on their depth, appear to be from crab traps. This site was classed as 'low trawl'.

West Bass: Gear marks were observed in several locations on 3 transects. Logbook data indicated low trawl effort in both time periods (1996-2003 and 2001-2003). This site was classed as 'low trawl'.

Cape Grim: Gear marks were observed in several locations on 3 transects. Logbook data indicated moderate trawl effort in both time periods (1996-2003 and 2001-2003). There was a clear correspondence between observations of residual fauna in coarse detritus matrix and trawl distribution. This site was classed as 'high trawl'.

Arthur: Gear marks were observed in many locations on 3 transects. Logbook data indicated moderate to high trawl effort in both time periods (1996-2003 and 2001-2003). There was overlap of trawl effort with both observed gear marks and coarse detritus matrix with residual or no epifauna. This site was classed as 'high trawl'.

Ling Hole: Gear marks were observed in many locations on 5 transects. Logbook data indicated high trawl effort in both time periods (1996-2003 and 2001-2003). There was overlap of trawl effort with both observed gear marks and coarse detritus matrix with residual or no epifauna, especially in the 250-350 m range. This site was classed as ‘high trawl’.

Pieman: Few gear marks were observed in transects despite logbook data showing high trawl effort in both time periods (1996-2003 and 2001-2003) throughout the canyon. This discrepancy is probably due to midwater trawl effort for blue grenadier being included in the effort mapping for this site. This site was classed as ‘high trawl’.

Strahan: Gear marks were observed in few locations on 2 transects which corresponded to areas where logbook data indicated moderate to high trawl effort in both time periods (1996-2003 and 2001-2003). This site was classed as ‘high trawl’.

Pt Hibbs: Gear marks were observed across each of the four complete transects. Logbook data indicated moderate to high trawl effort in both time periods (1996-2003 and 2001-2003) only in the deepest area of the site (~> 400 m). As such there was low correspondence between the location of observed gear marks and recorded trawl effort. This site was classed as ‘low trawl’.

High Rocky: Gear marks were observed in several locations on 3 transects, particularly at the deep ends. Logbook data indicated only low trawl effort in both time periods (1996-2003 and 2001-2003). This site was classed as ‘low trawl’.

Low Rocky: Gear marks were observed in many locations on all transects, particularly at the deep sections. Logbook data indicated medium to high trawl effort in both time periods (1996-2003 and 2001-2003) in deeper sections. Thus there was a clear pattern in the location of recorded trawl effort and observed gear marks at this site. This site was classed as ‘high trawl’.

Southwest Cape: Gear marks were observed in few locations on 3 transects. Logbook data indicated very low trawl effort in both time periods (1996-2003 and 2001-2003). This site was classed as ‘low trawl’.

Babel: No gear marks were observed. Logbook data indicated very low trawl effort in both time periods (1996-2003 and 2001-2003). This site was classed as ‘low trawl’.

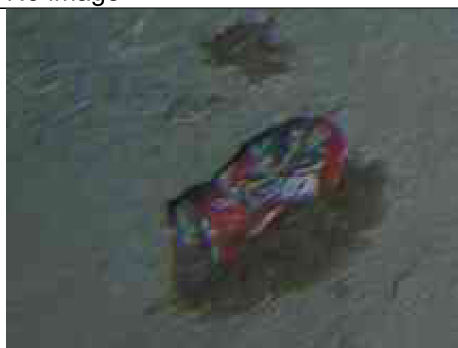
Banks Strait: Gear marks were observed in few locations on 3 transects corresponding to trawl effort distribution. Logbook data indicated low trawl effort in both time periods (1996-2003 and 2001-2003). This site was classed as ‘low trawl’.

St Helens: Gear marks were observed in few locations on the southernmost transect and were more consistent with traps or trawl doors than trawl rollers. Logbook data indicated moderate to high trawl effort in both time periods at this site, however not in the surveyed areas (1996-2003 and 2001-2003). This site was classed as ‘low trawl’.

Lost and discarded material

We observed occasional lost or discarded gears, as well as rubbish, and what appeared to be discarded catch (Table 7.2.4.1). Note the effect of catch discard (what is believed to be a ribbonfish, Table 7.2.4.1, image 4) for locally concentrated small scavenging hermit crabs – with small crabs and carrion both being potential food for giant crabs.

Table 7.2.4.1 Observations of anthropogenic impacts on the seafloor (other than gear marks)

Site	Video transect	Depth range (m)	Observed impact	Example image
King Island	S2-39	150-200	Trap (picture)	
King Island	S4-5	200-250	Trap	
Arthur	S4-16	100-150	Rope/cable	
King Island	S2-39	150-200	Rope/cable	
King Island	S4-5	200-250	Rope/cable	
Ling Hole	S2-75	300-350	Rope/cable	
Pieman	S2-63	400-450	Rope/cable (picture)	
Pt Hibbs	S3-26	100-150	Rope/cable	
Southwest Cape	S4-25	150-200	Rope/cable	
King Island	S4-6	400-450	Mesh net	
Pieman	S3-17	150-200	Mesh net	No image
Arthur	S4-14	250-300	Rubbish	
Low Rocky	S3-1	150-200	Rubbish (picture)	
Low Rocky	S3-2	150-200	Catch discard (picture)	
Low Rocky	S3-4	150-200	Catch discard	

Habitat recovery

This project offered a unique opportunity to examine the physical impact of a heavy towed epibenthic sled on shelf edge seabed habitat, and changes (recovery) over a 1-year time period between two surveys. Although the positions of the sled tracks were approximated as straight lines between start and end points, it was possible to cross two of them with video transects. The sled tracks were clearly observed close to their expected positions: Survey 2 – sled tracks S2-27 and S2-25 seen in video transects S2-32 and S2-39, respectively, and Survey 4 – sled-track S2-25 seen again in video transect S4-8 (Figure 7.2.4.2). Visual comparison of the gear marks observed during survey 2, within days of sled operations, and the ones observed on survey 4, one year after sled operations, shows that recovery within one year is minimal: the furrow made by the sled skid is still clearly visible and there is little indication of new epifaunal growth in it (Figure 7.2.4.3).

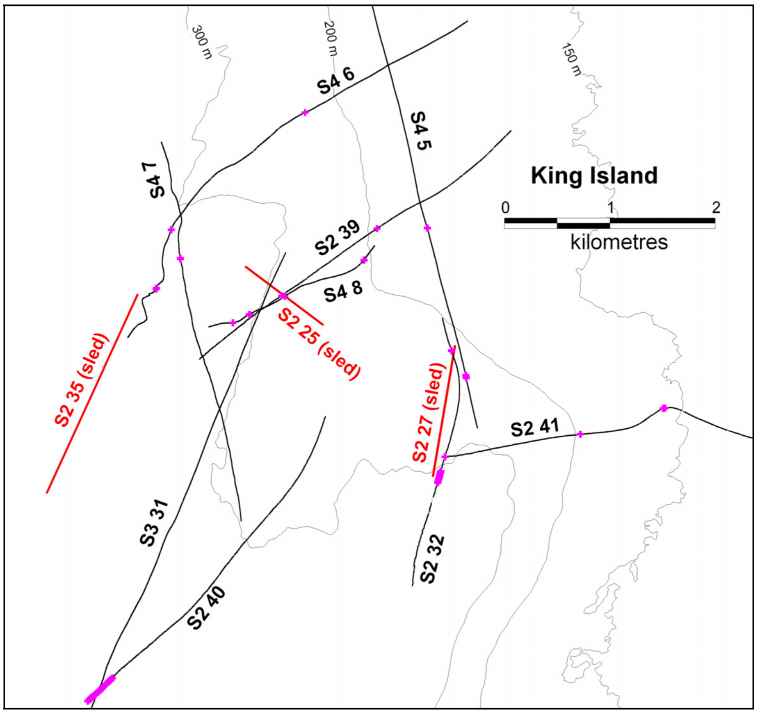
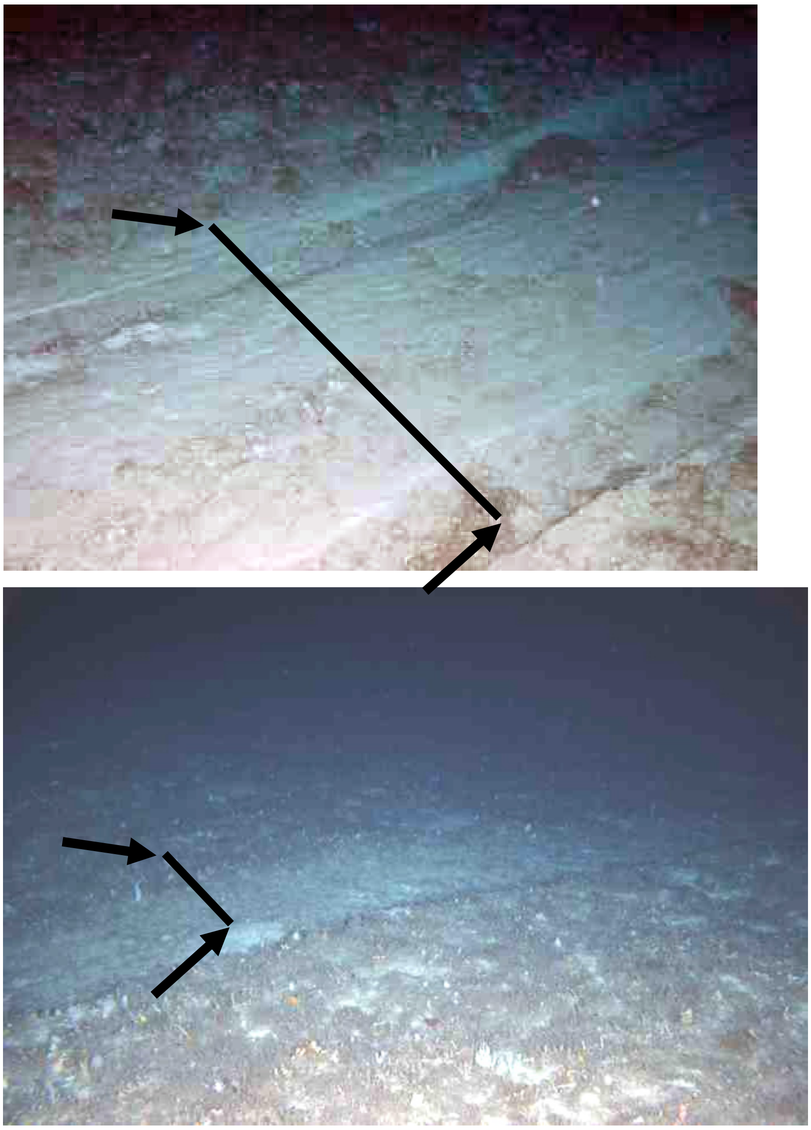


Figure 7.2.4.2 Map of the King Island site showing the video transects with gearmark observations highlighted (pink cross) and the approximated position of the epibenthic sled tows taken on survey 2.



(a)

(b)

Figure 7.2.4.3 Photographs of the marks left by an epibenthic sled at the King Island site, (a) within days of deployment (S2-39; 160-161 m), directly above the track and (b) after one year of recovery (S4-08; 154 m), at an oblique angle to the track.

7.2.5 Accessibility of hard bottom habitats to trawls

An aspect of habitat type that influences vulnerability to gear is accessibility; which was classified here into two types: trawlable and untrawlable habitat. Attribution of habitats into these categories is a key element of the PSA, and is also central to the fishery interaction being examined in this study.

In the broader SEF fishery, Williams et al., (2006) described “untrawlable” as seabed where it is not possible to tow the gear along the seabed, or where 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.

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) limestone and volcanic igneous rocks are relatively hard. Relatively soft types include friable sedimentary claystones and mud boulders, 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 between each door and the net giving a door spread of 80 m or more when fished. Untrawlable bottom may therefore occur where there are 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. 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. However, bedrock that just extends above surrounding sediments (subcrop) with a smooth profile at its perimeter is often accessible to trawls. It may also be possible to trawl heavy reef outcrop in a certain direction where the “dip”, or tilt of the rock provides angled ramp(s) rather than a vertical faces (e.g. elevated sedimentary rock may run 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.

What does this mean for the seabed area where the giant crab trap fishery and trawl fishery interact? In relation to potential risk, the vast majority of the seabed habitat in the area is based on sediments that are available to trawls, i.e. are trawled or are trawlable. These have low resistance to mobile gear and are ranked as "3" (highest risk) for the 'resistance' attribute. However, because they are not removable substrata and exist in large areas, they score at low risk for the "removablity" and "area" attributes. Harder, rocky, bottom types have higher resistance, and are ranked either "1" or "2". Lowest risk (highest resistance) apply to two of the five general categories of potentially untrawlable hard bottom observed (Section 7.1.4): the steep craggy rocky banks or 'reefs' (predominantly on the outer shelf) and isolated rocky outcrops (on shelf and upper slope). The remaining three categories are ranked medium risk, being either sedimentary, mobile or small: rocky edges/ ledges, slabs and boulders. Medium risk classification to trawls is based on a relatively greater level of accessibility (cf. rocky reefs) for the reasons outlined above, e.g. low relief, softer composition, having a distinct dip (tilt) allowing access from particular directions, or being movable.

In summary, hard bottom types can be classified in relation to 'trawlability', but the distinction between trawlable and untrawlable is often fuzzy, and a range of general and specific characteristics of hard bottom need to be considered. Examples of the attributes considered when doing this in this risk assessment are provided, and the importance of the insights provided by seabed imagery for assessing key characteristics such as relief, dip and composition are illustrated.

7.2.6 Discussion: considerations for management of fishery habitat

The end-point of the ERAEF Level 2 PSA is a list of units, in this case habitats, showing their potential risk (not absolute quantified risk) from an identified fishing activity. This is a screening, or prioritization, process to identify units (habitats, species or communities) that require greater management attention or further investigation. Experience and design shows that the approach is precautionary. As a result, the list of high-risk units can contain ‘false positives’ (units incorrectly scored as high), and the addition of further information may refine the score to medium or low. For high-risk units, managers and industry may decide to implement a management response, possibly requiring further analyses using Level 3 methods, which do assess an absolute level of risk.

Our analysis showed there is one conspicuous vulnerable habitat type, the bryozoan turf /thicket, potentially at high risk from trawling. The primary factors resulting in this outcome are that its entire Tasmanian distribution is available to the trawl fishery (based on the management boundary), there is a very high overlap of trawl effort with its distribution (high encounters), and, relative to other gears including crab traps, a trawl has a high degree of impact because it is heavy and has a large footprint. In addition, the habitat occupies a relatively small area, it has low physical resistance to this gear, and its fauna is fragile and completely removable. It occurs in deep water meaning it has relatively low resilience, having evolved in an environment with low natural disturbance and having a slow recovery following impact. Although the intrinsic vulnerability of bryozoan turf/thicket makes it potentially at risk to impact from any gear, it did not score at high risk from crab trapping mainly because it encounters traps in only part of its distribution where there is a low impact from a light, static gear with a small footprint.

The high risk score from PSA thus appears justified, which leads to consideration of a management response. Wayte et al (2006) state that a classification of vulnerability needs to be followed by an assessment of the size and location of that habitat.

The present project provides further data on these questions. Mapping of the most vulnerable habitat type, the bryozoan turf/thicket, shows that around Tasmania it is restricted to a relatively narrow depth stratum on the shelf-break and shallow upper slope (~200 to 350/400 m depth) on the west coast, and somewhat shallower, on the deep outer shelf into the shelf-break (~150 to

250 m), on the east coast. A coarse-scale interpolation of its distribution between survey areas, based in part on additional swath data, shows that around Tasmania the core bryozoan turf /thicket habitat type may cover an area of some 8054 km^2, distributed in a narrow ribbon of between 700 m and 3 km in width (up to 6 km wide at Strahan).

This knowledge of distribution and extent of the primary high risk habitat is the first step towards the other relevant considerations:

1. What is the real level of encounterability by fishing?

2. Does the distribution of high-risk habitat correspond to the area where sectors interact, meaning there is an issue of degradation of giant crab habitat, and the additional possibility of cumulative impacts from both sectors?

3. Is there an identifiable direct impact on habitat by fishing, and, if so, is anything known about its capacity to recover?

4. Has habitat been protected elsewhere in sufficient quantity to mitigate the potential impact occurring in the study area?

Estimating the real level of encounterability is difficult because it requires the percentage of the habitat fished to be estimated at relevant scales in time and space. In the ERAEF, fishing effort was typically mapped over time period for which ‘good’ data were available and that captured historical patterns, and at the ‘best’ spatial scale available from logbooks.

In the case of trawl, resolution at 1 km cell size was possible from shots recorded with reliable latitude and longitude since 1996. The GPS of crab trap logbook data have been recorded since 2000 with only ½ degree grid resolution in data from 1994 to 1999. Note that the precise location of gear can vary from the recorded vessel GPS position due to drift of gear as it sinks from the vessel to the sea floor, plus the position recorded relates to the centre of the shot, while other pots are spread around this point (typically 50 traps per shot). Likewise in the case of recent trawl data, there is a major source of error that has the effect of biasing the estimate of ‘area of trawled seabed’ upwards: the effect of ‘effort smear’. This appears to arise mainly from the combination of recording vessel position rather than gear on bottom – exaggerating the length of a tow at both the start and end. One effective way of reducing effort smear is to 'reflect' trawl effort off untrawlable seabed (Williams et al., 2006), but this requires a validated fishers' map of coarse scale habitats for the area in question. The effect of reducing effort smear on the estimate of trawl encounterability in the ERAEF, when compared to a data set with only standard processing to remove spurious data, was to reduce the encounterability estimate, e.g. from 90% to 65% for the upper slope (200-700 m). Notwithstanding, the upper slope as a whole is very widely trawled and trawl effort distribution may have expanded since the Williams et al. (2006) estimate for 1996-2001 while the distribution of auto-longline effort is also extensive and has expanded during the same period. Wayte et al. (2006) concluded that, collectively, these patterns point to the need to consider cumulative overlap and impact across sub-fisheries, and in combination with the presence of the highly vulnerable habitat, to regard the upper slope/ shelf break as a high priority for both further analysis and mitigation.

The nature of the trawl-crab trap sector 'interaction' can be defined by recent overlap in the region between ~150 m and ~350 m depths off the central/ northwest part of Tasmanian west coast where the giant crab fishery is most active. Depth boundaries of this interaction region can be visualized as the outer edge of untrawlable shelf reef (the shallow margin of the traditional crab trapping grounds) (~150 m) and the shallow boundary of the 'traditional' upper slope trawl grounds (~300 m). (Note, the traditional shallow trawl boundary is not defined by a single depth, but based on mapped logbook data, has been greater than ~300 m north of High Rocky.) Mapping from Section 7.1 shows the interaction region is composed of two distinct strata:

1. the outer shelf sediment terrace between the reef boundary and the shelf break – between ~150 and 200 m – which is variable in width ranging from very narrow (< 1 km off NW and E Tasmania) to relatively wide (6-10 km off Strahan and SW Tasmania). The extremes are at the Ling Hole (only 300 m wide) and off southern Tasmania (12-20 km wide).

2. the shelf break and shallow part of the upper slope between 200 and 350 m.

The bryozoan turf/ thicket habitat is present in each of these strata and is the dominant and characteristic fauna of the latter. Thus, the potentially high risk habitat is in the area where sectors interact, implying that some degradation of giant crab habitat is occurring. While the great majority of impact stems from trawling, there is also some additional impact from traps. The patterns will vary between east and west coasts due to different effort distributions in both sectors; for example most crabs are caught between 150 and 300 m on the west coast and between 250 and 350 m on the east coast.

Photographic imagery is a useful tool for observing and visualizing impacts, but we had less capacity to identify long-term fishing induced disturbance. This difficulty is compounded by lack of access to sites with known lack of impacts (even “low trawl / low trap” sites used in this study had some effort from each). Thus at the study sites, and at many, if not most, areas of the SESSF outer shelf and upper slope, it is difficult to establish what a large undisturbed area of vulnerable habitat may have looked like.

The important, albeit limited, opportunity to observe a turf/thicket habitat one year after impact from a heavy epibenthic sled showed no signs of recovery (no redistribution of sediments or regrowth of fauna. This is consistent with its precautionary scoring in the most vulnerable category for recovery of fauna (> decadal) in the PSA. Part of this consideration is that there may be a complex community interaction that requires the consolidation of surface sediments by bryozoans before other fauna (e.g. sponges, ascidians and hydroids) are able to re-establish.

Finally, is a management response needed? From a fishery perspective, it is necessary to consider impact on habitat at both the local and fishery-wide scales. Does habitat degradation off western Tasmania have a negative effect on the carrying capacity of that benthic ecosystem for the giant crab population, and then whether there is a negative fishery impact for giant crabs and other co-occurring species beyond western Tasmania. These are examined in the two following sections, 7.3 and 7.4.

Numerous approaches are available to manage fishery impacts on habitats including gear modifications, vessel constraints and spatial restrictions. Spatial closures employed in the SE region that regulate fishing access include fishery closures (including informal industry agreements and regulated arrangements), Commonwealth Marine Protected Areas, and occasional specific exclusions (e.g. around power cable infrastructure).

Parts of five recently declared Commonwealth MPAs cover the depth range of interest (200 to 350 m) around Tasmania, (Zeehan, Tasman Fracture, Huon, Freycinet, and Flinders)

Trawling is excluded from these zones, while crab trapping is permissible in parts (Multiple use zone A areas, but not the “strict nature” or recreational use zones). Recent surveys by one of the authors (AW) confirmed the existence of extensive bryozoan turf/ thicket at 200 m depth in both Tasman Fracture and Huon MPAs, so that Freycinet is the only of these five MPAs where the presence of the bryozoan community is unconfirmed.)

The total area of bryozoan zone in these Commonwealth MPAs is estimated at 454 sq km, which is 20.3% of the total area in this depth range around Tasmania south of 39.5ºS (2,230 sq km). Of this, 18.5% of the total area is in Multiple use A zones, with 1.8% of the total area in Strict nature or Recreational use zones. There is representation in each of the Provincial scale regions: Zeehan in the Tasmanian Transition Zone, Tasman Fracture and Huon in the Tasmanian Province, and Freycinet and Flinders in the Southeastern Transition Zone. The giant crab population extends around southern Tasmania, but very few individuals are captured off the south coast (Tasmanian Province). This means the coverage of bryozoan habitat in MPAs within the area where crabs are relatively abundant (supporting commercial fishing) is limited to the Zeehan, Freycinet and Flinders MPAs.

More specific management strategies to protect the bryozoan habitat such as gear constraints or fishery closures have not been proposed for the shelf break. There is active discussion of closures in depths > 700 m to protect species and delicate habitats, and restrictions for trawling on the shelf. On the upper slope there are voluntary seasonal closures (to protect stocks on pink ling, including at the Ling Hole) but the role and design of these closures is to restrict effort rather than protect habitats.

Additional protection for the habitats comes through a voluntary agreement reached between crab and trawl fishers on 27/1/2004. This agreement was that trawling would be excluded in depths between 200 m and 300 m along the west coast of Tasmania between 40°00’ and 42°45’, excluding the Ling Hole, Pieman Canyon and Strahan Canyon.

The effectiveness of this voluntary agreement was assessed by examining logbook records from benthic trawl operations to identify incidences where tows had transversed the voluntary zone. These incidences were identified where the start or end point of the trawl occurred within the zone or transversed the zone. Shots were filtered on the basis of being reported as demersal, and on reported location (lat and long) and depth.

A total of 106 shots were reported within the voluntary exclusion zone from 2005 to 2008. These were from 14 separate vessels, although disproportionately from one. Shots within the zone were greatest in 2005 and least in 2008 (Figure 7.2.6.1).

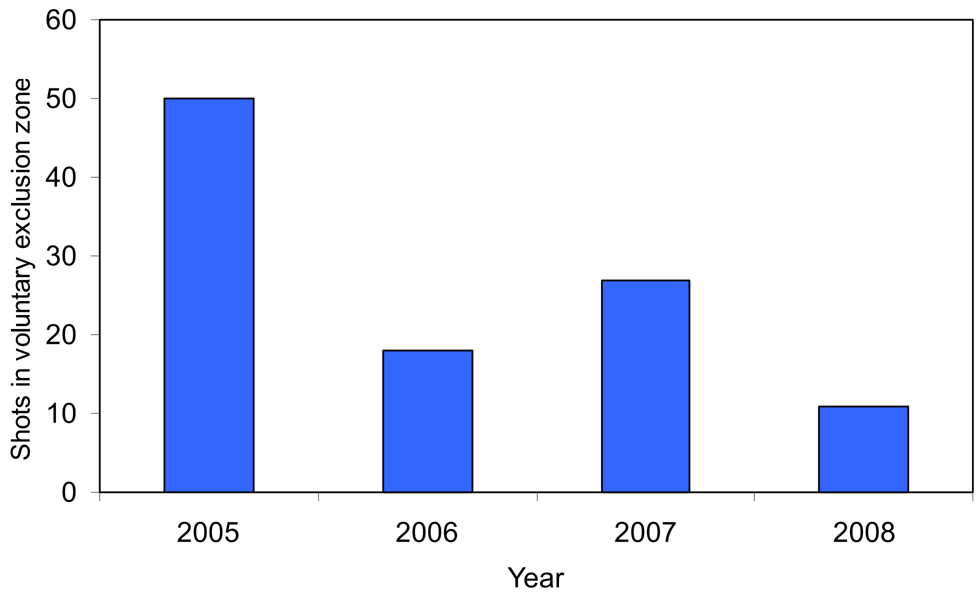


Figure 7.2.6.1 Reported demersal trawl shots within the voluntary exclusion zone, pooled for all vessels.

In conclusion, and before considering the mechanisms by which habitat degradation may impact the carrying capacity of the benthic ecosystem for the giant crab population and other co-occurring species (following sections), we make these observations:

- A bryozoan-based habitat, unique to the shelf edge (~200-350 m), occupies a large part of the seabed where giant crabs exist in commercial quantities.

- It has a potentially high risk of negative impact from benthic trawling, and other bottom contact methods using the same area will add (marginally) to this impact.
- Impacts include complete removal, recovery is likely to be slow, and (at least off western Tasmanian) there is little rocky bottom to impede benthic trawling.
- This habitat type makes up a large part of the depth zone (~150 to 350 m) where trawl sectors and giant crab fishing ‘interact’.
- No protection of bryozoan turf habitats occurs through formal fishery spatial management regulations.
- Some protection of bryozoan turf habitats occurs through Commonwealth MPAs (~6.5% of habitat distribution),
- Additional protection of bryozoan turf habitats may be occurring through an unregulated agreement between the trawl and crab fishers.

7.3 The distribution of exploited shelf-edge species in relation to habitat features

The information collected on habitat distribution outlined in Section 7.1 enabled comparison between habitat types and the distribution of commercial species. The distribution of species was mainly inferred from catch rates derived from commercial logbook data, although some information was also obtained through the video data collected for this study. Of particular interest was the distribution of catches relative to (1) the bryozoan habitat and (2) the shelf/shelf break sediment terrace for morwong, flathead, ocean perch, ling and giant crab

Video observations also provided information on distribution relative to microhabitats. This qualitative information can provide insight into habitat use and thus contributes to understanding vulnerability of habitats for exploited species. Examples of microhabitat usage include observations of partially buried female crabs, which was assumed to be associated with egg extrusion. While video observations provided many observations of crabs interacting with microhabitat, it was less useful for finfish as they appeared to avoid the towed video gear.

The broadly consistent patterns in habitat with depth along western Tasmania simplified research presented in this section. As a result, habitat requirements for exploited species could be inferred from commercial catch and depth information because of the consistent habitat pattern between transects.

7.3.1 Giant crab distribution

Broad-scale distribution

The distribution and abundance of giant crabs (*Pseudocarcinus gigas*) in the Tasmanian Giant Crab Fishery was mapped using the CPUE as a proxy for density (Figure 7.3.1.1) with the aim to identify regions of importance for this species in relation to benthic habitat. Catch rates were highest in the northwest of Tasmania between West Bass and Pieman; relatively low in the central part of Tasmania's west coast (Strahan and Point Hibbs) and very low to non-existent in the south-west (Figure 7.3.1.1). On the east coast catch rates were relatively low but even along the entire coast (Figure 7.3.1.1). Fishing effort for giant crabs was most concentrated in the 150 to 300 m depth range on in the west, and slightly deeper, 250-350 m, in the east.

Breaking these catches up into demographic groups, we found that the distribution of females and males generally overlapped along the west coast (Figure 7.3.1.2 and Figure 7.3.1.3) although some regions tended to have higher density of females. For example, sites 4 and 5 tended to have relatively high catch rates of females, while site 14 tended to have relatively high catch rates of males. Catch rate of males was low on the east coast, while catch rates of females on the east appeared to be concentrated to the north (note that males were caught on the east coast, but at relatively low catch rates so that they didn't plot in Figure 7.3.1.3 and Figure 7.3.1.2).

The distribution of undersized crabs (Figure 7.3.1.4) showed that the NW region, between King Island and Arthur appears especially important for this class (especially sites 4, 5 and 6), which suggests that this region may be an important area for recruitment. Fishers operating in this region have reported that this spatial pattern in undersize crabs occurred after the fishery developed and may be a recruitment pulse in response to removal of adults. The distribution of undersize giant crabs appears to be a function of larval advection, as explored further in Section 7.4.

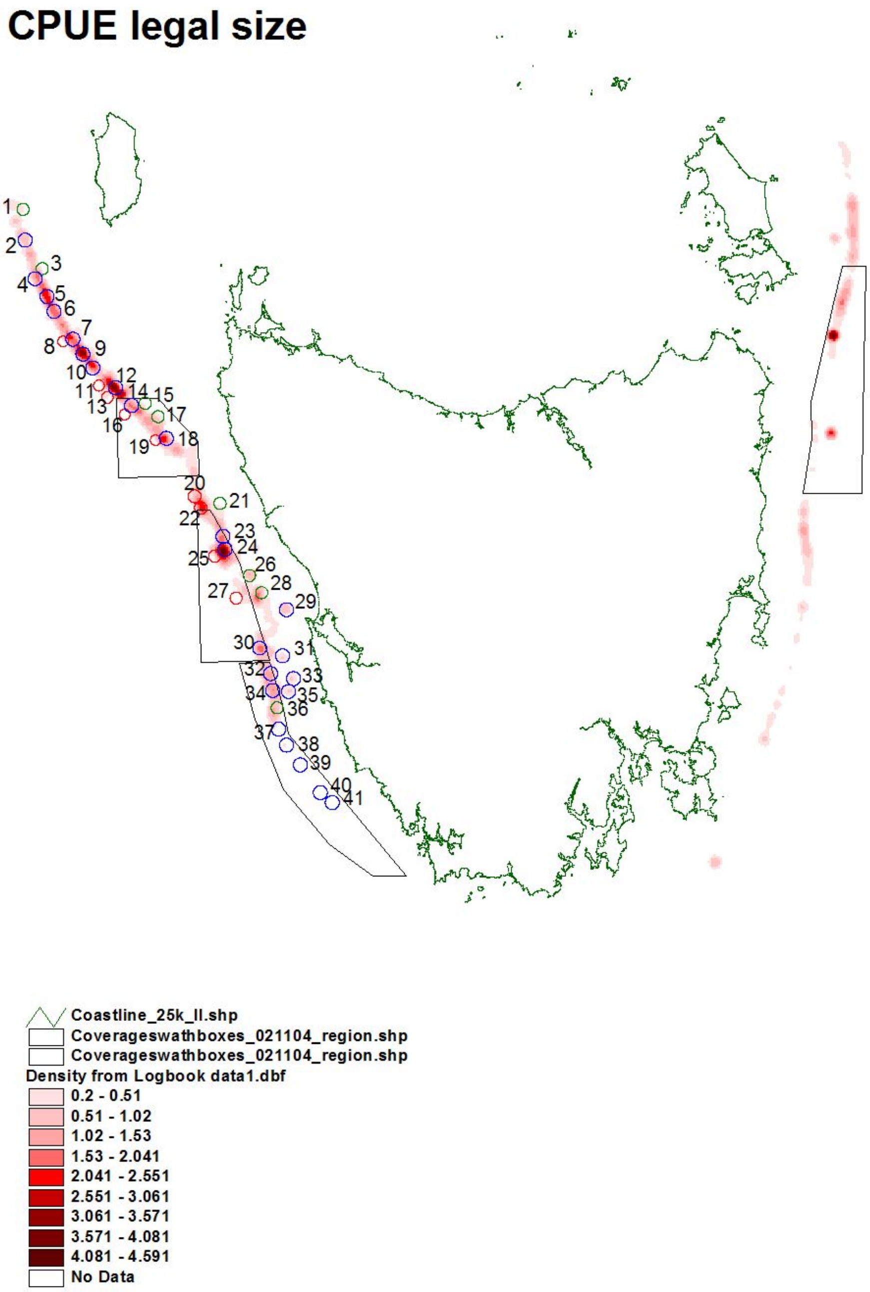


Figure 7.3.1.1 Density of giant crabs using CPUE from commercial logbooks as a proxy. Higher density is indicated by red shaded regions. Boxes marked are those areas targeted in swath mapping surveys conducted for this project. Circles indicate locations with specific attributes targeted as possible research sites for video transects.

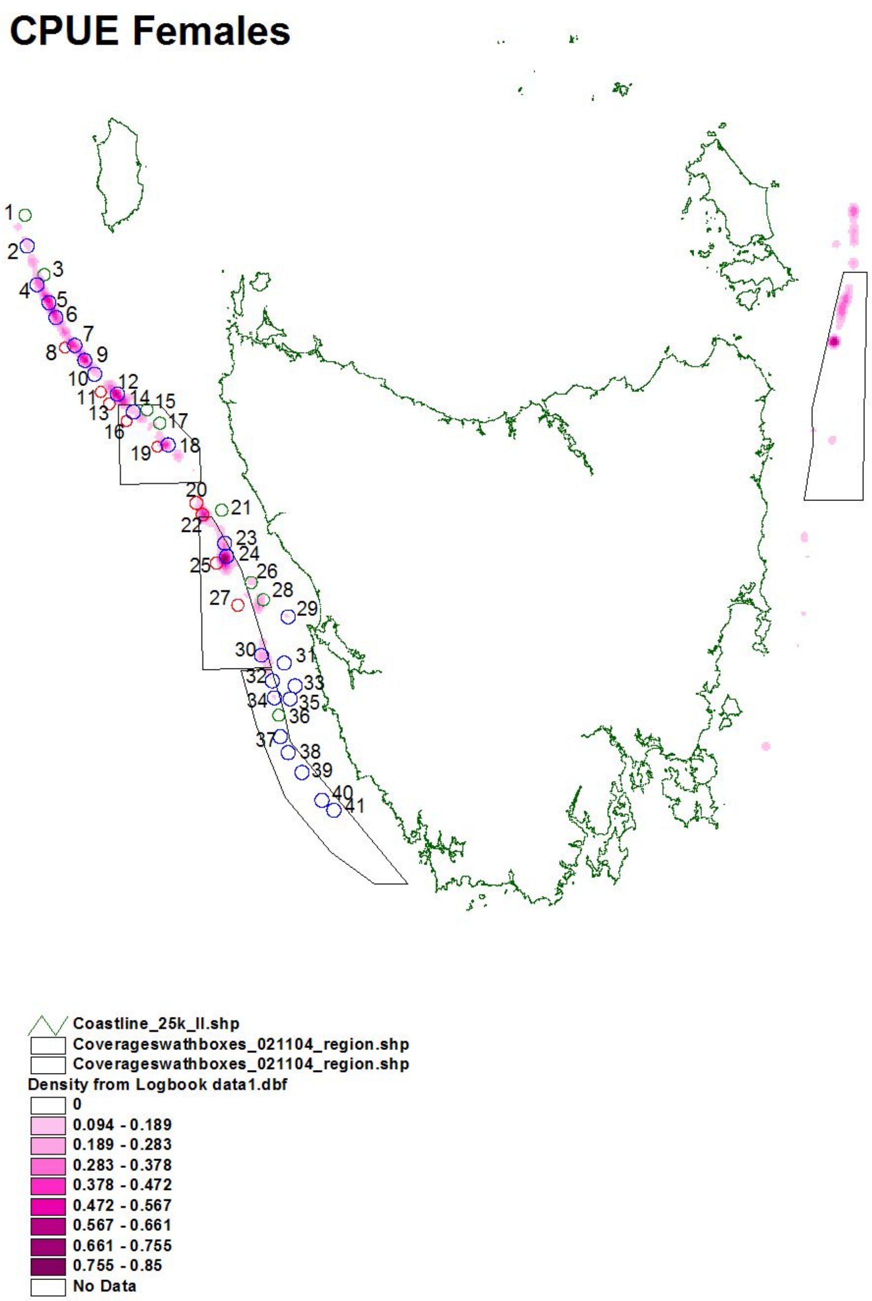


Figure 7.3.1.2 Density of female giant crabs using CPUE as a proxy shown by pink shaded regions. Boxes marked are those areas targeted in swath mapping surveys conducted for this project. Circles indicate locations with specific attributes targeted as possible research sites for video transects.

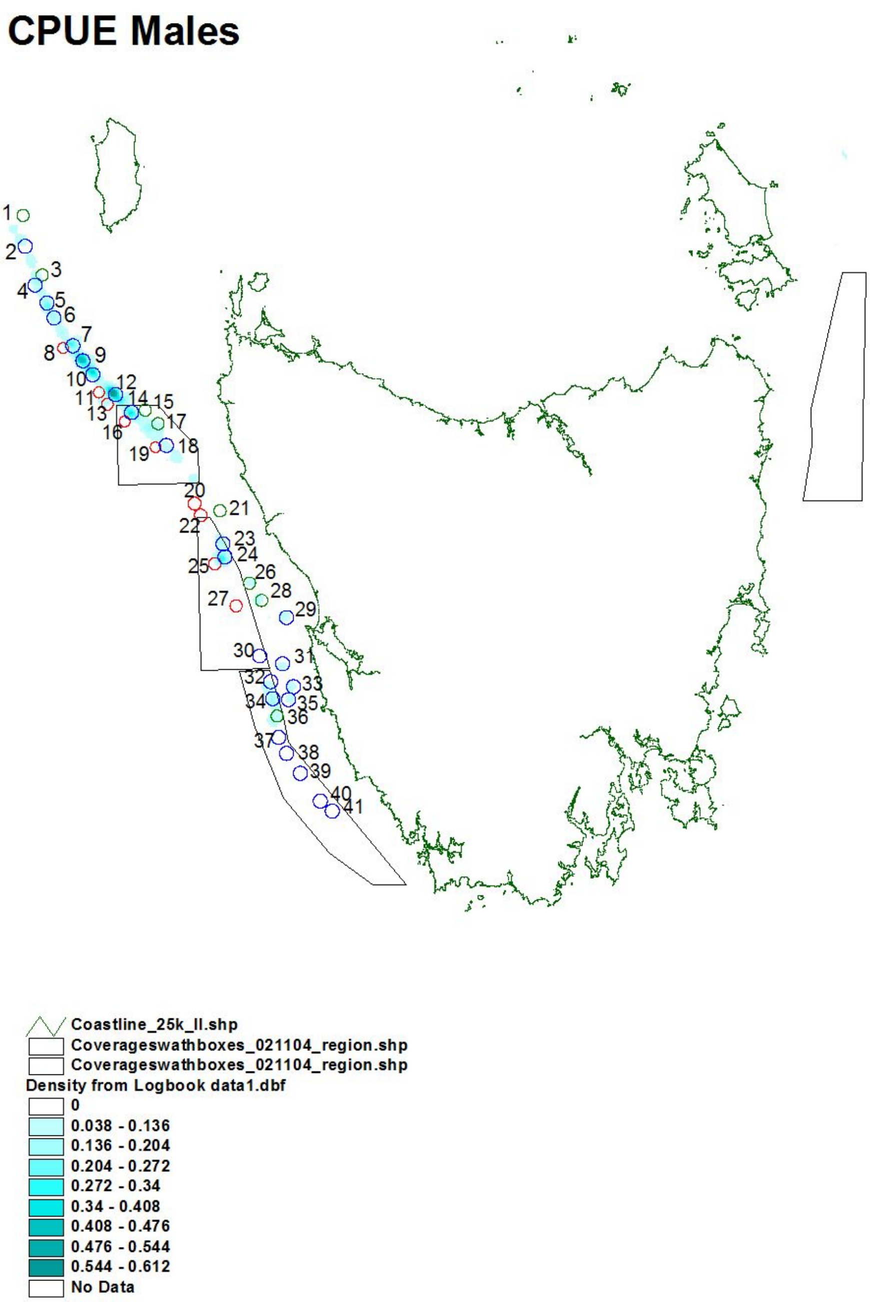


Figure 7.3.1.3 Density of male giant crabs using CPUE as a proxy shown by blue shaded regions. Boxes marked are those areas targeted in swath mapping surveys conducted for this project. Circles indicate locations with specific attributes targeted as possible research sites for video transects.

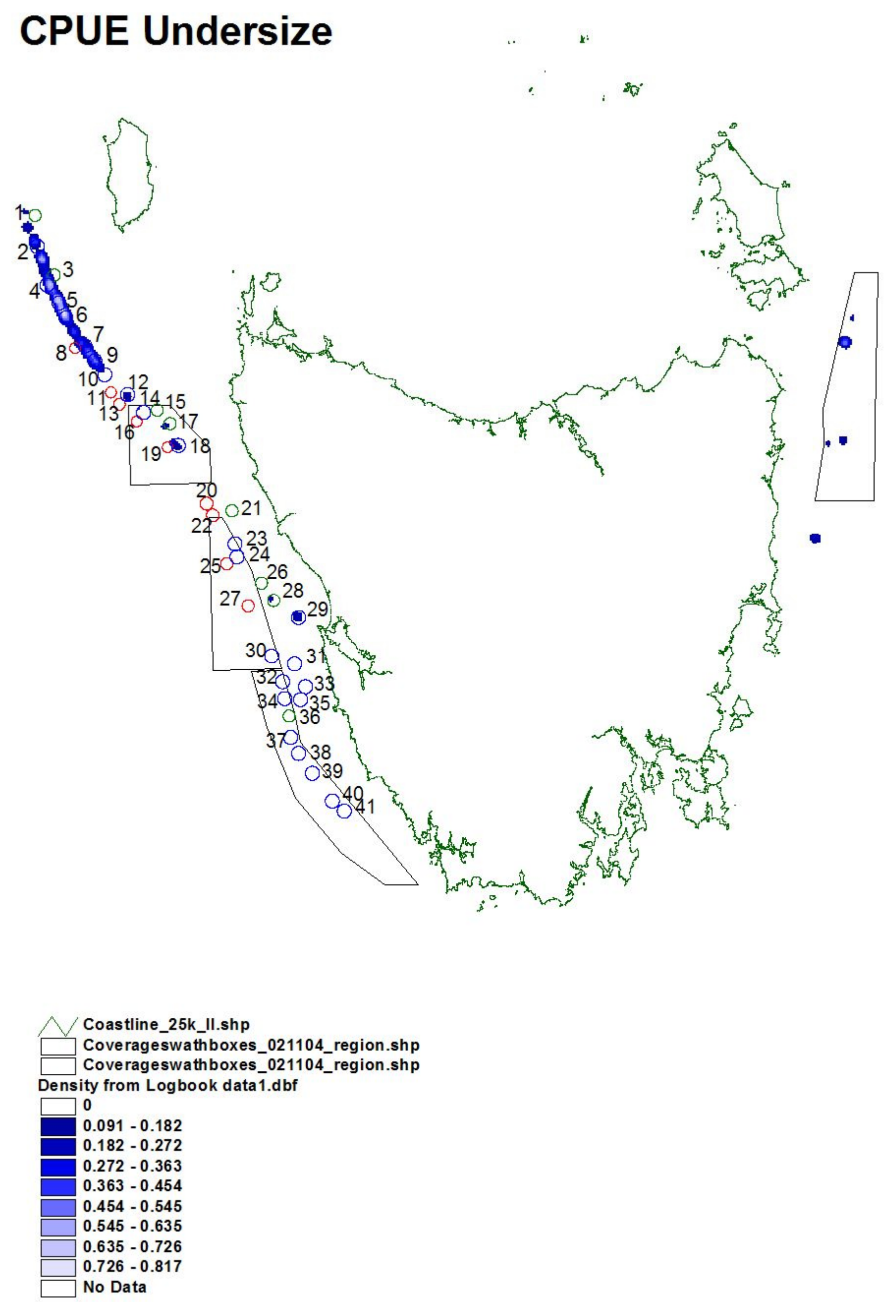


Figure 7.3.1.4 Density of undersize giant crabs using CPUE as a proxy shown by blue shaded regions. Boxes marked are those areas targeted in swath mapping surveys conducted for this project. Circles indicate locations with specific attributes targeted as possible research sites for video transects.

Fine scale distribution

Giant crab sightings by video were mapped in conjunction with habitat scores and this indicated that crabs were most often found on habitat boundaries between the bryozoan turf/thicket zone and less structured seabed. This pattern can be seen in many of the images in Section 7.1.4 where crabs were seen burrowing or digging in unconsolidated substrate adjacent to bryozoan turf/thicket habitat. The greatest number of crab observations was from the King Island site (Figure 7.3.1.5). There appeared to be some link between crab distribution and canyons at this site. The canyon areas in this site typically had bryozoan turf giving way to unconsolidated sediment in deeper areas with occasional rock outcrops.

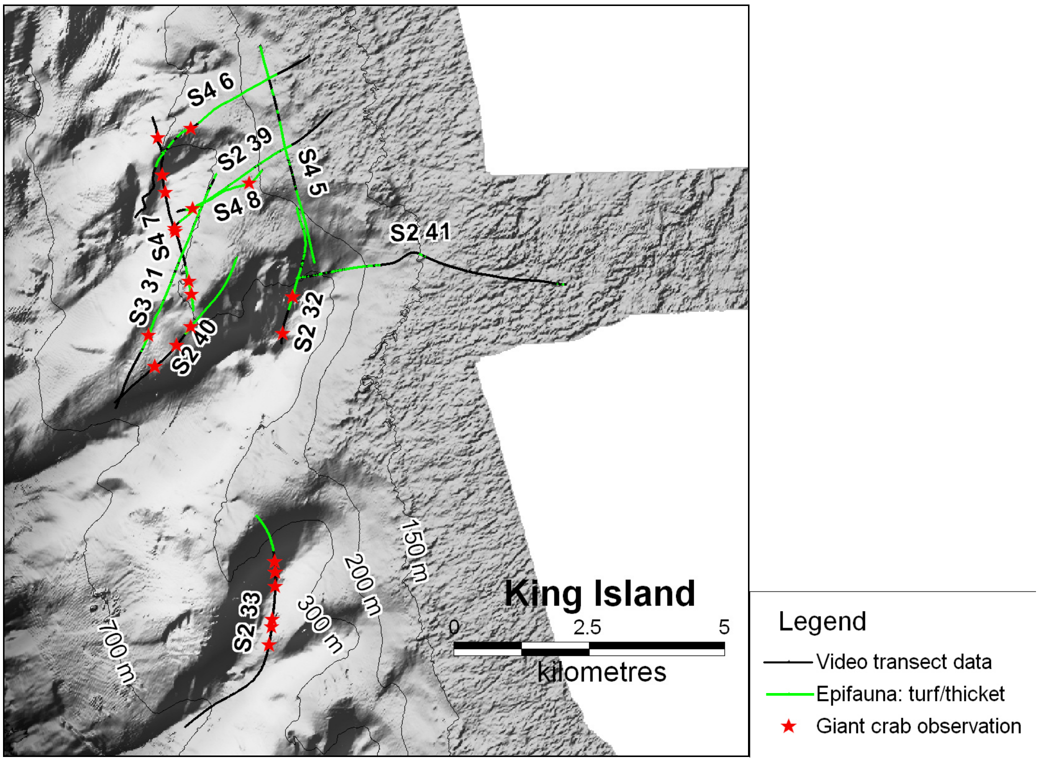


Figure 7.3.1.5 Distribution of giant crab observations in videos in relation to bryozoan turf/ thicket epifauna at King Island

7.3.2 Commercial fish species

Broad-scale distribution

The distribution of catch of commercial fish species was determined from commercial catch and effort logbook data. The aim was to identify regions of importance for commercial species in relation to benthic habitat so analyses were restricted to species associated with benthic habitat: flathead, morwong and ling. Data were pooled for two separate time-series: 1997-2000 and 2001-2004 for the purpose of showing changes in the fishery.

Catch was grouped into 1 km cells based on averaging along trawl positions. This process was most effective where numerous tracks existed in different orientations. The small scale of the data aggregation means however that we cannot show the mapped data due to confidentiality rules (5-boat rule).

Spatial patterns in catch are apparent from these data. These include the identification of key regions for each species and the range of species distribution. Flathead and morwong catch appeared to occur in similar regions along the west coast of Tasmania (south of Cape Grim), concentrated along the shelf-break zone. The majority of flathead catches were taken between 150 and 170 m depth, morwong between 160 and 180 m (Figure 7.3.2.1). Ling catch tended to be further offshore (> 350 m) (Figure 7.3.2.1) and extended northwards to King Island.

The withheld maps show clearly an increase in catches of flathead and morwong in more recent years (2001-2004 time period), which corresponds to the trawl fishery exploring shallower fishing grounds in that time.

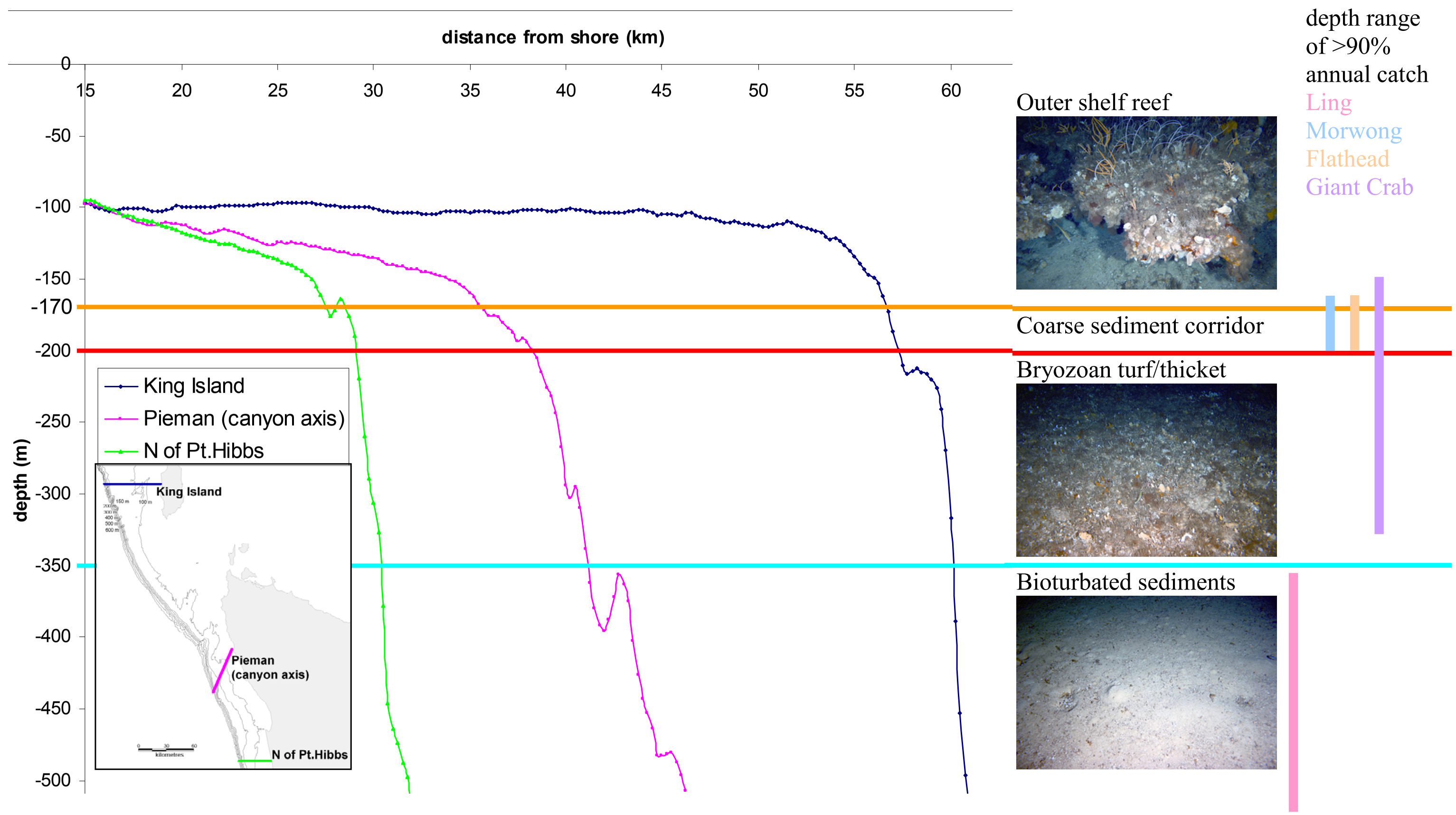
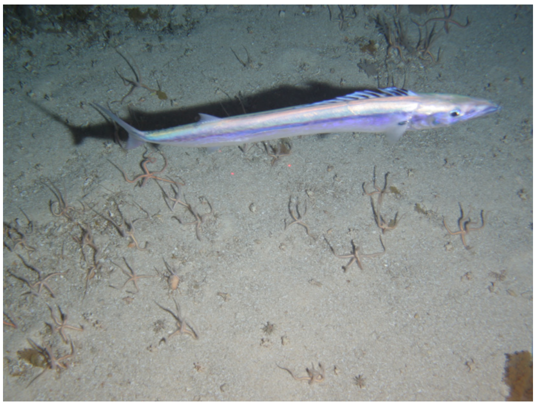


Figure 7.3.2.1 Schematic of the depth profile with distance from shore at three sites on Tasmania's west coast, indicating the main habitat categories identified in video with their associated depth zone. The depth distribution of the majority (90%) of commercial catch of major species is shown at the right in relation to depth and typical habitat category .

Fine-scale distribution

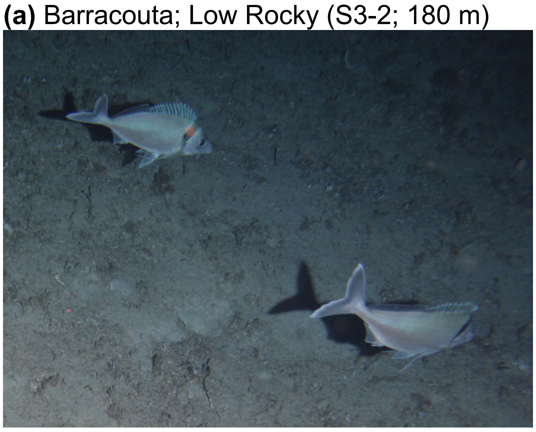
A variety of fish, including flathead, morwong and ling, were observed in videos. However, fish typically avoided the camera platform, probably scared by the bright lights and noise of the camera system. Thus fish observations were limited; in addition, it was difficult to positively identify species from the short glimpses of fish observed in videos.

Following are a few examples of commercial fish that were photographed during the video transects (Figure 7.3.2.2); while most fish observed were swimming, some were seen using features and fauna for shelter (e.g. Figure 7.3.2.2.b and d).

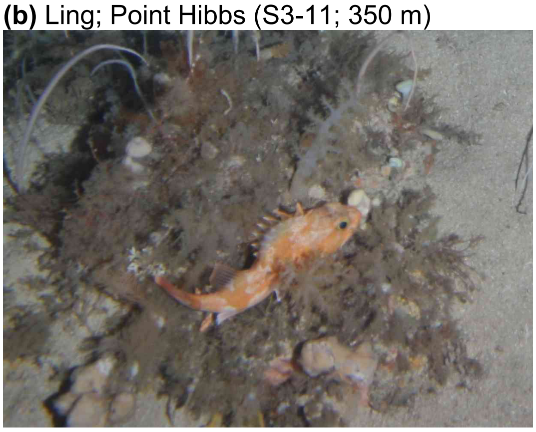


(a) Barracouta; Low Rocky (S3-2; 180 m)

(b) Ling; Point Hibbs (S3-11; 350 m)



(c) Morwong; King Island (S3-31; 333 m)



(d) Ocean perch; Point Hibbs (S3-26; 140 m)

Figure 7.3.2.2 Examples of commercial fish species photographed during video transects

7.3.3 Overlap between fisheries

One of the management issues being discussed prior to the commencement of this project was the extent of change in spatial distribution of fishing effort. Again, the small scale of the data aggregation means however that we are unable to show the mapped data due to confidentiality rules (5-boat rule).

Thematic maps of temporal change in the spatial distribution of fishing effort were constructed from the 1 km cell data discussed above (Section 7.3.2). This effort was restricted to benthic trawling, based on catch composition. Temporal change was readily apparent with a reduction in effort in some areas, and an increase in others. Broad trends were that there was a general decline in effort in deep water, especially off the mid west of Tasmania. Increases in effort occurred on higher slope habitats. A general increase in effort at all depths was apparent in far northern (off King Island) and far south (south of Strahan) areas.

7.4 Evaluate ecosystem links within habitats based on trophic, temperature and current-flow data

7.4.1 Trophic connections

One key ecosystem link between giant crabs and their benthic habitat is through trophic connections. Here we examined the distribution and habitat associations of prospective prey to assess whether vulnerable habitat provided an identifiable value to giant crabs.

Knowledge of the diet of giant crabs is limited. Heeren and Mitchell (1997) and Levings et al (2001) analysed and described stomach contents of wild caught giant crabs, but they had data for only 22 individuals (10 females and 12 males). Prey was mainly two species of gastropods, a single species of asteroid and a variety of decapod crabs, including hermit crabs, spider crabs and other giant crabs. Carrion was also observed, but formed only a minor component of the diet.

Two species of gastropods appeared to be present in giant crab diets, one identified by white shell fragments, and the other by flat brown opercula; they occurred separately and together in crab stomachs (Heeren and Mitchell, 1997). Gastropods were difficult to spot in our photographic images, but volute and spindleshells were observed (Figure 7.4.1.1) most often because of their relatively large size. Both are large, thick-shelled, carnivorous species; the former has a smooth, creamy coloured shell, no operculum, and is a relatively fast, active predator; the latter has a white to brown ornate shell, a brown, flat, comma-shaped operculum, and is a slow moving scavenger/predator (K. Gowlett-Holmes pers. com.). Spindleshells are probably more vulnerable to giant crab predation than volutes because they are slower with thinner shells. These species appear to be broadly distributed on sediments: in shallow waters Edgar (1997) reported spindle shells being observed on soft sediments near reef or other structured habitat, while volutes generally remain buried in sand during the day and forage on the sediments during the night.

The asteroids found in stomach samples were not described further by Heeren and Mitchell (1997), however they concluded from the ossicles and plates that only one species was found. We distinguished several types of Asteroidea (some of which may involve several species) in imagery from our sampling sites (Figure 7.4.1.1). Their total of 515 observations in our videos showed they were present on structured and unstructured sediment habitats, mostly on bare or bioturbated sediments (49%), with (34%) on turf/ thicket.

A variety of decapods were observed in imagery. Among the crab species, the most likely prey items for giant crabs are hermit crabs, such as *Strigopagurus sp.* (Figure 7.4.1.1) and the antlered crab *Dagnaudus petterdi* (Figure 7.4.1.1), which can easily be mistaken for a spider crab, especially if only fragments such as legs are observed. In addition, true spider crabs, squatlobsters (Galatheidae) and *Carcinoplax spp.* were seen (Figure 7.4.1.1).

Most of these crabs were mainly observed in photographs, being too cryptic for detection in the video. They used ledges and epifauna for sheltering in structured habitats and burrows in open/bare sediments. The exceptions to this were the antlered crabs and squat-lobsters. Antlered crabs were seen singly as well as in small groups, actively moving about in unstructured sediment areas (Section 7.1.4). Of the 391 observations in videos, they were mostly observed on bare or bioturbated sediments (43%) and in the matrix of coarse detritus with residual fauna (30%). They were equally distributed over low/encrusting fauna and turf/thicket ~ 13% of observations each.

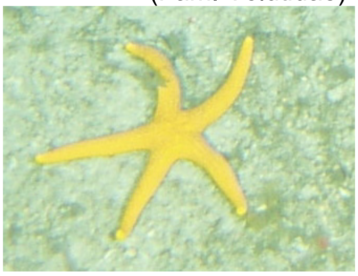
Squat-lobsters, on the other hand, were often seen in video retreating to shelter under structural fauna in dense bryozoan habitats, or more rarely to burrows in open sediments as the camera approached. They were fast moving, which presumably reduces the risk of predation from giant crabs. Of the 238 observations in videos, most were seen on turf/thicket (50% – 28% turf, 22% thicket). They were more or less evenly distributed over the other epifauna types: 18% low / encrusting, 16% matrix of coarse detritus with residual fauna, 16% no epifauna.

Another potential prey group, based on their size and high abundance, are ophiuroids. Large aggregations, either mobile on the seafloor or semi-buried in otherwise bare sediments (see fine scale score of 'mattress-like'), were observed in many locations. Aggregations of ophiuroid that were not buried were observed in 210-250 m at Pieman, 150-180 m at Low Rocky with the longest patches on the along depth transect at 165-170 m, and long patches in 160-210 m at the Southwest Cape site. On the east coast of Tasmania similar ophiuroid aggregations were observed much shallower (<140 m) off St Helens. Dr. T. O'Hara (MoV) noted that "We have large collections from the shelf break indicating that *Ophiothrix aristulata* (which is one of the possible species observed here) does occur in numbers in certain places. It is a mobile filter feeder. A congeneric species *Ophiothrix fragilis* is known to aggregate like this in Europe, sometimes at far higher densities."

In the video and stills image footage we recognised carrion only in very few instances. At Pieman we saw the skeleton of a seal, and at Low Rocky we observed what appeared to be a ribbonfish carcass covered with small pagurid crabs (Table 7.2.4.1). It seems probable that carrion would be doubly attractive to giant crabs by providing an easy meal and by concentrating natural prey. Trawl discard provides a source of carrion in this system, and would be expected to be most common around the main trawl grounds at Pieman and the Ling Hole, especially along the adjacent sediment terraces to the north and south where tows are finished.

Gastropoda: volute
(Fam. Volutidae)

Gastropoda: spindleshell
(Sub-fam.: Fasciolariinae)

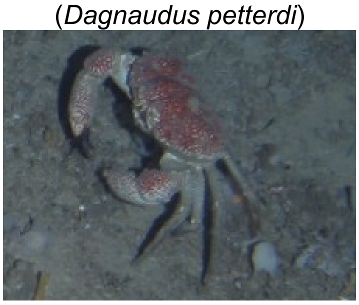


Asteroidea: selection of starfish

Decapoda: hermit crab
(*Strigopagurus sp.*)

Decapoda: antlered crab
(*Dagnaudus petterdi*)

Decapoda: spider crab
(*Leptomithrax* sp.)



Decapoda: giant crab
(*Pseudocarcinus gigas*)

Decapoda: squatlobster
(Fam. Galatheidae)

Decapoda: *Carcinoplax sp*

Figure 7.4.1.1 Examples of identified and potential prey of the giant crab *Pseudocarcinus gigas*

In conclusion, the collective distributions of prey (and inferred prey) groups of the giant crab, do not show a strong association with the structured and vulnerable bryozoan habitat occurring in the interaction area. It was clear from still imagery and a small number of physical samples that a myriad of mobile crustaceans, molluscs, echinoderms and fishes live in the structured and vulnerable bryozoan habitat occurring in the interaction area. However, all of these were also observed, together with juvenile *P. gigas* and/or *Carcinoplax sp*, in areas with less dense epifaunal cover (low/encrusting fauna or residual fauna in a matrix of coarse detritus). Thus, we can provide no evidence that degradation of bryozoan habitat is directly detrimental to giant crabs based on loss of habitat for their prey. Conversely, the deposition of carrion on to the seabed from the discarded component of trawl catches may provide an additional food source.

7.4.2 Physical Oceanography – temperatures and currents

Modelled data

The seasonal circulation around Tasmania at the surface "*displays a very different character off the east and west coasts. Off the east coast the variability is generated externally, being dominated by the western boundary dynamics of the East Australian current (EAC). In the west it is weaker and arises from the seasonal rise and fall of coastal sealevel due to the seasonal reversing wind pattern*" (Ridgway 2007). This leads to distinctive and different summer and winter patterns in the surface circulation on the east and west coast. On the east coast warm, saline water is advected polewards during summer (Jan-Mar), followed by a seasonal reversal of this flow in winter with cool fresh, modified subantarctic surface waters drawn up from the south (Ridgway 2007). The Zeehan current on Tasmania's west coast is strongest in winter when it projects warm, saline waters southward along the coast, and around the southern tip of Tasmania (Ridgway 2007).

The patterns described above are related to the surface waters. However, are these patterns consistent to the depths occupied by giant crabs? Levings et al. (2001) describes the oceanic climate on Tasmania's west coast: "*in general seafloor temperatures are cooler in summer due to upwelling, and warmer in winter due to downwelling and deep mixing*".

K. Ridgway provided modelled outputs from Bluelink of monthly temperature and dominant current patterns along Tasmania's west coast at four depths, 150 m, 200 m, 485 m and 685 m (Figure 7.4.2.1 to

Figure 7.4.2.4). Patterns at 150 m and 200 m depth are consistent with the general surface patterns described above. The Zeehan current showed strongest flow along the continental slope of western Tasmania in late autumn and winter (Apr-Aug), resulting in advection of warmer waters (14ºC or more) southwards. At 485 m and 685 m depth the currents are much weaker along the continental slope and, due to an eddy formation seaward off Strahan currents even reversed direction to northwards in late winter, early spring (July-Oct). Temperatures are lower at these depths (note the different scales between Figure 7.4.2.1 & Figure 7.4.2.2, Figure 7.4.2.3, and

Figure 7.4.2.4) still, the overall pattern of warmer waters in winter and cooler in summer are consistent even to 685 m depth.

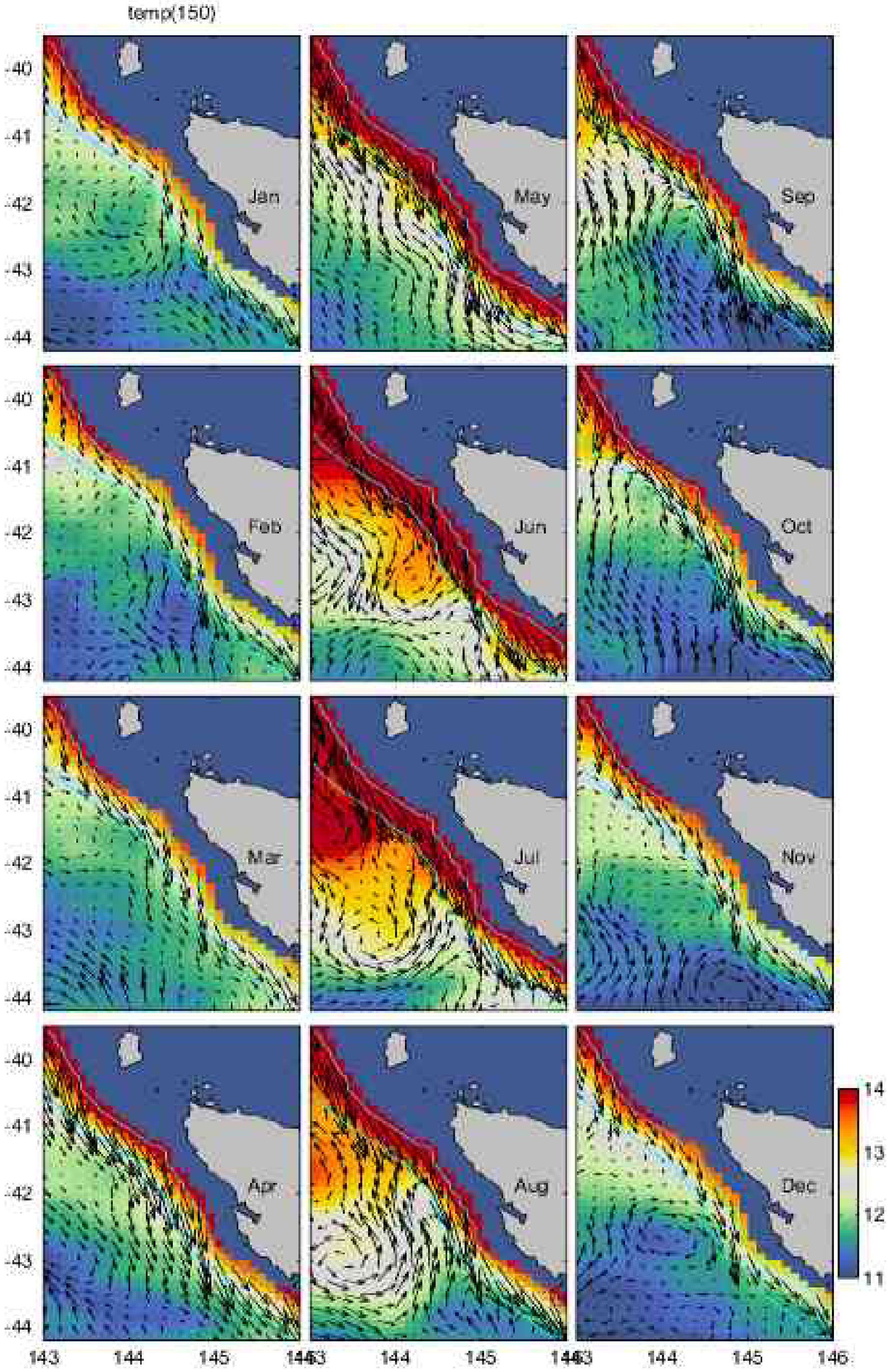


Figure 7.4.2.1 Model output from Bluelink showing monthly temperatures and current strength and direction at 150 m depth.

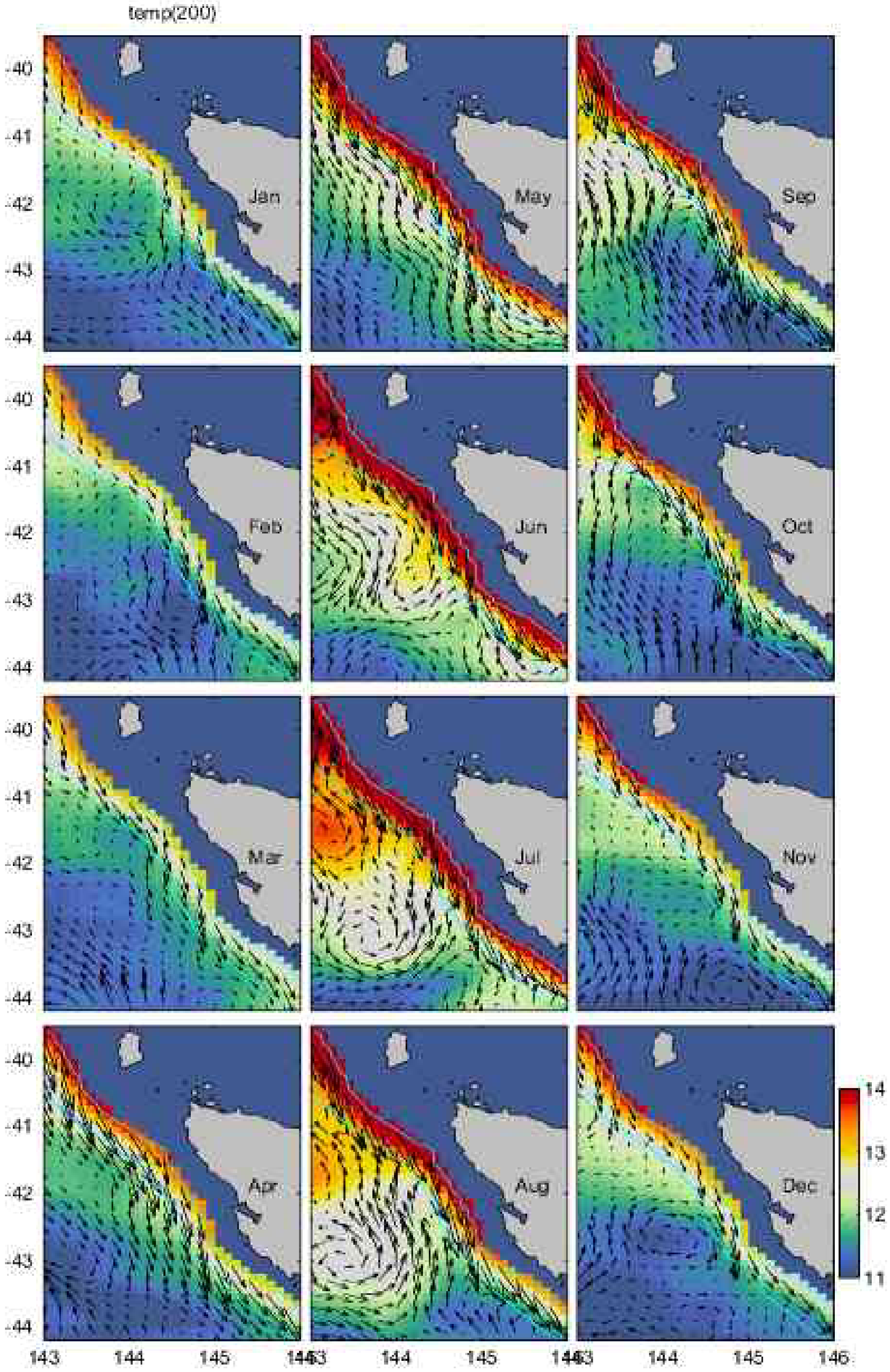


Figure 7.4.2.2 Model output from Bluelink showing monthly temperatures and current strength and direction at 200 m depth.

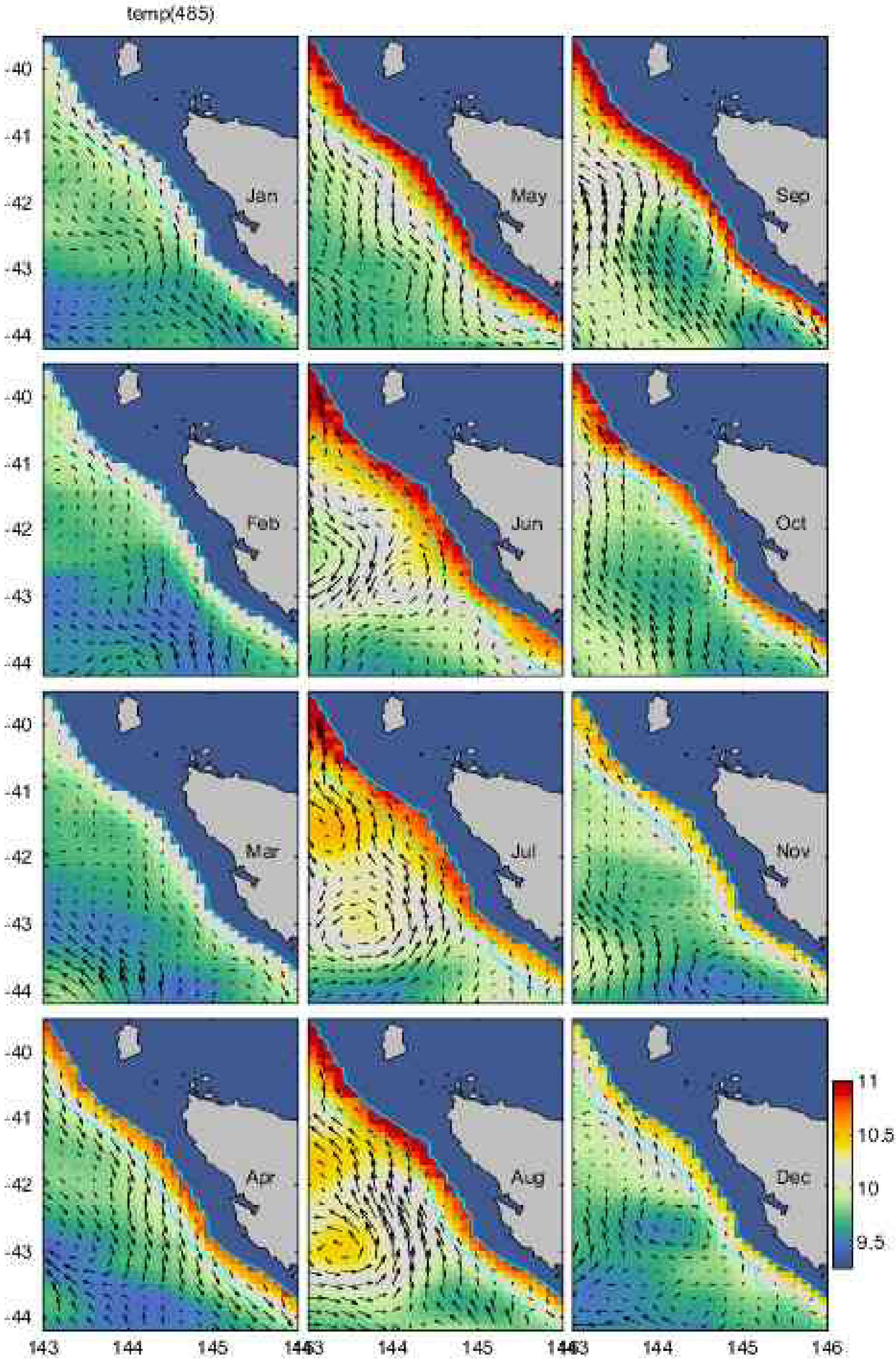


Figure 7.4.2.3 Model output from Bluelink showing monthly temperatures and current strength and direction at 485 m depth.

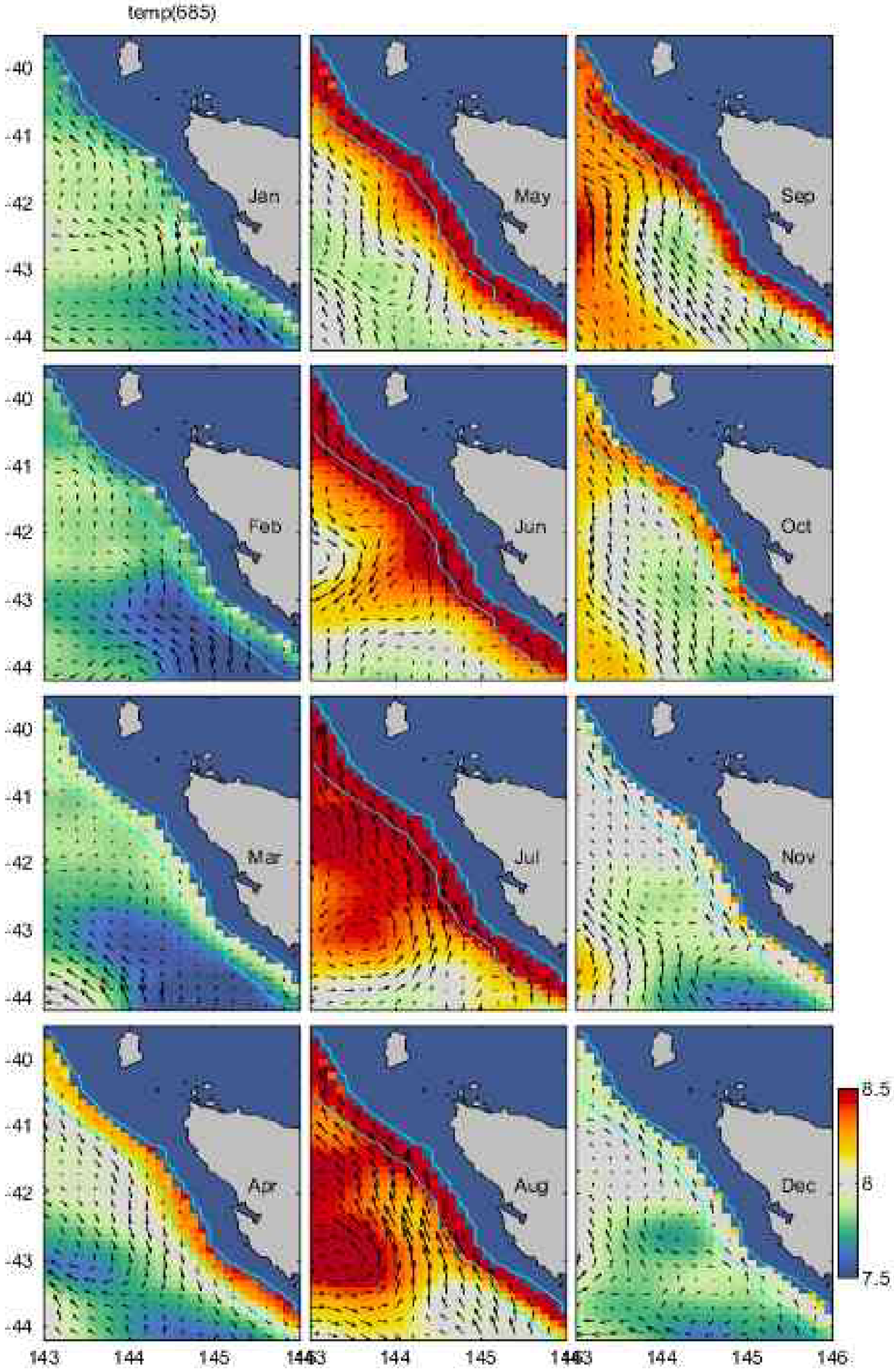


Figure 7.4.2.4 Model output from Bluelink showing monthly temperatures and current strength and direction at 685 m depth.

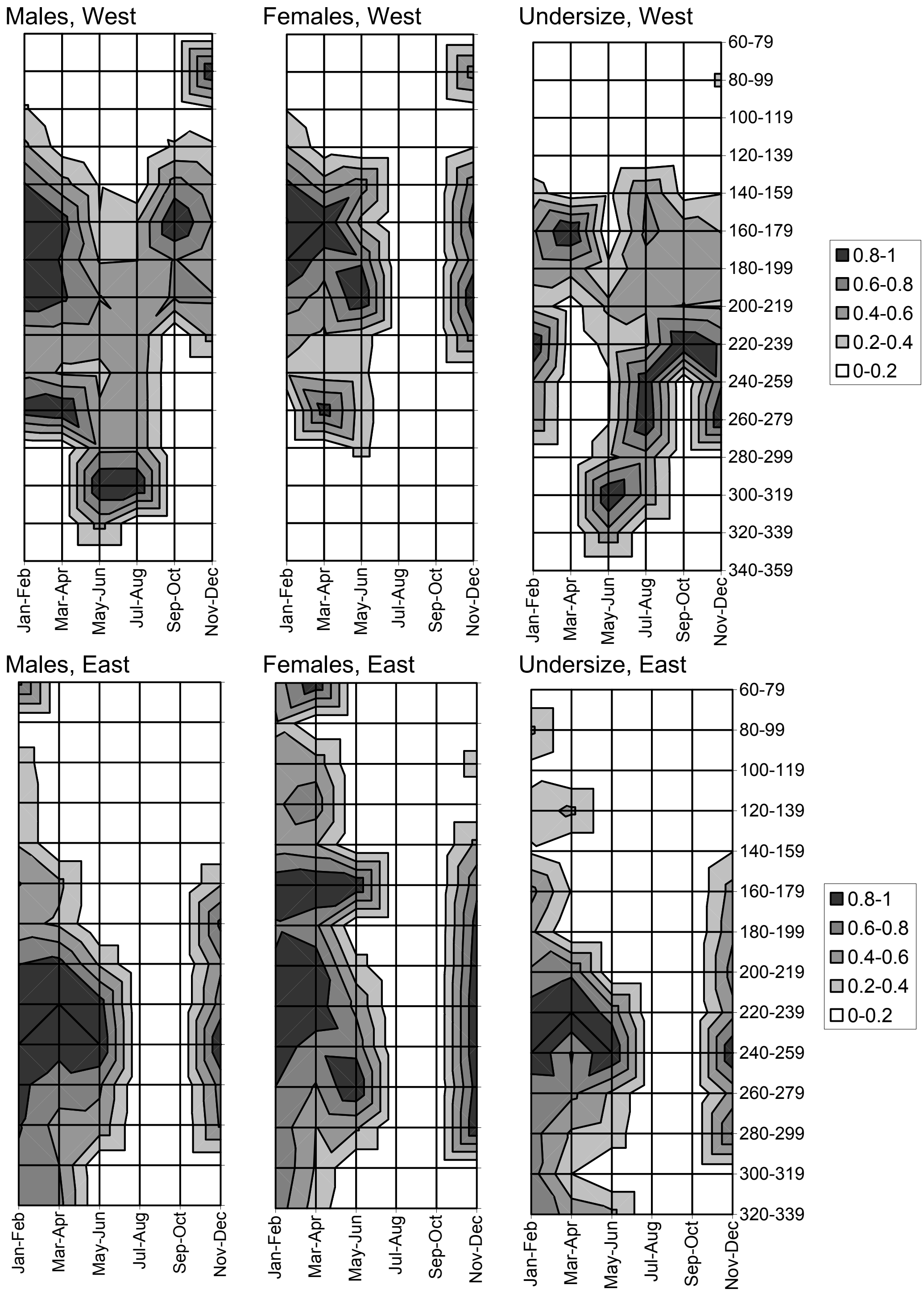


Figure 7.4.2.5 Seasonal patterns in catch rate of giant crab with depth (m). Data were pooled from 2000 to 2007 into 2 monthly bins with 20 m depth intervals and cells with less than 50 crabs were excluded. Catch rates were scaled to the maximum catch rate observed for any depth for that time period.

The depth distribution of giant crabs inferred from CPUE data illustrates that the depth range of crabs on both the east and west coasts of Tasmania is mainly between 150 and 300 m and thus centred on the bryozoan turf habitat as discussed in preceding chapters (also see Figure 7.3.2.1).

Data from eastern Tasmania are too sparse to infer seasonal patterns in depth distribution of crabs, however, patterns in CPUE of male and undersize crabs from western Tasmania are consistent with movement to deeper water in winter and shallower water in summer. This pattern may be driven by the seasonal patterns in water temperature with crabs moving to deeper water in response to warmer water in winter. Levings et al. (2001) termed this behaviour “nomadism in a thermal” niche and similar behaviour has been observed in other species of crabs inhabiting similar depths (e.g. *Chionoecetes opilio*, Ernst et al., 2005).

7.4.3 Regional patterns in recruitment and habitat linkages

The most distinctive spatial pattern observed in giant crab through analyses for Section 7.3 was the concentration of undersize crabs along the NW region of Tasmania. This observation begs the question of whether this hot-spot of undersize abundance is a function of habitat / environmental traits of the region or of larval supply.

Larval supply to regions around Tasmania were investigated using “Connie” or the Australian Connectivity Interface (Condie et al., 2005). This software enables simulation of larval dispersal and identification of likely larval sinks.

Model runs were conducted to simulate the dispersal of giant crab larvae for each year from 1995 to 1999 (i.e. a total of five dispersal seasons). Larval release was simulated to occur in October, the peak of normal larval release (Gardner, 2001). Larval duration was limited to 20 days, a function of the modelling constraints of Connie, noting that this is only around 2/3 of the typical larval duration (Gardner and Quintana, 1998). The depth of ocean current movement simulated by Connie is essentially surface layers (20 m) which is consistent with behavioural and plankton observations of *P. gigas* larvae (Gardner 1996, Gardner 1998a).

Results from simulations to determine the source of larvae settling in the NW indicted that sources were widespread although mainly from western Tasmania rather than the east coast (Figure 7.4.3.1).

Simulations to examine the sinks of larvae released at different sources around Tasmania indicated that larval drift was generally northwards towards north western Tasmania (Figure 7.4.3.2). This was the case for most releases on western Tasmania and also those from the SE. Thus patterns in larval drift alone appear sufficient to explain the concentration of undersize crabs in the NW region.

Observations on habitat in this NW region did not identify any traits that would explain the greater abundance of juvenile crabs in this region (Section 7.1) with apparently consistent habitat with depth down the west coast of Tasmania. It is also important to note that the critical depth and thus habitat for juvenile crabs appears to be same as for adult, based on reported catch rates of undersize crabs by the commercial sector (Section 7.4.2).

Observations reported in this section indicate the potential importance of bryozoan turf habitats in the NW region to the crab fishery. This region appears to be an important location for future recruitment to the fishery, based on both observed distribution of undersize crabs around the Tasmanian coast, and also larval dispersal simulation.

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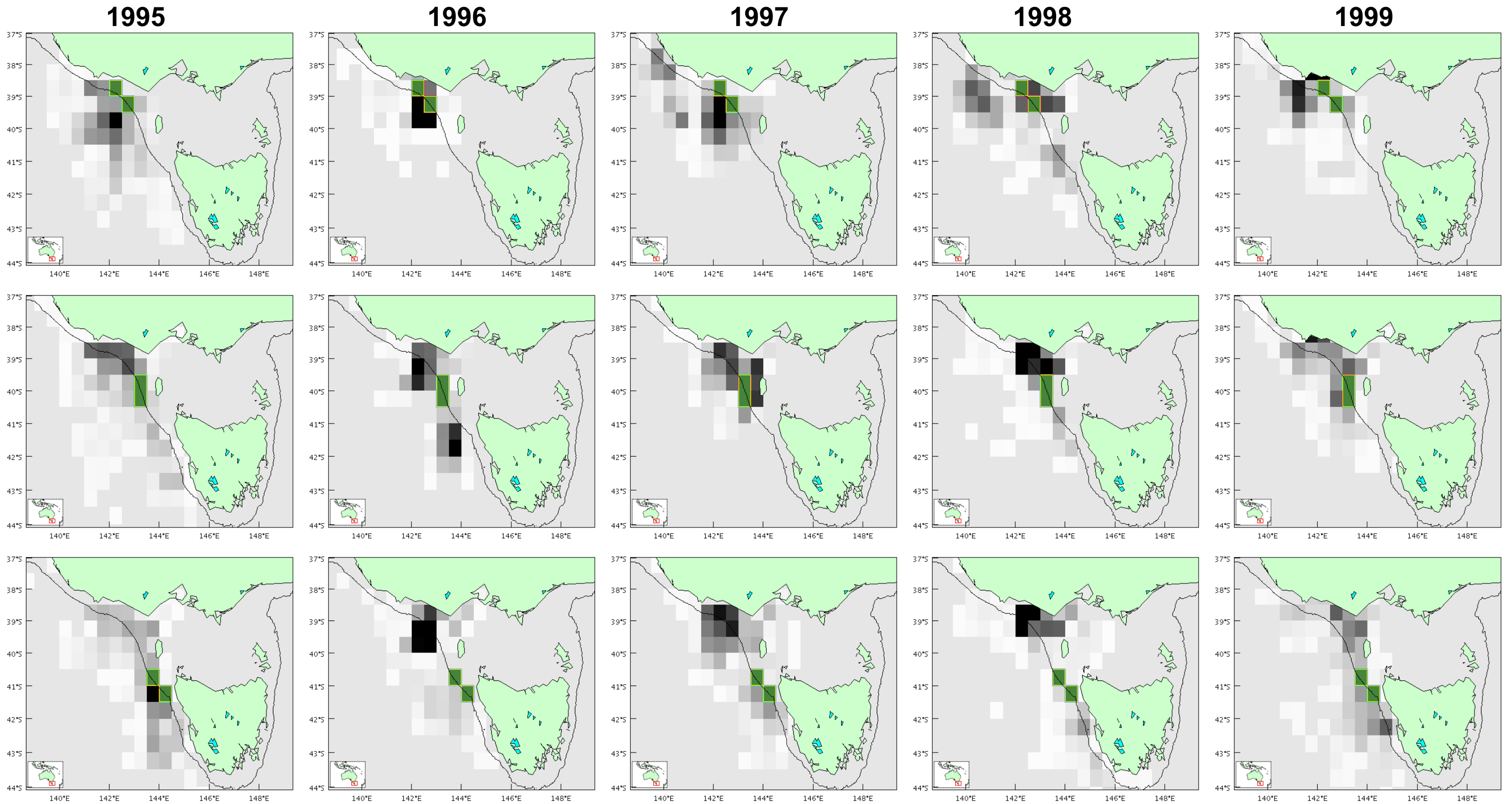


Figure 7.4.3.1 (pg 1/3) Simulation of giant crab larval advection for different years and various larval release locations around Tasmania. Sites of larval release are indicated by green cells, probability of larval distribution by grey cells with darker tones indicating increased probability of occurrence. Larval release in simulations occurred in October with larval duration lasting 20 days

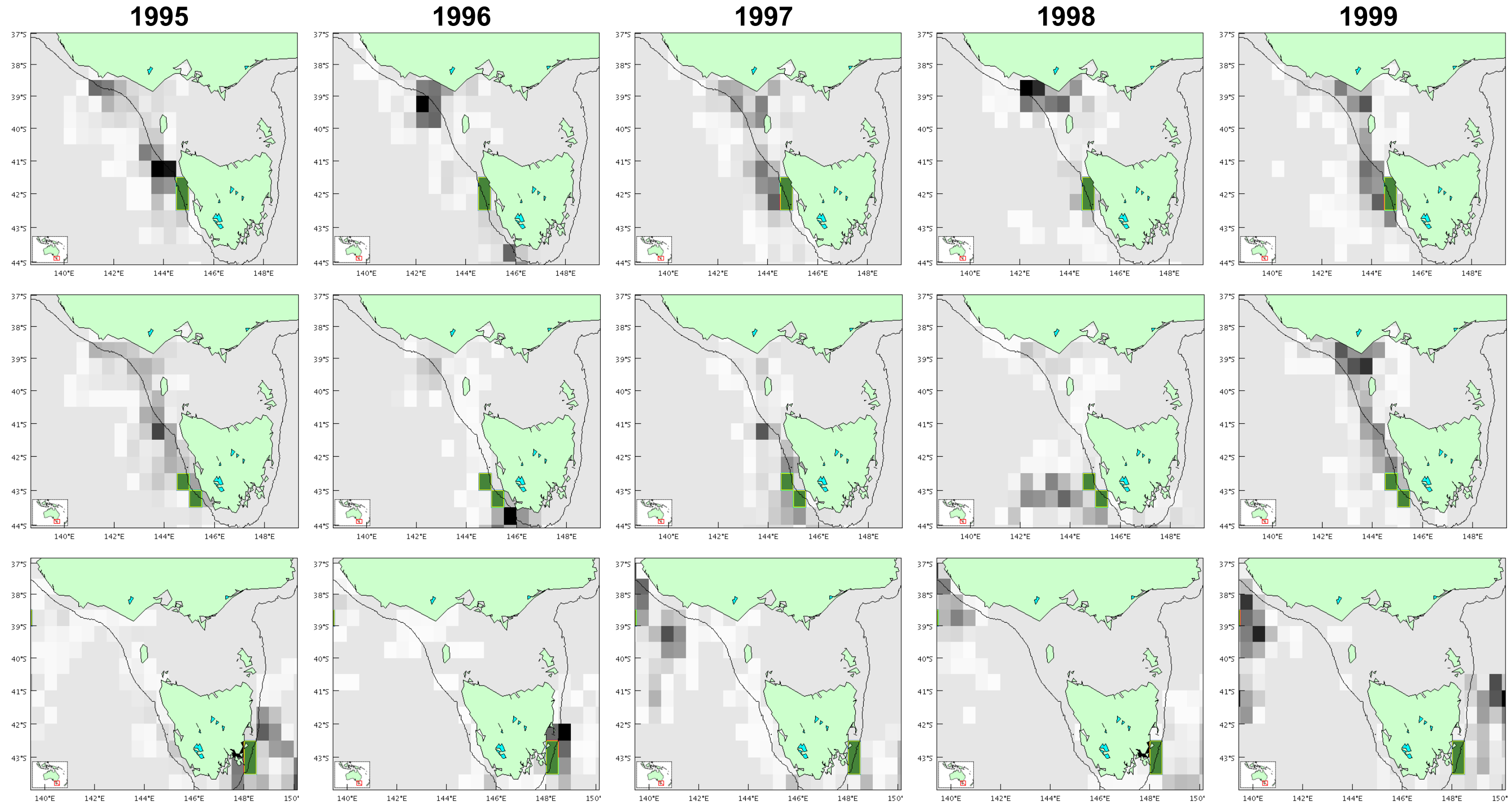


Figure 7.4.3.1 (pg 2/3) Simulation of giant crab larval advection for different years and various larval release locations around Tasmania. Sites of larval release are indicated by green cells, probability of larval distribution by grey cells with darker tones indicating increased probability of occurrence. Larval release in simulations occurred in October with larval duration lasting 20 days

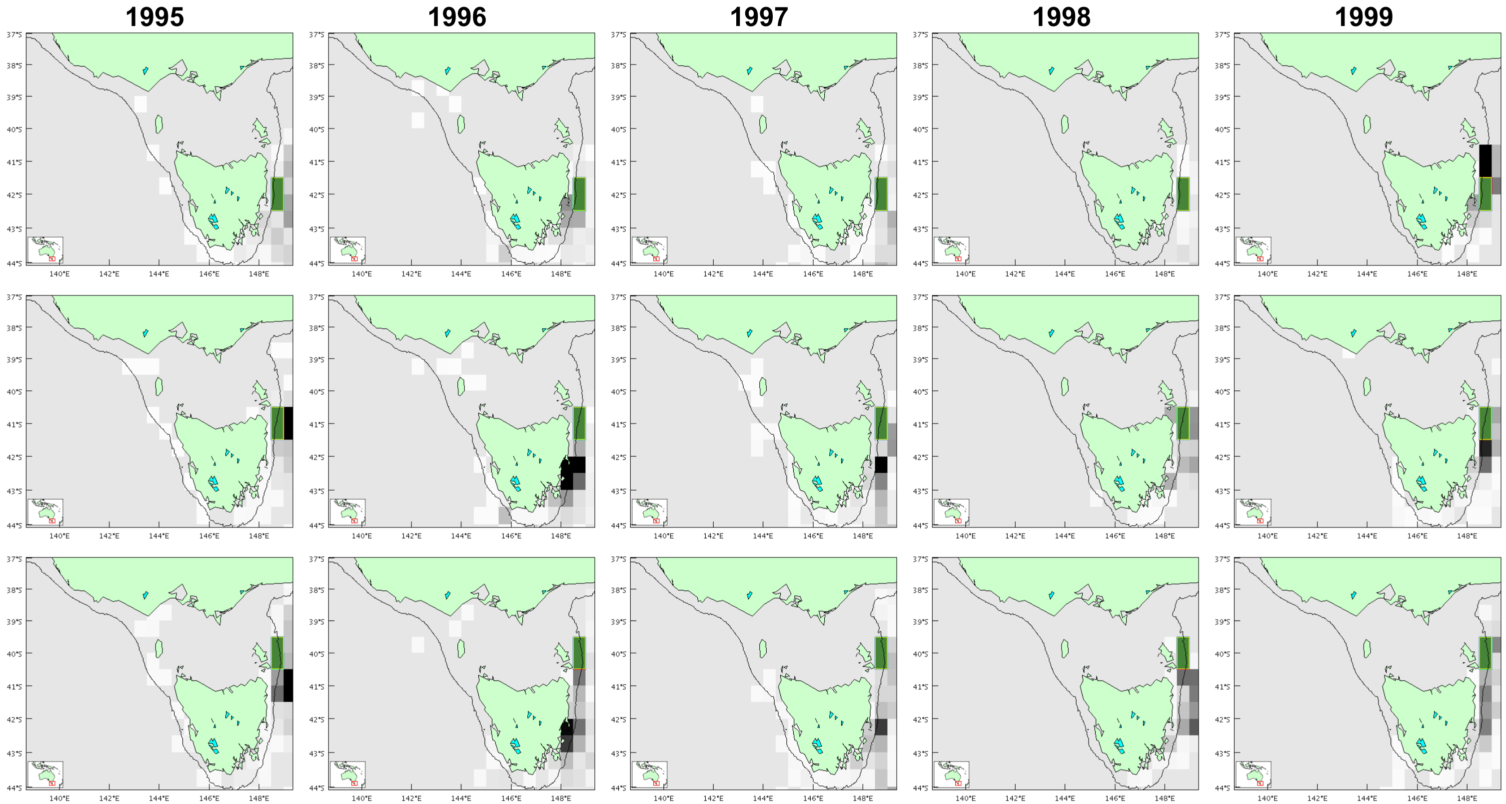


Figure 7.4.3.1 (pg 3/3) Simulation of giant crab larval advection for different years and various larval release locations around Tasmania. Sites of larval release are indicated by green cells, probability of larval distribution by grey cells with darker tones indicating increased probability of occurrence. Larval release in simulations occurred in October with larval duration lasting 20 days

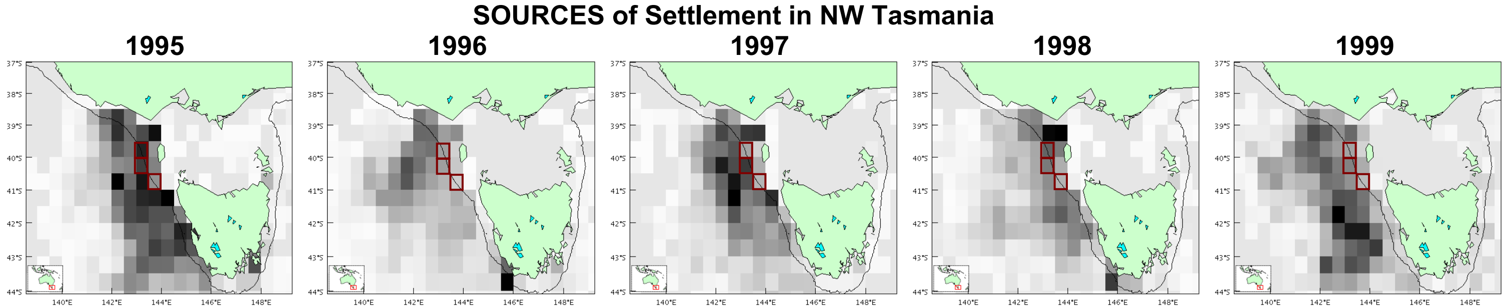


Figure 7.4.3.2. Simulation of giant crab larval sources that contribute to settlement in NW Tasmania. This is the region where observed abundances of juvenile crabs is especially high. Larval source appears to vary from year to year and is widely distributed along western Tasmania and Victoria. Sites of larval release are indicated by grey cells, cells with increased contribution indicated by darker shades of grey. Larval settlement sites in NW Tasmania indicated by red boxes. Larval release in simulations occurred in October with larval duration lasting 20 days.

7.4.4 Discussion: ecosystem links between giant crabs and benthic habitat

The outer margin of the continental shelf and the shallow continental slope around Tasmania harbours diverse communities that are consistent with depth. This project focussed on the shelf-break zone, which was found to be dominated by bryozoan communities that formed a stable matrix enabling other sessile epifauna to settle and grow. This habitat had many mobile fauna that are known prey to giant crab including antlered crabs, large gastropods and asteroids.

The giant crabs were generally observed in areas dominated by lower encrusting fauna or bare sediments, on the boundaries of the thick bryozoan habitats. Crabs were observed actively moving over these habitats, perhaps foraging, and also using microhabitat such as ledges or epifauna as shelter. Female crabs were seen around the time of egg extrusion partially buried in unconsolidated sediment, a behaviour that has been observed in tanks (Gardner 1998b) Figure 7.4.4.1.

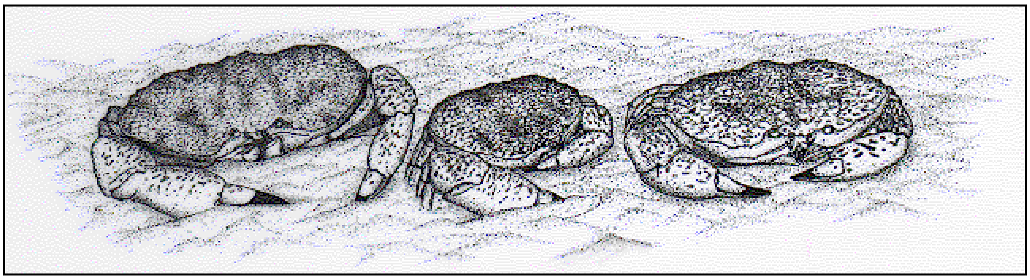


Figure 7.4.4.1 Female giant crabs *Pseudocarcinus gigas* during oviposition with their abdomens buried into pits in the substrate.

Levings et al. (2001) reported that fishers believe giant crabs migrate up and down the slope with consistent patterns across broad regions. They considered that this broad pattern was a function of seasonal movement in response to temperature. That is, the crabs preferentially occupy a thermal niche and that they move shallower and deeper as the temperature boundaries move with the seasonal change in current regime on the continental slope. Our data on change in catch rate of the commercial fishery with depth supports the observation that movement occurs up and down the slope, although patterns are relatively noisy. Regardless of the extent of seasonal movement, it is clear that areas of highest catch rate are centred on the shelf-break around habitats typically classified as bryozoan turf.

The distribution of undersize crabs in commercial catch data is highly regional with greatest catch rates occurring in the NW of Tasmania. Unfortunately, we were unable to compare this trap data with video observations of undersize crabs due to the difficulty in identifying small crabs from video. Although many small crabs that were seen in video, these tended to be partially obscured within burrows or microhabitat, and could not be positively identified as either *P. gigas* or *Carcinoplax* sp.

Habitats in this NW region that appeared important as a recruitment area did not appear to be distinct from habitat in other areas. That is, we were unable to identify a trait of the habitat in this region that could explain the apparently greater abundance of juveniles. However, modelling of larval dispersal predicted that this region would be a larval sink. Thus the apparently higher juvenile abundance in this region appears to be a function of current movement rather than habitat traits. Identification of this region as important to recruitment of giant crabs suggests that this region should receive special attention in any spatial management of the fishery.

7.5 Evaluate the use of video to obtain stock assessment information such as abundance, sex ratio, condition and size of target species, primarily the giant crab

One of the aims of the project was to evaluate the use of the towed video information for stock assessment purposes. A variety of target species were observed in videos, including pink ling, morwong, gemfish and giant crab. Fish species typically fled from the towed camera platform, and thus observations of fish were limited. In contrast, giant crabs typically showed little sign of avoidance, either remaining motionless as the gear approached or rising their chelae in defence as the system approached. In addition, positive identification of moderate to large sized individuals was clear and unambiguous. Thus, we evaluate the giant crab video observation data for its suitability to obtain stock assessment information, such as abundance, sex ratio, condition and size.

Giant crabs were of particular interest because of their high individual value and the use of length-based assessment modelling in their management system. It was anticipated that video information may assist in the following:

a) estimation of density for analysis of seasonal catchability (i.e. to what extent does commercial catch and effort data reflect abundance);
b) condition of crabs on the seafloor and whether incidence of crabs missing limbs is similar to that in commercial trap data;
b) measurement of gear selectivity (i.e. what is the relationship between size structure of crabs on the seafloor and size structure in traps).

7.5.1 Abundance observations of giant crab (*Pseudocarcinus gigas*)

We observed and positively identified 75 giant crabs that could be positively identified in the 77 hours of video collected throughout the surveys. As previously noted, very small crabs could not be distinguished as either *P. gigas* or *Carcinoplax sp.* and thus are not included here. *P. gigas* were observed on all surveys and throughout all depth zones; however, the majority (45%) were seen on survey 4, and as previously noted, 75% of all crabs were observed on the upper slope.

Most crabs (83%) were observed on the north-west coast of Tasmania, north of Strahan, and in particular off King Island (36%) (Table 7.5.1.1). The survey design did not allow for analyses of crab sightings by area or season, as most sites were only visited on one of the four surveys, while others like King Island were visited on multiple surveys, in addition, surveys were conducted at different times of the year (Table 7.5.1.1).

Table 7.5.1.1 Number of giant crabs (*Pseudocarcinus gigas*) observed in videos, by site and survey

Site	survey 1 (Nov 03)	survey 2 (Apr 04)	survey 3 (Nov 04)	survey4 (Apr 05)	Grand Total	% Total
King Is		16	1	10	27	36
West Bass				10	10	13
Cape Grim				5	5	7
Arthur				5	5	7
Ling Hole		3	1	3	7	9
Pieman			8		8	11
Strahan					0	0
Pt Hibbs			2		2	3
High Rocky			1		1	1
Low Rocky			2		2	3
SW Cape				1	1	1
Babel					0	0
Banks Strait N	3				3	4
Banks Strait S	3				3	4
St Helens	1				1	1
Grand Total	7	19	15	34	75	100
% Total	9	25	20	45	100	

Our video-based stock assessment calculations estimated 88 crabs per square kilometre, based on seeing 75 crabs from 77 hours of video, assuming a tow speed of 1.5 knots and transect width of 4 m. Extrapolation of this estimate to the size of the fishery (~6,716 km^2 —150 and 550 m depth excluding South West Cape to Cape Pillar) we obtained a stock of ~589,000 giant crabs. This is around double the number estimated for the 2004/05 period through length based modelling as part of ongoing stock assessments. Both measures are highly sensitive to the minimum size at inclusion in the analysis.

In conclusion, we make the following observations on the use of video sampling for giant crab assessment:

a) the financial cost of sampling effort relative to the number of crabs observed demonstrates that the technique is unsuitable as a tool for regular collection of assessment data;

b) crabs were observed at each of the sites where no fishing effort occurs, thus demonstrating that the entire stock is larger than the fished stock

c) giant crabs are not cryptic and are readily observed by video which implies density estimation is possible using swept-area methods. Density estimates derived from video data would be of value to validate estimates of stock size that are derived from length based modelling based on data derived from trap catches.

7.5.2 Condition of giant crabs observed in video

Damage to giant crabs sampled in catch sampling aboard commercial vessels has been recorded from 2004 to 2007 with 22377 crabs measured off the west coast of Tasmania during this period. The number of crabs missing one or both of their claws was stable at around 6%-7% through this period, much higher than the proportion that would be predicted from video observations where only a single crab of the 75 observed was missing a chelae (Figure 7.5.2.1).

Although the numbers of crabs observed in video surveys are very low, they do not support the hypothesis that crabs missing limbs are under-represented in trap survey data, with no apparent reduction in selectivity through loss of the chelae. On the contrary, they appear to be over-represented in trap data.

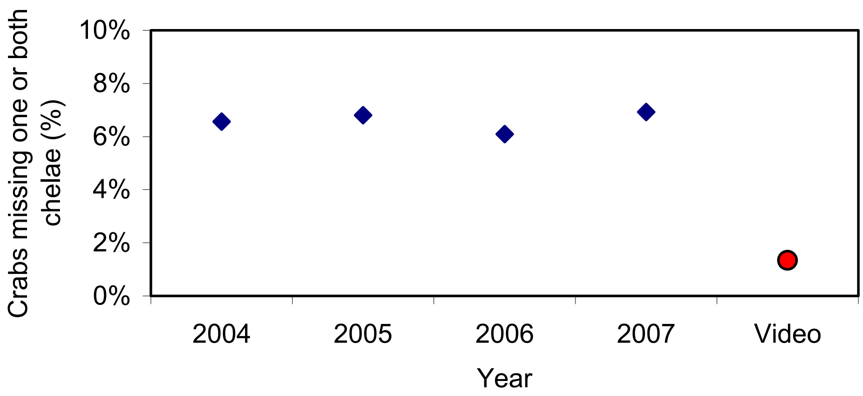


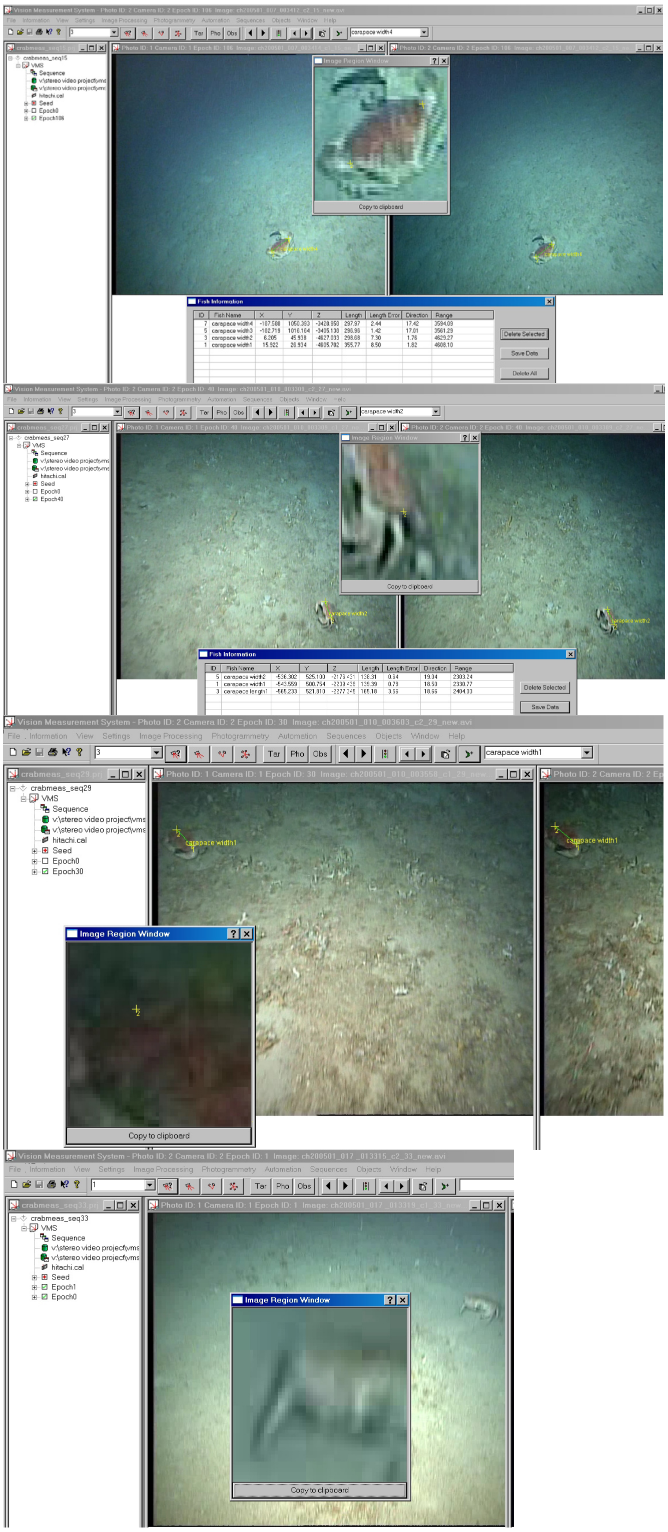
Figure 7.5.2.1 Incidence of crabs missing one or both chelae in trap survey data 2004-2007 (n=22377) and also in video surveys (n=75).

7.5.3 Size measurements from stereo imagery

Stereo video footage was captured on all surveys to enable measurement of targets in three-dimensional space. This system enabled the measurement of giant crabs *in situ* for fisheries research purposes; exploited finfish species could not be measured because of their flight response to the camera system. Calibrations and testing of measurement accuracy were done prior to and during surveys and are described in detail in Appendix 5.

Measurements of giant crabs from video

All 75 positively identified *P.* gigas sightings in video were examined for their suitability for measurements. This sample was reduced to 12 by eliminating observations where measurements could not be collected due to the position of the crab in the field-of-view (i.e. outside the overlap zone of the stereo cameras) or because of poor image quality that became particularly noticeable once magnified (see Figure 7.5.3.1.c). Accurate measurements relied on relatively steady flight of the camera platform at ~2-4 m above the seafloor; blurred images stem mainly from motion transmitted to the camera by vessel heave from swell and this occurred during most of our surveys.



(a)

(b)

(c)

(d)

Figure 7.5.3.1 A series of screen-grab example images from the measurement software to illustrate the problem of edge detection (and therefore ability to accurately measure giant crabs). The examples show (a) best case example with reasonable definition in the zoom box, (b) (c) & (d) average to poor image quality where it is obviously difficult to define the edge of the feature to be measured

Image measurement precision could be quantified by taking consecutive measurements whilst stepping (frame by frame) through an image sequence of the paired stereo video and comparing the measurements in each frame to determine the measurement reliability.

Twelve repeated measurements were taken of a claw length (210 mm) and a carapace width (330 mm) at an average distance of 3.8 m (Table 7.5.3.1). Based on ½ pixel image measurement precision, the estimated precision of these measurements could be estimated, and averaged 32 mm. The actual precision, based on the distribution of the measurements, was 33 mm. Whilst there was good agreement between the estimated and actual precision values, both are marginally worse than the base line expectation from calibration experiments conducted in a swimming pool (see Appendix 5). These results indicate that there is some degradation of precision for image measurements collected at-sea, most probably caused by pixilation in less optimal lighting.

Table 7.5.3.1 Results of consecutive measurements of the carapace width and claw length of a giant crab using VMS. By stepping through the image pair sequence multiple measurements made and compared to determine measurement variability.

#Ident	Object Name		Length (mm)	Precision	Range (mm)	Parallax
11	carapace	width1	299.1	23.1	3654.26	1.30
15	carapace	width1	332.6	38.4	3703.33	3.64
19	carapace	width1	318.8	14.9	3809.41	2.12
3	carapace	width1	390.0	55.0	3671.96	1.79
24	carapace	width1	291.3	5.9	3617.31	3.53
29	carapace	width1	411.1	56.8	3419.41	4.23
7	carapace	width1	320.9	23.6	3756.00	2.75
33	carapace	width1	315.2	38.8	3459.97	4.19
39	carapace	width1	292.4	9.0	3728.26	3.67
55	carapace	width1	318.6	16.9	3885.43	1.66
48	carapace	width1	318.6	34.4	3520.70	3.44
42	carapace	width1	325.9	30.1	3893.92	3.36
		Mean	**327.9**	**28.9**		
		Std Dev	**36.6**			
9	claw	length	262.1	77.0	4023.07	2.02
13	claw	length	218.3	60.1	3949.28	3.61
17	claw	length	181.8	4.1	4041.62	0.11
1	claw	length	184.7	30.2	3989.85	0.24
22	claw	length	198.9	47.9	3801.85	6.69
26	claw	length	214.6	57.9	3652.76	5.74
5	claw	length	243.6	68.4	3929.87	4.09
31	claw	length	205.9	54.2	3660.64	6.49
35	claw	length	265.5	69.4	3732.19	5.38
37	claw	length	202.0	53.4	3917.51	4.94
53	claw	length	211.4	57.0	4021.16	1.09
44	claw	length	171.9	26.7	3774.99	4.05
			213.4	**50.5**		
			30.1			

Analysis

Mean actual precision	33.3
Mean estimated precision	39.7
Ratio	0.84
Actual image precision	3.4
Proportion of pixel size	0.52

7.5.4 Gear selectivity for giant crabs

Of the 75 crabs observed by video, 12 could be measured across the carapace. These measurements of carapace width were converted to carapace length, as used for assessment modelling, by the linear equation:

$$CL = 0.6996CW + 6.3045$$

using carapace length (CL) and carapace width (CW) collected from landed crabs with both sexes pooled as per video samples (n = 82; 58 females, 24 males; $r^2 = 0.94$). Note that the high correlation coefficient is indicative of similar carapace morphology between male and female crabs and implies our approach of pooling sexes was reasonable. This process of conversion from CW to CL was conducted for both mean CW estimates from video and also the lower limit of the CW estimate (i.e. CW estimate – estimated precision).

Length observations collected from trapping surveys off western Tasmania were collected concurrently with the video surveys in both 2004 (n = 4796) and 2005 (n = 5459). As per video observations, these were pooled for both sexes.

A comparison of the distribution of length frequency data from trap and video origin is shown in Figure 7.5.4.1. Although numbers of crabs measured by video are obviously extremely low, data generated from this process is nonetheless interesting. Crabs measured by video tended to be much larger than those recorded through normal trapping surveys. This is consistent with a lower gear selectivity for larger crabs. This was true even when the lower limit of the estimated crab length was used (i.e. when assuming the lower limit of CL based on estimated precision of CW from sampling of multiple frames).

Clearly the low numbers of crabs measured in the video samples are insufficient for quantification of gear selectivity but the general patterns are of interest. They imply that larger crabs may be more common on the seafloor than would be predicted from trap-based sampling. This possibility has long been speculated due to constraints on trap neck diameter in fishery rules that may prevent larger crabs from entering the gear. Regulations of the diameter of trap necks are set for the affiliated rock lobster fishery and larger crabs can become jammed in the necks, unable to fully enter.

The current selectivity curves used for length-based modelling of the giant crab resource is shown in Figure 7.5.4.2 and it can be seen that these curves remain flat with increasing size once crabs become fully recruited to the gear. The video observations reported here imply that the general shape of these curves may be incorrect with dome-shaped selectivity being more appropriate. Much more extensive sampling would obviously be required to quantify selectivity curves of this form; however, the implications for conclusions form the assessment may be significant.

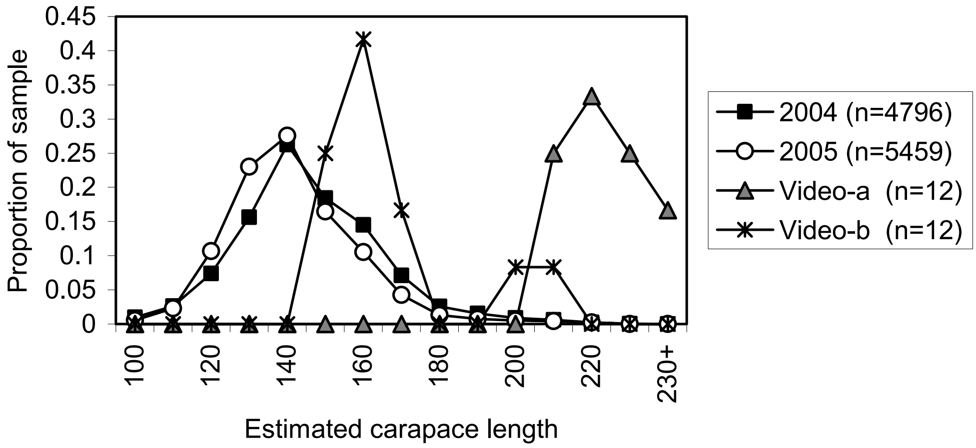


Figure 7.5.4.1 Length frequency distributions of giant crabs with data collected by either traps (2004 and 2005 data series), or through video observations. Two series are shown for video observations – the "best" estimate of carapace length (Video a) and the lower limit of carapace length estimation based on precision estimates drawn from repeated measurements of crabs over multiple frames (Video b).

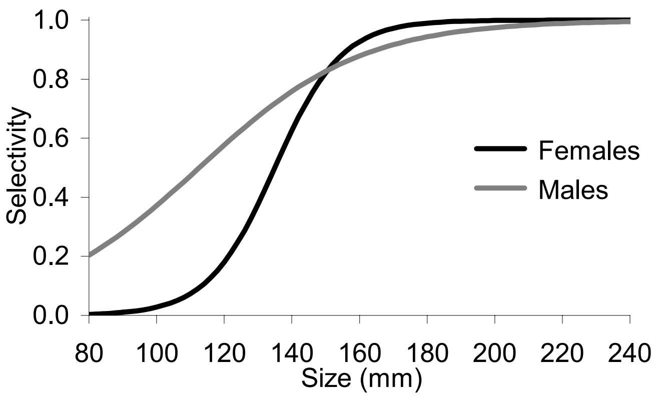


Figure 7.5.4.2 Gear selectivity curves used in population modelling of giant crabs from southern Australia. Note that these curves assume no reduction in selectivity of larger crabs with 100% selectivity maintained once the crabs become fully recruited to the gear.

7.5.5 Discussion: video as a stock assessment tool

The towed camera system was assessed for its overall suitability to survey exploited species with results summarised in Table 7.5.5.1. The evaluation is split into 3 categories of camera types as the camera system carried both stereo, single video and the digital stills camera. The criteria of evaluation were judged against the camera types and show that the three image sources were often complementary.

Table 7.5.5.1 Application of video data for giant crab fisheries assessment

Criteria	Video	Stereo video	Digital stills	Comments
Regular density / abundance estimation	✗	✗	✗	Expensive with specialist equipment, staff and vessel required.
Validation of model based density estimates	✓	✓	✓	Point estimates of crab abundance in a restricted region would be of great value for validation of length based model estimates from trap data.
Sex ratio	✓	✓	✓	Crabs could be sexed from chelae and thus provide information on sex ratios. This has value for validation of model estimates.
Length frequency data for model inputs	✗	✗	✗	Accuracy limited by image quality and resolution, configuration (camera separation), range of subject and depth effects
Gear selectivity model form	✓	✓	✓	Point estimates of length measurements would enable the form of the selectivity function to be evaluated (which drives biomass estimates).
Onset of maturity	✗	✗	✗	Maturity data from trap samples is potentially biased by catchability. However, video observations do not offer an alternative with presence of eggs unclear.
Condition i.e. missing chelae	✓	✓	✓	Generally possible.
Behaviour	✓	✓	✓	Observations re activity (mobile/sedentary), reaction to camera system, gregarious, feeding.
Use of habitat	✓	✓	✓	Observations of giant crabs using structure and evidence of burrowing
Size of habitat	✗	✓	✗	Measurements of larger scale habitat possible where +/- 200 mm ok

Overall, we conclude that the towed camera system is not a cost-effective tool for collection of routine data for stock assessment. Finfish typically avoided the gear while too few giant crabs were observed relative to the expense of the surveys and equipment to make this aspect of camera surveys viable.

Although the collection of routine assessment data was not feasible, the observations indicate potential value of video surveys for collection of point information on the crab fishery. That is, single projects at a point in time to validate or test some of the more critical aspects of the assessment process. For example, biomass estimates are strongly influenced by the selectivity curve and data collected here suggests that the form of the selectivity curve should be adjusted. Likewise, the system was highly effective at measuring the density of crabs on the seafloor over small areas. This type of sampling could be expanded to give good coverage over a small region, which would be of great value for validating model outputs.

One of the interesting observations from the video data collected in this study was that crabs (and exploited fish species) were observed in regions where there was little or no commercial effort. This demonstrated the total stock is larger than the fished stock. This type of mapping of the total range of exploited species and the extent of spatial refugia is clearly expensive but a demonstrated application of the type of data collected here.

Other biological and behavioural information was collected on crabs that would have been impossible to obtain by other means. These include the extent of gregarious behaviour (low here but common in many crab species), burrowing, and insights on microhabitat use (Section 7.1.4).

As this video data relied on new technology it is reasonable to assume that there will be future developments that increase the application and lower the cost of data collection. Possible future developments that would increase the value of further video sampling include lower costs deployments for prolonged periods (e.g. by AUV) and improvements in levels of measurement accuracy.

8 Benefits and Adoption

The project was designed to provide information for management of habitats along the shelf break off western Tasmania. Prior to this project there was very limited information about this region – essentially only coarse bathymetry and inferred geomorphological features such as canyons. This project has produced fine scale swath mapping of many regions that provides both high-resolution bathymetry and also bottom characterisation. Habitat types and faunal assemblages have been visualised for the first time. This process has revealed a defined pattern of habitat type in relation to depth along this region. The habitat maps are thus now available for management of activities in this region and can be combined with risk assessment processes to assess probable impacts of specific activities.

There has been some adoption of outputs from the project already through the formation of voluntary agreements between the trawl and crab sectors (conducted early in the project when very little of the data presented here was available) and also for risk assessments of fishery activities.

At the commencement of the project, the greatest industry support for the research came from conflict between the trawl and crab fishers that resulted from increasing interaction. Through the course of the project this interaction has reduced in intensity. As a consequence, the outputs of this project are expected to facilitate a less emotive and more informed discussion of management of shelf habitats for benefit of the community.

9 Further Development

Habitat information collected through this project is stored at CSIRO and is available for future uses. Mapping and investigation of benthic habitats around Australia is ongoing and highly active. We anticipate that the information available through this project will be expanded through time as more information is collected from varying sources. This will contribute to further refining of the scale of habitat maps produced here.

One of the interesting components of the research reported here is where temporal change was observed in habitats (such as between periods of trawling or in re-colonisation of sediments sampled in dredge tows). Considerable effort was directed to geo-referencing the position of video and other habitat information so the precise same locations can be revised in the future.

The collection of assessment information was limited to giant crabs as other exploited species avoided the video system. While the system was clearly unsuited for conducting regular surveys of crabs to collect abundance data, it did suggest that valuable information could be collected on selectivity. Crabs on the seafloor tended to be larger than would be predicted from data collected in trapping surveys, which implies a bias in stock assessment modelling. This issue would be valuable to explore further because it affects the management decision making process. The concept is equally valuable for species where gear selectivity is not readily estimated and the species is readily visualised.

The project identified a region of the northwest coast that appears especially important for juvenile recruitment. This region has been reported by fishers but is now mapped and linked to a defined habitat type. On the level of habitat analyses conducted here we were unable to identify habitat traits that differentiate the bryozoan turf in this region from that found elsewhere along the coast. However, more detailed analysis, say by greater intensity of dredge sampling, may identify important trophic links within this region that is apparently so important to recruitment.

10 Planned Outcomes

The principle outcome for this project has been capacity to include information on benthic habitat along the Tasmanian shelf edge in management decision-making. Through the course of this project several processes have occurred that have relied on habitat information, such as debate between different and interacting fishing sectors, MPA declarations and risk assessments as part of EBFM.

The shelf break region is an area of relatively high productivity and several different fisheries rely on these habitats. The productivity of this region suggests that habitat management discussions will continue to occur and these are now far less speculative.

Notable aspects of this expanded knowledge base include: the description of habitat types present at different depths and mapping of these habitats along western Tasmania; the definition and bounding of areas of special value to different sectors; and risk assessments of habitat vulnerability.

This resource facilitates management to minimise impact of fishing on habitat and reduce interaction between sectors.

11 Conclusion

This project contributes information for management of fisheries along the shelf break off western Tasmania. Collection of habitat information in this region was challenging and we relied extensively on towed video using a system that had been developed only shortly before commencement of this project. The project has successfully addressed each of the objectives.

Objective 1. Define and map key habitats on the shelf edge (~80-180 fm — i.e. 150-330 m**) at locations around Tasmania where fisheries using different gear types interact.**

Key habitats on the shelf break were defined and mapped. It was found that four categories of sessile fauna predominated. Habitats were generally consistent between regions within depth zones. Canyons were notable exceptions as they often had benthic habitat devoid of sessile fauna at depths where bryozoan turf habitat dominated elsewhere. A bryozoan turf habitat was dominant in the region of the crab fishery although individual crabs were often seen on unconsolidated sediment adjacent to consolidated bryozoan turf.

Objective 2. Evaluate the resistance and resilience of habitats to impact from fishing gears using the semi-quantitative 'Ecological Risk Assessment' framework

A standard ecological risk assessment process was applied using the same approach as applied for the Ecological Risk Assessment of the Effects of Fishing (ERAEF). This process led to the conclusion that the shelf-break (200-

300 m) was the area of highest risk in respect of both trap and trawl fisheries: > 50% of all images on the shelf-break rated as high risk for trawl, and as medium risk for trap. Aside from the ERAEF process, we conclude that this habitat has low resilience to gear because of limited observed recovery on sites impacted by experimental dredging over a period of 12 months. In contrast, the outer shelf habitats were mostly not vulnerable to either fishing method due to either limited sessile fauna or low accessibility.

Although the intrinsic vulnerability of bryozoan turf/thicket makes it potentially at risk to impact from any gear, it scored at high risk from trawl but only medium risk from crab trapping. This was mainly because of differences in gear footprint – being considerably greater for trawl.

Objective 3. Detail the distribution of exploited shelf-edge species in relation to habitat features

The distribution of commercial species was mainly inferred from catch rates derived from commercial logbook data, although some information was also obtained through the video data collected for this study. Of particular interest was the distribution of catches relative to (1) the bryozoan habitat and (2) the shelf/shelf break sediment terrace, for morwong, flathead, ocean perch, ling and giant crab.

Giant crabs mainly occupy the bryozoan turf habitat. This distribution overlaps with several commercial finfish including flathead (mainly taken between 150 and 170 m) and morwong (especially 160 and 180 m) while ling catch tended to be further offshore (> 350 m).

Objective 4. Evaluate ecosystem links within habitats based on trophic, temperature and current-flow data.

Potential and known prey items of giant crabs were compared across habitat types. Based on distribution of prey items, there was no evidence that degradation of bryozoan habitat would be directly detrimental to giant crabs capacity to forage for prey. Conversely, occasional observations of carrion on the seabed suggests the discarded component of trawl catches may provide an additional food source. Note that these observations cannot be extended to juvenile crabs, which could not be positively identified in this study from other species of crabs that were similar in appearance (*Carcinoplax spp*.).

Patterns in CPUE of undersize and male crabs from western Tasmania were consistent with movement to deeper water in winter and shallower water in summer, presumably in response to patterns in water temperature. Although crabs appeared to range over depth, this movement up and down the slope was insufficient to take them outside the bryozoan turf habitat.

Undersize crabs appeared to occupy the same depth range as legal sized crabs, although a distinctive spatial pattern was observed with a concentration of undersize crabs along the NW region of Tasmania. This hot-spot of undersize abundance appears to be largely a function of larval supply. The observation highlights the potential importance of the NW for any discussions of spatial management of the bryozoan turf habitats.

Objective 5. Evaluate the use of video to obtain stock assessment information such as abundance, sex ratio, condition and size of target species, primarily the giant crab.

This objective was completed successfully for giant crab which typically showed little sign of avoidance. Finfish tended to either avoid or were attracted to the camera system. . We observed 75 giant crabs that could be positively identified in the 77 hours of video collected throughout the surveys. This clearly indicated that abundance and density estimation by video to contribute to regular assessments would not be feasible due to cost. However, we identified complementary and valuable uses for video data for point estimates of some assessment input data: : (i) quantification of gear selectivity, as a portion of the crabs observed could be measured by stereoscopy; (ii) validation of model based estimates of crab abundance of a smaller subset of the fishery using swept area methods.

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13 Appendices

13.1 Appendix 1 – Summary of Workshop

Understanding shelf-break habitat for sustainable management of fisheries with spatial overlap — Workshop to review methods

October 28, 2004

Present: Nic Bax (CSIRO; Chair), Caleb Gardner (TAFI), Dave Mills (TAFI), Matthew Barwick (FRDC), Hilary Revill (DPIWE), Rodney Trellogen (TRLFA), Robert McConnaughey (US National Marine Fisheries Service), Ian Knuckey (Fishwell Consulting), Roland Pitcher (CSIRO), Alan Williams (CSIRO), Bruce Barker (CSIRO), Rudi Kloser (CSIRO), Gordon Keith (CSIRO), Mark Bravington (CSIRO), Franzis Althaus (CSIRO).

Summary of suggested changes to methodology

1) Inclusion of video tows parallel to the contours to examine variability between standard transects that are run down the slope. (DONE- see methods on sampling at each site).

2) Address the issue of over-sampling or double-counting in quantification of video data. This will occur if 1 second intervals are used between scored frames; in particular when looking at abundance of individual species or things like lost gear. (DONE- see 13.4, Appendix 4 – Video scoring).

3) Planning of sample sites should be based on data excluding mid-water trawl data. (DONE- see analysis methodology on sampling at each site).

4) Investigate potential for measurement of fluorescence using additional instrumentation attached to the camera frame. This may provide an index of productivity. (This option was investigated but not implemented due to: (i) cost for instrumentation with suitable depth capability; (ii) the need to test whether point estimates of productivity from this method could be misleading if used to categorise habitat productivity was beyond the scope of the project).

5) Undertake more extensive mapping of fisheries data to define areas of low/high crab abundance for planning of transect locations (rather than relying on marks supplied by fishers). (DONE- see analysis methodology on sampling at each site).

6) Sample over the abundance range of crabs to identify (using statistical model) the habitat variables important to the crabs; then consider these variables in terms of vulnerability to gear impact. This represents a shift to include areas of low and medium crab abundance, not just hot-spots. (DONE- see analysis methodology on sampling at each site).

7) Need logical step-through of the mapping the habitats based on swath and video data then overlay crab abundance and look at the causality: aim to

establish if differences in abundance appear trawl or habitat driven. (DONE- see Section 7.2).

8) Although participants at the workshop identified no additional ERA attributes, it was suggested that we could use web-literature of fishing gear impacts to guide identification of additional ERA attributes. It was noted that most attributes related to sediments and habitats rather than faunal attributes such as regeneration capability. This could be one area of expansion. This view was tempered by the observation that more ERA attributes may not be desirable because it increases the need for weighting - which is fraught with problems. Agreed to review attributes when benthic faunal counts become available with statistical advice. (DONE – statistical analyses indicated the need for both amalgamation and splitting of categories. The 'low/encrusting fauna' category was further split as described in the Section on Fine-scale scoring within Section 6.2. Several categories were auto-correlated and these pooled for analyses in Section 7.1).

9) The sled tow sites from earlier in 2004 should be revisited with video to collect information on recovery of benthic fauna. (DONE - Sled tow sites sampled in voyage two were revisited on each of the two subsequent voyages by video transect).

13.2 Appendix 2 – Intellectual Property

No commercially valuable intellectual property arose from the research. No compelling reason was identified to restrict the distribution of results so these have been made publicly available with no protection or confidentiality.

13.3 Appendix 3 – Staff

Project staff were:

Dr Caleb Gardner, Tasmanian Aquaculture and Fisheries Institute, University of Tasmania (Marine Research Laboratories).

Dr David Mills, Tasmanian Aquaculture and Fisheries Institute, University of Tasmania (Marine Research Laboratories).

Dr Alan Williams, CSIRO Marine and Atmospheric Research

Bruce Barker, CSIRO Marine and Atmospheric Research

Franziska Althaus, CSIRO Marine and Atmospheric Research

Karen Gowlett-Holmes, CSIRO Marine and Atmospheric Research

Mark Bravington, CSIRO Mathematical and Information Sciences

Matt Sherlock, CSIRO Marine and Atmospheric Research

Pamela Brodie, CSIRO Marine and Atmospheric Research

Roland Pitcher, CSIRO Marine and Atmospheric Research

Rudy Kloser, CSIRO Marine and Atmospheric Research

Tim Ryan, CSIRO Marine and Atmospheric Research

13.4 Appendix 4 – Video scoring

13.4.1 Scoring rules

The video is run continuously, stopping only where a change in any of the SGFA categories is observed. The change is recorded once it has passed the mid-line of the screen (in cases of small patches or solitary fauna the attachment point has to have passed the mid-line), and in case of small patches or solitary fauna it will only be scored until the attachment point of the animal/group has passed through one-third of the screen starting at the centre (scored screen-section – see Illustration below). Post-processing will be used to attribute the recorded scores to 1 second frames for the entire length of the video transect.

The reason for limiting the scoring to the lower half of the screen is that the camera is pointed obliquely forward-looking and with the pitching of the camera frame often the top half of the view in screen is off-bottom and forward-looking. This decision was based on viewing sequences of all tapes from the four surveys.

The rule to limit the screen-distance a solitary organism/small patch of habitat is only scored for (one-third of the screen) is intended to avoid excessive overlap between consecutive frames Figure 13.4.1.2. We found that it takes 3.8 seconds (N = 172, StDev = 1.9) for a point to pass through the screen by randomly picking and viewing 5 segments out of every three-hour video tape taken in the four crab surveys and in each segment tracking a recognisable point from when it can be first distinguished until it leaves the screen. Figure 13.4.1.1 shows the frequency distribution of the time-intervals a point was tracked for.

In scoring SGFA precedence is given to larger/rarer features, if a large erect animal was seen entering the scoring field the score reflected this animal rather than the smaller fauna surrounding it. For example, if a sponge, stalked crinoid or octocoral was observed in a mat of bryozoan thicket the former would be scored for the duration of it passing through the scored screen-section. This also applies to outcrops, boulders, etc.

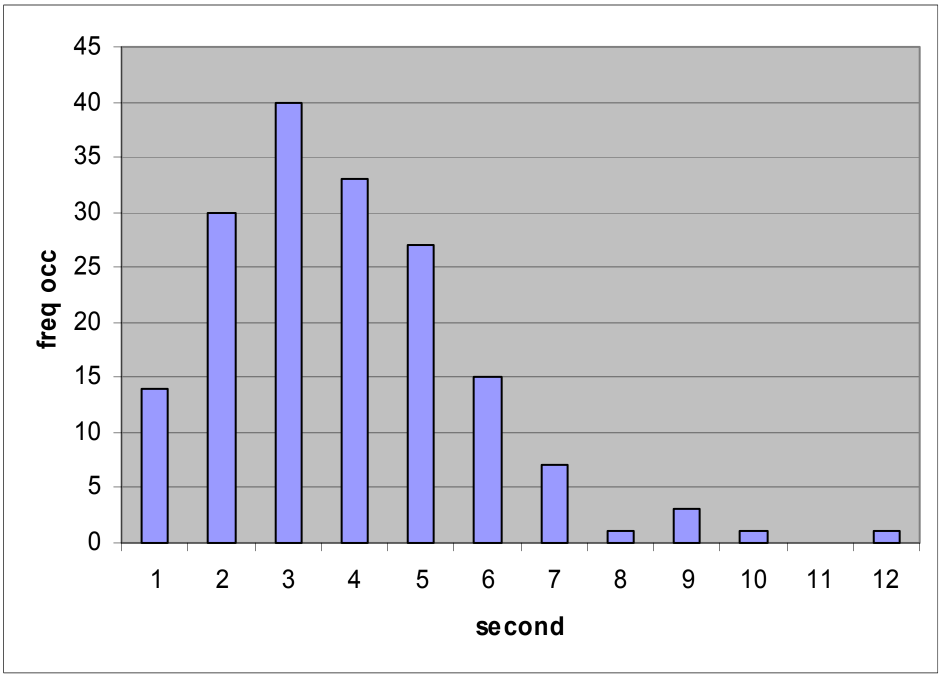

Figure 13.4.1.1 Frequency of occurrence of *i* second time-intervals a point could be tracked passing through the field of view (*i* = 1, 2, 3, …, 12)

Discrepancies between sediment type scores from video and acoustics can occur. Hard bottom types can be covered with a veneer of fine sediments. The video score can only reflect what is seen i.e. the soft sediments. If there is attached fauna such as ascidians and/or large sponges, interpretation allows for the geomorphology score of subcrop to be applied, giving the reflecting the hardness of the bottom in the combined SG score. If no fauna s present the SG score might be contradicted by the acoustic profile of the bottom.

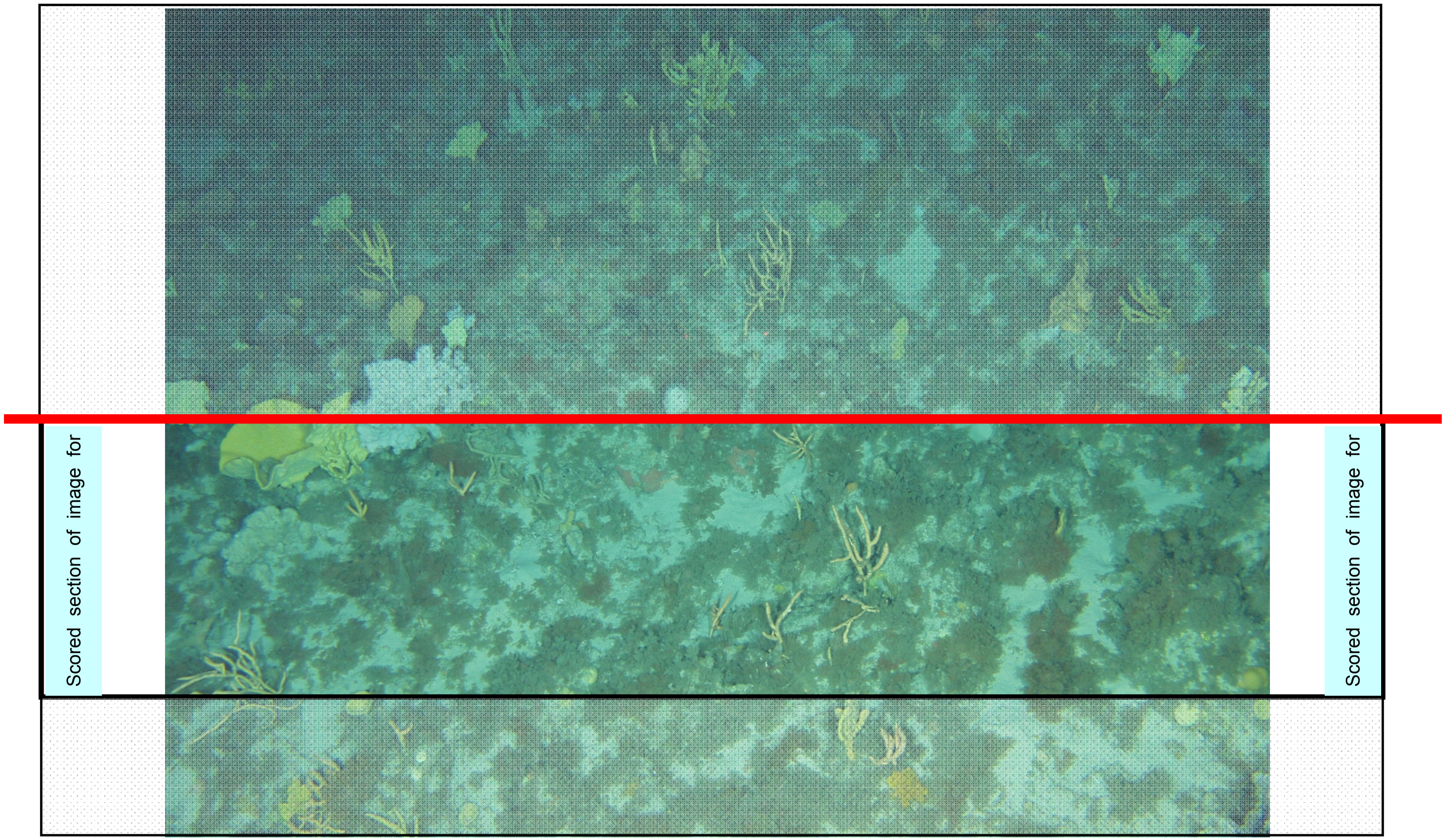

Figure 13.4.1.2 Illustration of the scoring-window on the TV screen used for scoring videos

13.4.2 Recoding of Video scores

Table 13.4.2.1 Recoding of sediment (S) and geomorphology (G) scores: detailed list of original SG scores as they mapped into the combined sediment and geomorphology (SG) category

S-score	G-score	Sediment & Geomorphology (SG)	Sediment & Geomorphology (SG) descriptor
-99	99	-99	No data
1	0	1	Flat, fine sediments
1	1	2	Rippled, fine sediments
1	3	3	Irregular, fine sediments
2	0	4	Flat, coarse sediments
3	0	4	Flat, coarse sediments
2	1	5	Rippled, coarse sediments
2	3	6	Irregular, coarse sediments
2	4	6	Irregular, coarse sediments
2	6	6	Irregular, coarse sediments
2	7	6	Irregular, coarse sediments
2	9	6	Irregular, coarse sediments
3	3	6	Irregular, coarse sediments
3	6	6	Irregular, coarse sediments
3	7	6	Irregular, coarse sediments
1	5	7	Subcropping rock
2	5	7	Subcropping rock
3	5	7	Subcropping rock
4	5	7	Subcropping rock
6	0	7	Subcropping rock
6	1	7	Subcropping rock
6	3	7	Subcropping rock
6	5	7	Subcropping rock
4	4	8	Outcropping rock or boulders
4	6	8	Outcropping rock or boulders
4	7	8	Outcropping rock or boulders
4	9	8	Outcropping rock or boulders
6	6	8	Outcropping rock or boulders
6	7	8	Outcropping rock or boulders
6	8	8	Outcropping rock or boulders
6	9	8	Outcropping rock or boulders

Table 13.4.2.2 Recoding of epifaunal scores: detailed list of original fauna (F), abundance (A) and fine-scale (f) scores as they mapped into the combined epifaunal (FAf) category

F-score	A-score	f-score	Epifauna (FAf)	epifauna (FAf) descriptor
-99	-99	-99	-99	No data
0	1	0	1	No apparent fauna
0	1	1	1	No apparent fauna
0	1	4	1	No apparent fauna
8	1	0	1	No apparent fauna
8	1	1	1	No apparent fauna
8	1	4	1	No apparent fauna
8	2	0	1	No apparent fauna
8	2	1	1	No apparent fauna
8	2	4	1	No apparent fauna
8	3	0	1	No apparent fauna
8	3	4	1	No apparent fauna
9	1	0	1	No apparent fauna
9	1	1	1	No apparent fauna
9	1	4	1	No apparent fauna
9	2	0	1	No apparent fauna
9	2	1	1	No apparent fauna
9	2	4	1	No apparent fauna
9	3	0	1	No apparent fauna
9	3	1	1	No apparent fauna
9	3	4	1	No apparent fauna
0	1	2	2	Residual fauna in matrix of coarse detritus
8	1	2	2	Residual fauna in matrix of coarse detritus
8	2	2	2	Residual fauna in matrix of coarse detritus
8	3	2	2	Residual fauna in matrix of coarse detritus
9	1	2	2	Residual fauna in matrix of coarse detritus
9	2	2	2	Residual fauna in matrix of coarse detritus
9	3	2	2	Residual fauna in matrix of coarse detritus
2	1	0	3	Low / encrusting faun
2	1	2	3	Low / encrusting faun
2	1	4	3	Low / encrusting faun
2	2	0	3	Low / encrusting faun
2	2	2	3	Low / encrusting faun
2	3	0	3	Low / encrusting faun
2	3	2	3	Low / encrusting faun
6	1	0	3	Low / encrusting faun
6	1	2	3	Low / encrusting faun
6	1	4	3	Low / encrusting faun
6	2	0	3	Low / encrusting faun
6	2	2	3	Low / encrusting faun
6	2	4	3	Low / encrusting faun
7	1	0	3	Low / encrusting faun
7	1	1	3	Low / encrusting faun
7	1	2	3	Low / encrusting faun
7	1	4	3	Low / encrusting faun
7	2	0	3	Low / encrusting faun
7	2	2	3	Low / encrusting faun

F-score	A-score	f-score	Epifauna (FAf)	epifauna (FAf) descriptor
2	1	5	4	Turf / thicket
2	1	6	4	Turf / thicket
2	2	5	4	Turf / thicket
2	2	6	4	Turf / thicket
2	3	5	4	Turf / thicket
2	3	6	4	Turf / thicket
6	1	5	4	Turf / thicket
6	1	6	4	Turf / thicket
6	2	5	4	Turf / thicket
6	2	6	4	Turf / thicket
6	3	0	4	Turf / thicket
6	3	2	4	Turf / thicket
6	3	4	4	Turf / thicket
6	3	5	4	Turf / thicket
6	3	6	4	Turf / thicket
8	1	5	4	Turf / thicket
8	1	6	4	Turf / thicket
8	2	5	4	Turf / thicket
8	3	5	4	Turf / thicket
8	3	6	4	Turf / thicket
1	1	0	5	Erect fauna
1	2	0	5	Erect fauna
1	3	0	5	Erect fauna
3	1	0	5	Erect fauna
3	2	0	5	Erect fauna
3	3	0	5	Erect fauna
4	1	0	5	Erect fauna
4	2	0	5	Erect fauna
5	1	0	5	Erect fauna

13.5 Appendix 5 – Camera length measurement calibration

13.5.1 Camera calibration

The internal characteristics of the cameras and their lenses were determined initially by an in-air calibration. A sequence of paired images was taken of a cube structure (Figure 13.5.1.1) with reflective targets (coded and uncoded) at varying angles of tilt and rotation. These images formed the basis of the initial calibration determined using VMS software. Once the internal calibration characteristics of the cameras were determined, in-water calibrations of the stereo cameras were performed in a swimming pool. We again recorded image sequences of the calibration cube with varied rotations and angles of tilt. This enabled subsequent calibration of the configuration and camera characteristics (in the pressure casings and through view ports) in water. An underwater unit with flashing LED's was used to later synchronize the paired image sequences during analysis (Figure 13.5.1.1).

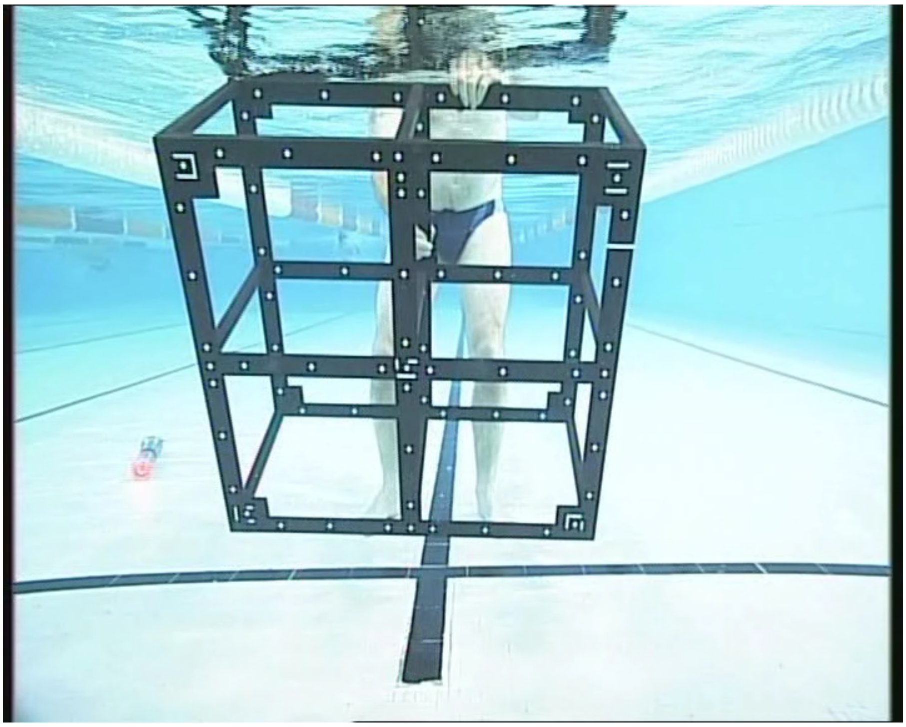

Figure 13.5.1.1 The in-pool calibration of the stereo cameras using a cube frame with reflective circular targets and 'coded targets' for automated recognition by the calibration software. A flashing red light enabled synchronization of the image pairs during analysis.

Calibration results

The results of the stereo camera calibrations in the pool show typical levels of precision and accuracy for calibration of the cameras and determination of the relative orientation between the two cameras on the base bar. The quality of the calibration was indicated by two factors. The first was the image measurement precision, which was a measure of the internal consistency of the calibration network. Three separate calibrations of the Hitachi cameras produced results in the range 0.5-0.8 micrometers, or approximately 1/10 of a pixel in the image. This level was typical for DV tape camcorders with broadcast TV resolution (approximately 750 by 500 pixels), combined with discrete, circular targets on the calibration fixture. The second factor was the root mean square (RMS) error of the measurement of distances on the fixed bars of the calibration fixture, a measure of external accuracy. The RMS errors ranged from 20 to 40 micrometres, which once more is typical for this style of calibration.

A further measure of the quality was the internal consistency of the relative orientation computations. The mean values of the relative orientation parameters were based on analysis of every stereo pair used in the calibration network. Once more the levels of precision were typical of these camera systems. For example, the precision of the base separation of the cameras, a component of the relative orientation, varied from 2 to 4 mm.

Experimental estimates of precision do not translate directly into the precision of measurement in operating conditions. The precision and accuracy of distances measured in the field is based on a single stereo pair of images, and this reduces the precision of the measurements. Further, measurements made under field conditions are based on natural features, not discrete targets, and the image measurement precision changes from approximately 1/10 of a pixel to the range of ½ to ¾ of a pixel, depending on the clarity of the edge being measured to define the extent of the object.

Based on the characteristics of the stereo camera system and an image precision of ½ of a pixel, the following table shows the predicted precisions of lengths measurements (Table 13.5.1.1).

Table 13.5.1.1 Predicted precision of length measurements using camera separation, inclination and lens parameters.

Distance to Object (m)	2	2.5	3	3.5	4
Precision of Length Measurement (mm)	8	12	17	23	30

The precision shown is an average between the best and worst cases: measurement of a distance perpendicular and parallel to the line of sight to the object, respectively. This predicted precision represents an ideal scenario in which there are no effects from pixilation, through water visibility, nor the interlace displacement caused by the relative motion between the cameras and the object as the body is towed through the water.

To validate the predicted levels of precision, a test was conducted in a swimming pool with an aluminium rod with targets of known separations. The rod was approximately one metre long and had targets at separations of 800mm and 900mm. Measurements were taken at ranges of 1.2m and 2m with the rod in various orientations with respect to the cameras. The RMS error of the lengths was 4.6mm, with only a slight deterioration with increased range. This level of precision was a best case scenario, as the range was low, the targets were well defined, the water clarity was high, there was no interlace displacement and the environment was stable. However, the primary reason for the improvement over the base line prediction in the table above is the target definition

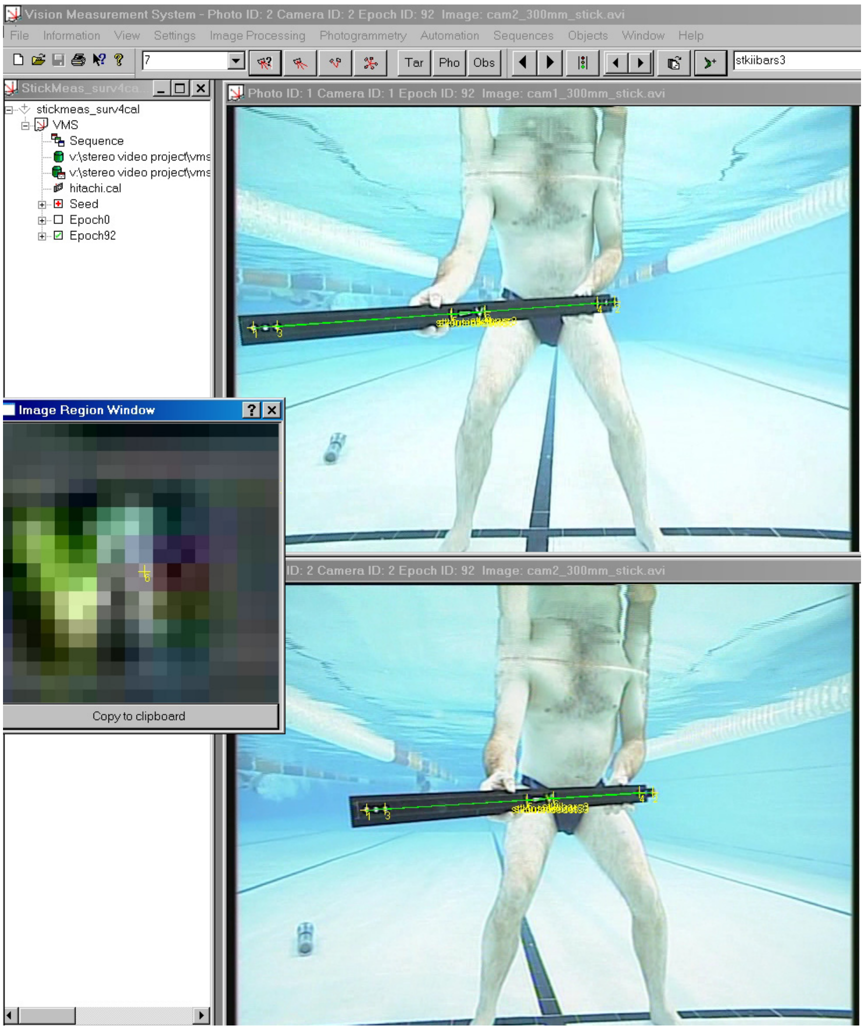

Figure 13.5.1.2 Paired images from the stereo cameras from the in-water verification of measurement accuracy following calibration of the cameras. Measurements between reflective targets on an aluminium rod were made at various rotations, distances and angles.

13.5.2 Depth effect on measurement accuracy (survey 4)

During the fourth crab survey an experiment was conducted to determine the effects of depth on the accuracy of stereo camera calibrations. The current procedure for stereo camera calibration is to record imagery of a calibration fixture in a swimming pool. From this imagery camera calibration and relative orientation is derived, and this allows subsequent three-dimensional stereo measurement. There was a concern that there may be measurement inaccuracies resulting from the application of a camera calibration carried out in shallow water to imagery gathered at depths of several hundred metres. It was suspected that as the cameras are deployed to greater depths, the increased pressure may deform the camera housings and view ports, and invalidate the camera calibration performed in shallow water.

The experiment involved the deployment of a 16-laser array. The laser array was mounted between the stereo cameras (see Figure 13.5.2.1 below). During deployments to various depths ranging between 25 and 510 metres the laser system was switched on and a set of imagery recorded. The laser system automatically rotated through a series of 8 different orientations, and by recording imagery of the projected laser pattern it was possible to calibrate both the stereo camera system and the laser projector at the depth of deployment effectively removing any depth effects.

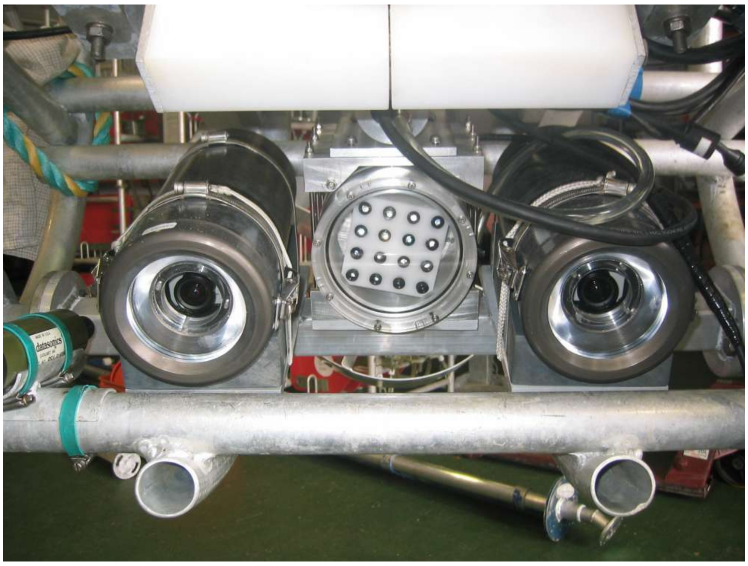

Figure 13.5.2.1 Laser projection system mounted between stereo cameras

Over the various laser system deployments it was found that depth did have an effect on the stereo camera calibration. Figure 13.5.2.2 shows the percentage error for measured distances caused by depth. The maximum error observed is around 8% (at a depth of 200 m). Interestingly, there was little correlation between depth and the error caused. It was assumed that the observed depth effect was caused by somewhat unpredictable settling of the camera housing view port. The view port component is made of a lens and several housing components and involves multiple o-ring seals. It appeared that the view port compresses on descent, and does so in a slightly different manner each time the camera system is deployed.

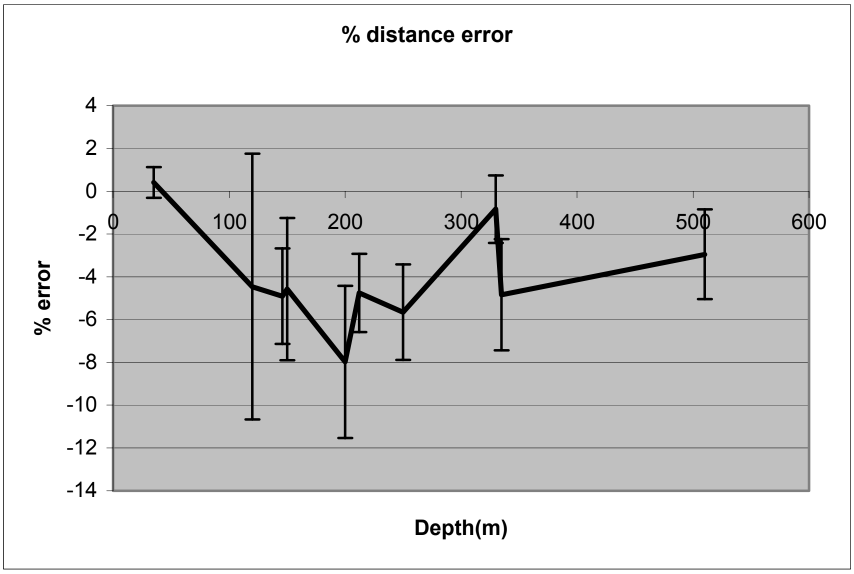

Figure 13.5.2.2 Error in distance measurement caused by depth effects

Although the experiment did suggest some significant depth effects, the experiment was slightly deficient in that it lacked a scale reference. A pair of parallel lasers was used to provide a scale reference, and although these lasers had a very small housing and view port, and should remain stable at depth, they were not ideal. It is intended to repeat the experiment and confirm results using a fixed mechanical scaling. The experimental deployment has led to some design changes in subsequent camera systems in order to try and eliminate the effects of view port settling. It has also suggested the viability of performing in situ camera calibrations at depth using a laser projection system.